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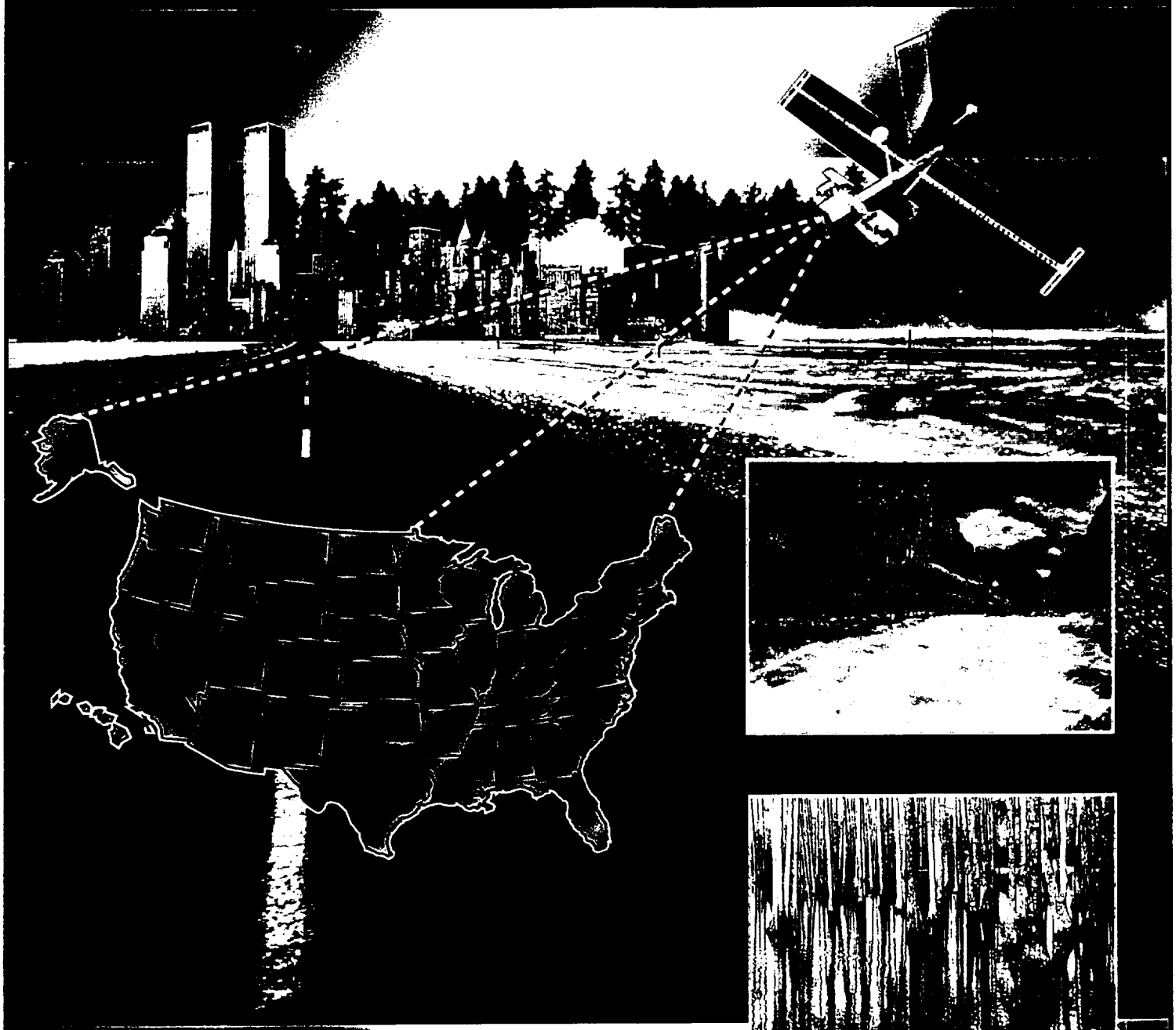
NASA as a Catalyst:
Use of Satellite Data in the States

National Aeronautics and Space Administration

Office of Mission to Planet Earth

Lisa Warnecke, Ph.D.



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Author's Note and Acknowledgments

This report includes a review of NASA's past efforts with state governments and a compilation of known experiences with satellite data in each of the 50 states. This work is based on and includes some of the author's past work regarding geographic information in the states. Several methods were used to obtain information about these conditions as described in the methodology. However, it is likely that some satellite data applications were not discovered and are not included in the report. Any such omissions were not intentional, and sincere apologies are offered as appropriate. Views expressed in this report are solely those of the author and as reported during a meeting of state officials convened by NASA in 1995; they do not reflect the policies or views of NASA or any other organization.

Many individuals from states and NASA were instrumental in providing information or facilitating production of this report, and they deserve special recognition and thanks. In particular, the dedication and perseverance of Alexander J. Tuyahov at NASA Headquarters and Jerry Garegnani, now at NASA's Goddard Space Flight Center, were essential at every step in the project to ensure that this report would be completed, published, and provided to state representatives and others. Alex, along with Richard H. Weinstein from NASA Headquarters, also provided key information about their experiences with NASA's outreach program for states during the late 1970s and early 1980s. Jerry prepared earlier text about the meeting of state officials convened by NASA in 1995, and he also gathered the graphic examples of satellite data use from state officials that are incorporated in the report. John E. Estes of the University of California at Santa Barbara recognized the importance of states and their unique experiences, and he incorporated and encouraged state perspectives in his work with NASA. Gary Shelton at NASA Headquarters coordinated the final version of this report through its page layout and printing stages.

Several other people provided information used in the report. Much of the information was derived directly from multiple state government officials in each of the 50 states. State officials in attendance at the state meeting sponsored by NASA in 1995 are particularly thanked for their time and efforts at and following the meeting in addition to providing this information. These and other state officials also provided the graphic examples of satellite data applications that are included in the report. In addition, James Monsour of the Kentucky Legislative Research Commission conducted a search of state statutes to identify statutory references to satellite data. Specific information about the national Gap Analysis Program was provided by J. Michael Scott, Michael D. Jennings, Elisabeth Brackney, and Becky Sorbel; information about the Coastal Change Analysis Project was furnished by Jerry Dobson and Donald Field. Representatives of EOSAT, SPOT, and ERDAS Corporations also provided useful information.

The Printing and Design group of the Communications Management Division at NASA Headquarters applied the finishing touches and produced this final version. Special thanks are extended to Stephen Oberti and Kelly Rindfusz for their layout and graphics work, Jonathan Friedman for final editing and coordination, and Stanley Artis and Michael Crnkovic for their printing expertise.

Sincere and personal thanks are offered to everyone named here, as well as to those representing individual states that are too numerous to mention but are listed in the State Profiles in Appendix B. After having gathered information about states for more than 10 years, it is a pleasure to consider many state officials and others involved in this report as personal friends, as well as top-quality colleagues and public servants.

Abstract

NASA revolutionized our view of the world in 1972 with the launch of the first satellite to monitor the Earth. Recognizing the importance of states in governing the United States, NASA then established a program in the late 1970s to educate and assist states in using satellite data products. This report reviews this brief, but beneficial program that laid a foundation and catalyzed satellite data work that continues today in several states. More recently, outreach efforts as part of NASA's Mission to Planet Earth program and growing state government roles, responsibilities, and initiatives led NASA to begin a new effort in 1994 to understand and work effectively with states. This effort included an investigation and synthesis of current satellite data conditions in each of the 50 states that are included in this report. It provided strong evidence that some state governments are applying satellite data to an increasing array of government needs, while other states have very limited applications to date. A wide range of satellite data applications in executive branch agencies are described, as well as the recent status of the Gap Analysis Program in each of the states with this program. The report also reviews the status of satellite data and geographic information coordination efforts in each of the 50 states. In addition to this investigation, NASA convened a meeting of representatives of 12 states experienced with satellite data to identify future satellite data uses and needs, as well as NASA opportunities to enhance the utility of satellite data products. The findings and recommendations from this meeting, the 50 state investigations, and NASA's past state programs are also included in the report; they provide the rationale for NASA to establish a new outreach effort with state governments in the late 1990s.

Preface

During the last 25 years, NASA has developed a technology that serves important social purposes: satellite remote sensing. The data produced from platforms designed, developed, launched, and operated by NASA have been used for an incredibly broad range of applications at the Federal, state, and local levels, in academia, and in the private sector. Resource inventory, conservation, and development have been facilitated. The synoptic perspective provided by satellite remote-sensing platforms has helped us understand, appreciate, protect, and wisely use the irreplaceable resources found on this jewel, our Earth.

Following the launch of Landsat 1, NASA had the foresight to offer a program to state government users interested in applying remotely sensed data to real-world problems in an operational context. As explained in this report, the program was very effective and well received by the states, even though it was relatively short-lived. NASA provided technology transfer assistance, and state representative organizations (such as the National Conference of State Legislatures and the Council of State Planning Agencies) provided institutional support and intergovernmental coordination. Many states benefited from this program, and more states are using this important technology today as described here. These NASA efforts helped establish the groundwork on which an entire industry is being founded.

With a growing devolution of responsibilities to the states and impending commercialization of the space segment of remote sensing, state use of NASA-developed technologies is once again receiving attention. NASA convened a work group of state satellite remote-sensing users in 1995 to consider and explore where they fit into the picture, as well as what NASA might do to help them better apply this technology. This report reflects the deliberations of that group, and it lays out a course of action for moving us ahead, together. A solid user base will be critical to the realization of the benefits of NASA technology, and it will be a crucial element for the successful commercialization of satellite remote sensing. In partnership with NASA and the private sector, the states can achieve important social and economic purposes. Focused support from the technology developers at NASA will further this process and result in enhanced state abilities to carry out devolved responsibilities, as well as new commercial opportunities for America's entrepreneurs. It is time for NASA's "Mission to Planet Earth" to come home and "strut its stuff."

Paul Tessar, Chief
Geo Services Section
Wisconsin Department of Natural Resources

1. Introduction

The National Aeronautics and Space Administration (NASA) catalyzed early uses of satellite data and other geographic information technologies in state governments and other organizations more than 20 years ago. However, many of these initiatives ceased in the early 1980s because of funding constraints. In preparing for the 21st century, NASA should reassess and reaffirm its strategy regarding state and local governments in light of emerging issues and initiatives identified in this report. This approach will appropriately assert NASA's leadership to extend Mission to Planet Earth resources and capabilities to governments with growing roles and responsibilities in our Nation's governance.

1.1 Expanding State Government Roles and Initiatives

Several societal and governing trends are being experienced simultaneously within the United States. Such trends are encouraging Federal agencies to consider state and local governments to help accomplish national goals. Our Federal Government is characterized by two sets of checks and balances. The horizontal dimension provides that the three Federal branches share authority. The vertical dimension provides that state governments have certain sovereign authorities in relationship to the Federal Government as granted by the U.S. Constitution. Local governments also have important roles and responsibilities as authorized by state statutes or home rule provisions. This arrangement is known as "federalism," in contrast to other countries with "unitary" forms, where a nation's central government has authority over subnational governments. Thriving as a form of government throughout the world, federalism has direct implications for information use and management because each governmental level has differing interests, roles, and authorities.

While states have always been important governing actors in our Nation, their roles are more crucial as numerous Federal initiatives are devolved to states and fiscal limitations stymie activities within all governments. Federal authority has been devolving to states and localities in many areas of public policy since the 1970s, and particularly in the 1990s, resulting in growing state implementation of many Federal programs. States have also strengthened their internal direction, capacity, and discretion in many areas of governance. In addition to managing their own and Federal programs, states are the key middle level between the Federal and local governments and have direct authority over and provide services for localities. The aggregate result of these trends has been to increase the relative authority, responsibility, and initiative of state governments, including the management of the Nation's environment and natural resources. NASA's sponsorship of this report is evidence of its growing awareness and response to these crucial trends in the Nation's governance and the growing role of state governments.

1.2 Geographic Information in States

An expanding state initiative of importance to NASA is the increasing use, coordination, and institutionalization of geographic information and related technologies. "Geographic information" (GI) is used in this report to broadly include all geographically based information, including data provided in cartographic, image, or tabular form. A "geographic information system" (GIS) uses one or more related packages of computer software to manage, analyze, and display this information. Several GI technologies are used by states and other organizations, such as satellite data, the global positioning system (GPS), GIS, image processing, and other software. GIS is often used as a comprehensive term, and it sometimes includes or implies the inclusion of other data and related technologies.

The acronym "GI/GIS" is used in this report to include geographic information and related technologies as defined above. However, the focus and conditions regarding GI/GIS within states vary significantly, particularly in terms of

statewide and coordinating initiatives. The use of this acronym in the report does not necessarily imply that a state's scope of effort or set of activities includes all GI or related technologies. While the incidence of these initiatives is increasing, many states do not have a clearly defined scope or focus for their coordination initiatives. As a result, it is unclear whether or not a statewide GI/GIS coordinating initiative in an individual state includes or addresses satellite data. Section 5 of the report provides a summary of GI/GIS use, coordination, and institutionalization and related trends in the Nation's 50 states as they relate to satellite data and NASA.

1.3 *Satellite Data Resources for States: Past, Present, and Future*

Technological advances ensure that remotely sensed data will have an increasing impact on society. While remote sensing, by definition, includes data obtained from various sources, such as aerial photography from aircraft, this report focuses exclusively on remotely sensed data derived from satellites. Satellite data, in particular, will have a profound effect on the information resources used by many organizations and, in turn, the decisions and processes of governments that will impact our lives.

Future state use of satellite data will be determined based on several factors and trends, in addition to the governing and state GI/GIS trends discussed above. Early satellite data were only provided and available through the U.S. Government. The first in a series of satellites designed to monitor and provide repetitive global coverage of the Earth's land masses was launched on July 23, 1972. Known at the time as the Earth Resources Technology Satellite-1 (ERTS-1), the satellite operated until 1978, while the second in this series (ERTS-2) was launched in 1975. This satellite was renamed Landsat 2, and subsequent satellites were named sequentially, with Landsat 7 scheduled to be launched in 1998. NASA was responsible for operating Landsat satellites through the early 1980s. Section 2 describes how NASA encouraged and facilitated the use of data in states and other organizations, but ceased these efforts in the early 1980s.

The government then "experimented with how to best make the practical benefits of [Landsat] available at the least cost to the taxpayer" and felt that "the research and development period had provided a sufficiently mature technology" (American Society of Photogrammetry and Remote Sensing (ASPRS) 1996, p. 5). As a result, Congress commercialized the Landsat system in 1984, with exclusive sales rights given to the Earth Observation Satellite Company (EOSAT) as it remains today. It is generally acknowledged that Landsat's commercialization served to limit data use in states and other organizations because of increased costs.

Landsat commercialization was followed by satellite data initiatives in other countries. In 1986 and 1988, France and India, respectively, launched their own satellites and later began to make these data available to states and other organizations. While most states with satellite data experience use Landsat products, some states use data from France's SPOT Image Corporation.

Section 3 of this report reviews the past and current uses of satellite data in the Nation's 50 state governments from an investigation that was sponsored by NASA in 1994. The majority of the text of this report is in Appendix B, which provides detailed findings about the use of satellite data in each state, as well as contact individuals and contextual information about GI/GIS conditions. Section 4 builds on this analysis by identifying leading data uses and the needs of representatives of 12 states with extensive satellite data experience, as determined in a 1995 meeting sponsored by NASA.

Technological advances and cost reductions have provided a market incentive for private companies in the United States to launch satellites and provide data products. Several

companies plan to launch satellites with many different sensor types in addition to the government. The next decade is expected to have available a range of resources, including at least three wide-area Landsat-like systems, probably two high-resolution systems that could provide up to 1-meter accuracy, and the continuation of at least two radar systems, with as many as 47 satellites recently identified as either in operation since 1990 or planned to be launched by 2004 (ASPRS 1996). Figure 1 provides a summary of the imaging satellites planned to be operating in the year 2000, including both public- and private-sector initiatives. These systems are categorized by four sensor types, including:

- Landsat-like satellites are designed for the multispectral monitoring of land-cover changes for large areas (all but one of which is government sponsored).

- High-resolution, largely commercia systems are expected to provide data at 1- to 3-meter scales that are currently provided by the airborne sensor industry.

- Experimental systems will evaluate the potential of increasing the accuracy of spectral identification of landcover classes by increasing the number of spectral bands (which are sponsored by the U.S. Government).

- Radar systems, primarily used to see through clouds, are among the most promising and least understood of these sensors for several applications (countries other than the United States have primarily sponsored these satellites).

In addition to the increased availability of these data resources, technologies critical to the utilization of these data are becoming more readily available and usable—and at lower costs. These technologies, such as desktop image processing, soft-copy photogrammetry, GPS, GIS, and others, are further encouraging satellite data use. An increasing pool of qualified personnel is also becoming available through several universities with programs in remote sensing.

The combination of more and better data, increasing availability of technology, and more qualified personnel is expected to increase satellite data use and complement other state conditions and trends. In particular, data can be more effectively used with GI/GIS to help meet a growing variety of state government needs and responsibilities.

1.4 NASA's Mission to Planet Earth

The U.S. Global Change Research Program was initiated in the 1980s to respond to public concerns regarding environmental change and stemmed from several earlier national and international programs. The program includes the efforts of NASA, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Departments of the Interior, Agriculture, and Energy, the Environmental Protection Agency, the National Science Foundation, and others. It represents one of the largest Federal programs in recent years for science, particularly as it provided new funding in these agencies. While the program was originally designed to monitor a wide range of global change investigations, Congress limited its scope to primarily monitor global climate change in 1992. Annual expenditures among the 12 participating agencies is approximately $1.6 billion, with more than 75 percent of these funds expended by NASA.

Administered by the Office of Mission to Planet Earth (MTPE), NASA's efforts include several intermediate-sized satellites known as the Earth Observation System (EOS), a series of smaller satellites known as EarthProbes, a major information system named the EOS Data and Information System (EOSDIS), associated research, data analysis, and operational activities to support these missions, and the Landsat 7 satellite, which will be the joint responsibility of NASA and NOAA. Landsat 7 and the first of several EOS satellites are scheduled to be launched in 1998. Figure 2 provides a list of EOS sensors of potential interest to state, regional, and local agencies. MTPE's science themes for the next 5 years include:

Figure 1:
Land Imaging Satellites Planned to Be Operating in the Year 2000

Country	Sat Owner	Program	Instrument (s)	Launch	Sensor Types	RESOLUTION IN METERS: THEMATIC MAPPER BANDS: PAN	VNIR 1	VNIR 2	VNIR 3	VNIR 4	SWIR 5	SWIR 7	TIR 6	RADAR res, band	STEREO Type	SW KM	GLOBAL COVER REPEAT days
FREQUENT GLOBAL COVERAGE, LANDSAT-LIKE CLASSIFICATION CAPABILITY																	
U.S.	Gov.	Landsat 7	ETM+	'98	M&P	15	30	30	30	30	30	30	60			185	16
U.S.	Com.	Resource 21	Resource 21	'99	M		10	10	10	10	20					200	4**
INDIA	Gov.	IRS-1 D	LISS-3, PAN (WIFS)	'97	M&P	6		23	23	23	70				C/T	148	22
INDIA	Gov.	IRS-P5	LISS 4, LISS-3'	'98	M			<10	<10	<10	70				C/T	148	22
INDIA	Gov.	IRS-2A	LISS 4', LISS-3' (WIFS)	'00	M			5	5	5	70				F/A	148	22
FRANCE	Gov.	Spot 4	HRVIR (Vegetation)	'97	M&P	10		20	20	20	20				C/T	120*	26
CHINA/ BRAZIL	Gov.	CBERS	CCD, IRMSS	'97	M&P	20 & 80	20	20	20	20	80	80	160		C/T	120	26
JAPAN	Gov.	ADEOS	AVNIR	'96	M&P	8	16	16	16	16					C/T	80, 40	45 & 90
HIGH-RESOLUTION, SMALL AREA COVERAGE (PAN & VNIR ONLY)																	
U.S.	Com.	Earth-Watch	Early Bird	'96	M&P	3		15	15	15					F/A	36	120
U.S.	Com.	Earth-Watch	Quick Bird	'97	M&P	1	4	4	4	4					F/A	20	148
U.S.	Com.	Space-Imagir	SIS	'97	M&P	1	4	4	4	4					F/A	12	247
U.S	Com.	Space-Imagir	SIS	'98	M&P	1	4	4	4	4					F/A	12	247
U.S.	Com.	Orbimage	OrbView	'97	M&P	1 & 2	8	8	8	8					F/A	4 & 8	740&370
U.S.	Com.	GDE	?	'97	P	1									F/A		
INDIA	Gov.	IRS-P6	PAN	'99	P	2.5									F/A	10	296
RUSSIA	Gov.	SPIN-2	KVR-1000 TK-350	'96	P(f)	2 & 10									F/A	40 & 300	
RUSSIA	Gov.	ALMAZ 1B	1SLR 3 SARs 4 Scanners***	'98	M&P&R	2.5		4 & 10	4 & 10	4 & 10				5, 40 S	F/A	20 & 170	
MULTISPECTRAL, HYPERSPECTRAL APPLICATION TESTS																	
U.S.	Gov.	TRW Lewis	HSI	'96	M&P	5	128 bands @ 30				256 bands @ 30					8	370
U.S./ JAPAN	Gov.	EOS-AM1	ASTER (MODIS)	'98	M			15	15	15	6 bands @ 30		5 @ 90		F/A	60	49
RADAR																	
CANADA	Gov.	Radarsat	SAR	'95	R									10-10C C		50-500	
ESA	Gov.	Poem	ASAR	'98	R									30 C		100	
RUSSIA	Gov.	ALMAZ 1B	1SLR 3 SARs 4 Scanners***	'98	M&P&R	2.5		4, 10	4, 10	4, 10				5, 40 S	F/A	20, 170	

M Multispectral
P Panchromatic
R Radar
(f) Film
IR Infrared
VNIR Visible and near IR
SWIR Short wave IR
TIR Thermal IR

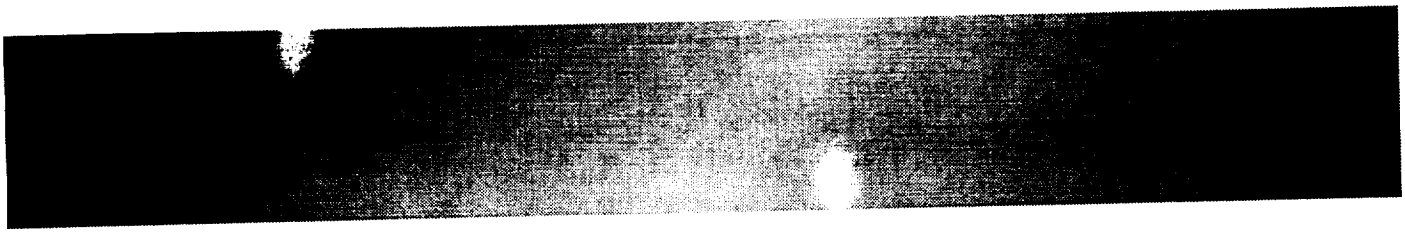
All satellites in polar sun synchronous orbits except SPIN-2 (65 Deg Incl) and ALMAZ 1B (73 Deg Incl)
F/A = fore/aft stereo, C/T = side to side stereo. All stereo satellites have 2 to 3 day site repeat capabilities
( ) = Wide swath, lower resolution inst.
*= Swath is achieved by two side by side instruments
**= 4 satellites are planned to provide 3.5 to 4 day global repeat coverage
***= SLR-3, SAR-3, SAR-10, SAR-70, OES, MSU-E (MSU-SK, SROSM)

Figure courtesy of the American Society of Photogrammetry and Remote Sensing, proceedings of conference titled *Executive Summary of Land Satellite Information in the Next Decade "The World Under a Microscope,"* September 25–28, 1995 (Vienna, VA: American Society of Photogrammetry and Remote Sensing, 1996), p. 24.

Figure 2:
Mission to Planet Earth Sensors of Potential Interest to State, Regional, and Local Agencies

Mission	Launch Date	Sensor	Type of Data Gathered
Landsat 7	1998	ETM	Enhanced Thematic Mapper will gather high spatial resolution land images in the visible, mid-infrared, and thermal wavelengths (30/30/90M resolution), including a co-registered 15-meter panchromatic band—16-day repeat cycle.
EOS-AM1	1998	ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer will gather high spatial resolution images of land, water, ice, and clouds in the visible, mid-infrared, and thermal wavelengths (15/30/90M resolution)—16-day repeat cycle/stereo capability.
		MODIS	Moderate Resolution Imaging Spectroradiometer will measure biological and physical processes with 36 spectral bands in the visible, mid-infrared, and thermal wavelengths (250/500/1000M resolution selectively)—1- to 2-day global coverage.
EOS-Color	1998	OCI	Ocean color instrument, similar to Coastal Zone Color Scanner, will collect 8 spectral bands (402–885nm)—daily global coverage.
EOS-PM1/2/3	2000 2005 2010	AMSU	Advanced Microwave Sounding Unit will provide atmospheric temperature measurements from the surface—up to 40-km resolution.
		MHS	Microwave Humidity Sounder will provide atmospheric water vapor profile measurements—13.5-km resolution.
		MODIS	See above description under EOS-AM1.
EOS-ALT1/2/3	2002 2007 2012	TMR	TOPEX Microwave Radiometer will provide atmospheric water vapor profile measurements at nadir.
EOS-CHEM1/2/3	2002 2007 2012	HIRDLS	High-Resolution Dynamics Limb Sounder will observe global distribution of temperature and concentrations of O_3, H_2O, CH_4, N_2O, NO_2, HNO_3, N_2O_5, CFC-11, CFC-12, $ClONO_2$, and aerosols in the upper tropo-, strato- and mesosphere—profile spacing 400 by 400 km.
		SAGE III	Stratospheric Aerosol and Gas Experiment III will obtain global profiles of aerosols, O_3, H_2O, NO_2, NO_3, OClO, clouds, temperature, and pressure in the meso-, strato-, and troposphere.
EOS-AM2/3	2003 2008	EOSP	Earth Observing Scanning Polarimeter will provide global aerosol distribution—12 bands, 0.41–2.25 µm, 10-km resolution.
		TES	Tropospheric Emission Spectrometer will generate 3-D profiles on a global scale of virtually all infrared active species from the Earth's surface to the lower stratosphere.
		MODIS	See above description under EOS-AM1.
EOS-Aero1/2/3/4	2003 2006 2009 2012	SAGE III	See above description under EOS-CHEM.
		EOSP	Earth Observing Scanning Polarimeter will provide global aerosol distribution.

Information provided by Paul Tessar, Wisconsin Department of Natural Resources



- *Land-Cover and Land-Use Change Research*—What are the nature and extent of land-cover and land-use change and the consequences for sustained productivity?

- *Seasonal-to-Interannual Climate Variability and Prediction*—Can we enable regionally useful forecasts of precipitation, temperature, and weather on seasonal-to-interannual timeframes?

- *Long-Term Climate Natural Variability and Change Research*—What are the causes and impacts of long-term climate variability, and can we distinguish natural from human-induced drivers?

- *Natural Hazards Research and Applications*—Can we learn to predict natural hazards and mitigate natural disasters?

- *Atmospheric Ozone Research*—How and why are concentrations and distributions of atmospheric ozone changing?

Several accomplishments have already been realized in each of these areas.

While MTPE was primarily developed and funded to support global climate change research, this work can have applicability in states. NASA has applications research and development efforts to conduct knowledge transfer and improve user awareness of MTPE research results for and beyond global change research. Work is also being conducted to transform MTPE science products into new and innovative applications-oriented information products. The goals are to leverage non-NASA capabilities in remote sensing, environmental activities, and information systems and to advance the value of MTPE data through data fusion, such as with GIS. Efforts are under way with others, particularly Federal agencies, to jointly identify and test applications where benefits can be derived from using satellite data. A series of regional applications workshops are being conducted in 1997 and 1998 to enhance the dialog regarding applications among various organizations, including states.

An important component of MTPE is EOSDIS, which is a new data system for distributing Earth science data based on NASA's commitment to provide open access to data. While EOSDIS will primarily serve the global change research community, it is being designed so that these data might also be useful in environmental protection, natural resources management, and other functions of government by several sectors, including states, localities, and others. Innovative means are being developed to manage and distribute data, including the EOSDIS Federation, which includes a set of competitively selected Earth Science Information Partners (ESIPs) to generate EOSDIS data products. NASA has developed specific outreach strategies for education and the private sector.

1.5 NASA Initiatives With State Governments

This report provides an overview of NASA's past and recent outreach initiatives regarding state governments. Section 2 provides an overview of state programs conducted during the late 1970s and early 1980s. Essentially no dedicated efforts were conducted regarding states until 1994, although a few state agencies received applications funding through the Science Applications Research Program. In addition, some universities with projects funded by NASA included state participants in their research.

Recognizing the increasing role of states and their satellite data applications, NASA began a new effort in 1994 to (1) understand current conditions, needs, and implications regarding satellite data in the states and (2) determine how NASA can best help states make use of data that will be available through EOSDIS. This initiative was conducted to complement MTPE efforts to develop an EOSDIS User Model with Dr. John E. Estes and other researchers of the

Information Science and Research Group at the University of California at Santa Barbara.

This recent NASA effort with states included two components described in this report. Section 3 includes an investigation of satellite data use in the Nation's 50 state governments. This work included contact with at least one official per state to determine (1) state users, uses, and plans regarding satellite data and (2) primary and additional entry points for EOSDIS efforts in each of the 50 states. This detailed information is provided in Appendix B. Section 3 also includes an aggregation of existing state satellite data uses by government function to determine the range and extent of satellite data applications in the 50 states. This work was conducted, in particular, to identify additional applications that might not have been considered when investigating Federal Government and other data uses, as well as to address them in EOSDIS planning efforts.

Section 4 provides a brief report of a meeting sponsored by NASA that included representatives from 12 states that have extensive experience using satellite data. Conducted at NASA Headquarters on March 29 and 30, 1995, these officials discussed their current and anticipated uses of satellite data, ways in which NASA could assist states by providing access to NASA's data and research results, the potential role of states in the MTPE program, and how future data systems could be designed to better accommodate state needs. The results of this meeting are discussed in Section 5.

Section 6 provides the states' rationale for NASA's involvement in satellite data and some important implications for NASA based on the agency's early efforts with states, as well as current conditions from the recent analysis of satellite data and other conditions in the 50 states. Section 7 provides recommendations for a strategy to maximize EOS opportunities in states, based on specific recommendations by experienced state officials at the 1995 meeting sponsored by NASA. This is followed by a brief summary and conclusions in Section 8.

2. Building on NASA's Past Outreach Efforts for States

Twenty-five years ago, NASA began a new era of Earth resource monitoring and data to help resource managers and scientists in multiple governments and organizations. The launch of the first satellite for remote sensing in 1972 prompted NASA to develop a technology transfer and outreach strategy through the Technology Transfer Division in the Office of Space and Terrestrial Applications. The purpose of this strategy was to enable various organizations to become aware of and utilize data resulting from these technological advances.

Many early efforts concentrated on other Federal agencies and academic institutions. However, largely because of one of NASA's employees, Alexander J. Tuyahov, NASA created an outreach program specifically designed for state and local governments. As a former employee of the State of Texas, Tuyahov saw that state and local governments required a customized approach because they could not be expected to learn about and use satellite data as a byproduct of other technology transfer efforts.

Specific state and local efforts were established beginning in 1976 to determine potential state and local satellite data needs and applications, to educate officials about Landsat resources and opportunities, and to assist governments in using satellite data. An important feature of NASA's approach was to build state and local capacities through state and local government associations and to provide education to officials representing individual state governments.

2.1 User Requirements and Awareness Program

NASA's first initiative to work with states and localities was known as the User Requirements and Awareness Program. It was developed to determine current state conditions, needs, and applications regarding satellite data, specify the technology transfer programs needed to maximize the usefulness of satellite data, and educate and assist state and local government officials. The key components of this initial program were to (1) involve and work with state and local associations, (2) conduct several and diverse symposia targeted for differing audiences, and (3) publish educational documents specifically designed for states and localities.

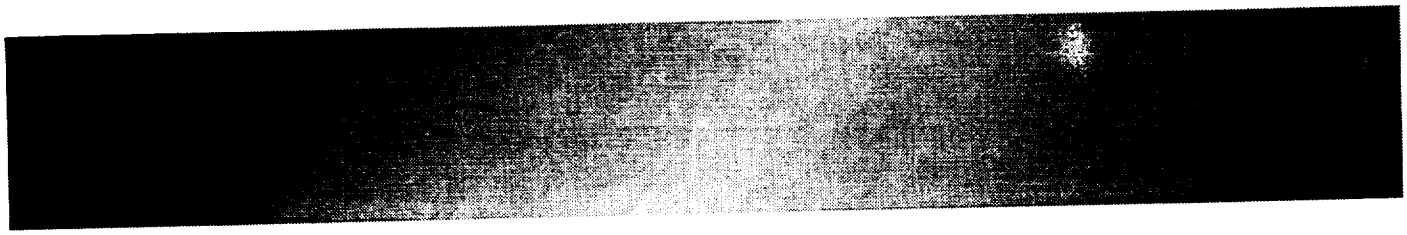
This approach enhanced state and local awareness about this emerging technology, including current and future data resources, applicability for governmental needs and applications, and appropriate limitations. To be most effective with states and localities, NASA worked with associations representing both the legislative and executive branches of state government, as well as local government associations, including:

- National Conference of State Legislatures
- Council of State Planning Agencies
- National Association of Counties
- Public Technology, Inc.

NASA also worked with several regional associations of governments, which included officials from neighboring states. Beginning in the 1960s and at the request of governors, the Federal Government established these consortia, such as the Federation of Rocky Mountain States, the Southern Growth Policy Board, and the Pacific Northwest Regional Commission, to address regional issues. NASA developed outreach efforts with many of these associations, in addition to those dedicated to state and local governments across the country.

2.1.1 National Conference of State Legislatures

NASA initiated the first and largest of its association relationships with the National Conference of State Legislatures (NCSL) in 1976. With NASA support, NCSL established a task force composed of state legislators to review the feasibil-



ity of using Landsat technology in state and local governments. The task force determined that Landsat data could uniquely satisfy many state legislative information needs and unanimously endorsed the satellite program's continuation. Specific recommendations were also made to help transfer this technology from the Federal Government to the states.

NCSL initiated a Satellite Remote Sensing Program to implement these and other recommendations. The program was specifically directed toward informing state lawmakers of the capabilities and limitations of satellite remote-sensing, as well as fostering communication between the states and satellite remote-sensing experts in the private sector, universities, NASA, and other agencies of the Federal Government. Several Federal laws and programs were reviewed to determine new roles of states that could benefit by using satellite data. Inventories of legislation in each of the 50 states were also undertaken to determine new data requirements and data applications. The program included various educational and liaison activities, including regional and state-level workshops throughout the country. It was funded until 1981.

2.1.2 *Council of State Planning Agencies*

The Council of State Planning Agencies (CSPA), which is now the Council of Governors' Policy Advisors, established the Earth Resources Data Project with NASA support in 1978. NASA funded this project to serve as an executive branch complement to the NCSL program, although it was a smaller project. While the focus of the NCSL program was on educating and influencing legislators, this 3-year project had a more operational and technical thrust to maximize data utilization. The project encouraged two-way communication and ongoing information exchange among the states, NASA, NOAA, and other Federal agencies on remote sensing and other natural resource data issues; it also provided a forum for the coordination of state and Federal actions. The project helped identify state needs and provided technical assistance to other state officials, including information about satellite data projects in other states.

Executive branch participants included state planning and natural resource agency staff representing various parts of the country. An Earth Resources Data Council composed of some of these officials served as a communications and advisory network for the project, as well as a policy recommendation group for CSPA. Council members maintained contact with appropriate state officials within their regions, distributed pertinent information, and obtained feedback on natural resource data issues.

2.1.3 *Program Results and Benefits*

NASA's work with state and local associations and the following additional programs during this 5-year period produced several results and benefits. Much information was disseminated to the states and localities about satellite data resources and opportunities. In addition, various sessions and other symposia were used to categorize and prioritize state and local needs for data according to applications areas and then to determine specific user needs. Requirements analyses were specified from these symposia, and additional symposia were held to publicize and hear reactions to these results. The identified needs were correlated with science results and products to define several applications projects through the programs described below. Moreover, some state legislatures appropriated funding for satellite data use and included satellite data analysis capabilities in formulating state legislation.

NASA also conducted direct work with the National Association of Counties (NACo) and Public Technology, Inc. (PTI), after the state programs were initiated. NACo's program included a further definition of local government needs and requirements through a user survey and conference sessions. PTI developed a remote-sensing procurement package to assist state and local governments with planning,

organizing, staffing, and implementing an effort to procure data and services. NASA also conducted efforts to attract the interest of the private sector in providing services to states and localities.

NASA support enabled several educational documents to be published that were specifically designed for states and localities. These documents provided information and guidance about remote-sensing contacts and data resources, potential and example state and local government data applications, state government institutional approaches and contacts, and approaches and methods for governments to procure data, including an inventory of private-sector resources to assist in data work. Among the documents published by state and local organizations with NASA funding and assistance were the following:

- National Conference of State Legislatures, *A Legislator's Guide to LANDSAT* (Denver, CO: NCSL, 1979)
- Tessar, P., and Caron, L.M., *A Legislator's Guide to Natural Resource Information Systems* (Denver, CO: NCSL, 1980)
- Seladones, S., and Harwood, P., *Earth Resources Data and the States: A Guide to Information Tools for Natural Resources Management* (Washington, DC: CSPA, 1981)
- Public Technology, Inc., *Remote Sensing Procurement: An Executive Summary, A Management Report for State and Local Governments, A Technical Guide for State and Local Governments*, and *The Remote Sensing Industry Directory* (four-document series) (Washington, DC: PTI, 1981)
- Caron, L.M., and Stewart, D.S., *An Inventory of State Natural Resources Information Systems* (Lawrence, KS: Kansas Applied Remote Sensing Program, University of Kansas, 1984)

Although funding diminished in the early 1980s, NASA conducted a last effort to inventory state satellite data use through an inventory of state natural resources information systems, which is reported in the last document cited above. NASA also provided a mechanism for states and localities to provide input and feedback on agency activities. As stated above, the associations created advisory groups to provide communications channels among the states and with NASA and other remote-sensing experts. Requirements and feedback on technology transfer programs were determined in several ways. In addition to the educational purpose of several group meetings, symposia, hearings, and workshops, these sessions provided opportunities for officials to provide input to NASA about satellite data, as well as specific feedback about its plans and activities.

2.2 Applications Systems Verification and Transfer Program

Results from the User Requirements and Awareness Program were used by NASA in other programs. The first, the Applications Systems Verification and Transfer (ASVT) Program, was initiated in 1976 to integrate the results of science research with the requirements and needs of state, local, and other organizations that were defined through the User Requirements and Awareness Program. Accordingly, NASA funded some cooperative pilot projects, known as "pathfinders," that tested, prototyped, and verified the use of satellite data for selected applications. NASA issued an "Applications Notice" or call for proposals on an annual basis and chose projects using a competitive process. Selected projects were funded for 3 to 4 years and were required to include an end user, university, and private company in their efforts.

NASA staff participated with project researchers to help build internal capabilities, with the greatest assistance during the early phases of each project. NASA also held annual conferences to encourage cross-fertilization among the participants of the funded projects. Upon the comple-

tion of each project, NASA's direct involvement ended, and the end user was anticipated to have adopted and integrated the use of satellite data for the designated application. A symposium was held at the completion of the program in 1981 to disseminate the results of the projects to similar users. A total of 25 projects were funded through the ASVT Program.

2.3 *Regional Applications Program*

The Regional Applications Program (RAP) was established in 1977 to verify and develop the successful applications determined from the ASVT Program. While the focus of ASVT was to test and prototype the application of science results for state and local applications, RAP was designed to conduct technology transfer, thereby directly educating and assisting states in their use of satellite data. Program activities were specifically endorsed and encouraged by the participants in the NCSL and CSPA projects to ensure the usefulness and successful implementation of RAP efforts in individual states.

RAP included a liaison and awareness effort, orientation and training in techniques to analyze remotely sensed data, cooperative user/NASA demonstration projects to show Landsat's capability as a resource management tool, and technical assistance to help users locate sources of services and systems, to help them apply the technology to their own projects, and to keep them informed on advances in technology. RAP drew on the expertise and resources of all the NASA centers, but it was concentrated in three NASA field installations that each covered a specific geographical area of the country:

- Northeast—Eastern Regional Remote Sensing Applications Center (ERRSAC), Goddard Space Flight Center, Greenbelt, Maryland
- Southeast—Earth Resources Laboratory (ERL), National Space Technology Laboratories, Bay St. Louis, Mississippi
- West—Western Regional Applications Program (WRAP), Ames Research Center, Moffett Field, California

A unique focus of RAP, as compared to NASA's earlier programs, was that it was designed to address the needs of and conduct outreach with each of the 50 states. Each center conducted user outreach, technical assistance, and technology demonstration, transfer, and training with the states in its region. Several training activities were conducted about remote sensing and GIS, with courses ranging from 1 to 4 weeks in length. Educational programs were held at each center's facilities and at individual states. Several mobile facilities, such as vans, were equipped with technology and traveled to specific sites to assist educational efforts in individual states and groups of states. The vans were also helpful in publicizing NASA's projects to interested observers.

For example, when a session was held at a state, preliminary arrangements were made to invite representatives from several agencies. This approach enabled state officials with similar activities in different agencies to learn about each other's work and to collaborate on a project. State officials found this approach beneficial because interagency mechanisms did not necessarily exist otherwise. This audience learned about satellite data resources and opportunities, heard examples from their own and other states, and then underwent a process enabling state attendees to prioritize a cooperative project with NASA.

Each center's staff also provided technical assistance to help states establish internal systems and capabilities, develop requests for proposals (RFPs), and analyze and evaluate RFP responses. In addition, an annual symposia was conducted in each region among state participants to provide and share updated information and to enable state participants to provide input and feedback to NASA.

By the time RAP ended because of a lack of funding in 1982, satellite data demonstration projects had been conducted in almost all 50 states. More than a third of the states had some in-house expertise or an operational system, and almost half the states had a university center with data expertise. RAP is also credited with facilitating some state remote-sensing and GIS initiatives that continue to exist today, such as in Arizona, Idaho, and New Mexico. Activities initiated through RAP also furthered remote-sensing advances outside state governments, such as the development of image-processing software by ERDAS Corporation. NASA received many compliments about RAP from state officials and others.

2.4 University Applications Program

While not having a direct focus on states and localities, the University Applications Program also encouraged and aided state and local use of satellite data. Initiated in 1971, this program developed and integrated remote-sensing expertise and experience in universities having existing Earth science disciplines. Grants of 5 to 7 years in duration were given to selected universities to develop curricula for college-level use and also to diffuse remote-sensing education into primary and secondary education programs using transportable modules. Funded university programs were encouraged to be interdisciplinary and to include multiple departments in the design and implementation of their activities. The program is credited with integrating remote sensing into geology and geography programs in several universities. By 1982, when funding ceased, almost half the states had a university center with satellite data expertise.

An additional important component of the program was that participating universities were required to work with state and local governments. These cooperative efforts encouraged academic researchers to apply their remote-sensing expertise and technology to actual government problems, which in turn enhanced the value of their work. University programs were also required to conduct technology transfer efforts with relevant government officials. This program complemented the other three programs described above, which specifically encouraged the development of satellite data capabilities and uses within state and local governments.

Analysis of Satellite Data Use in the 50 States

Little research has been conducted to analyze satellite data use in state or substate governments since the investigations sponsored by NASA in the early 1980s. However, NASA staff, including Alexander J. Tuyahov, Jerry Garegnani, and others, determined in 1994 that an investigation about conditions and priorities in the 50 states would be helpful for future Mission to Planet Earth (MTPE) outreach efforts.

An understanding of satellite data use in states was determined by (1) providing support for an analysis of satellite data activities in the 50 states and (2) sponsoring a meeting of representatives of some states with the most extensive experience using satellite data. This section describes the analysis of conditions in the 50 states, and Section 4 reviews the results of the meeting.

3.1 Scope and Methodology

NASA staff decided to investigate satellite data conditions in the executive branches of the 50 state governments, including the determination of:

- Which agencies in each state use and are important in coordinating satellite data
- How the 50 states currently use satellite data
- Primary and additional entry points for EOSDIS efforts in each of the 50 states

It was decided to build on past related work to enable the findings to be analyzed independently and within the context of other state activities. Lisa Warnecke, a consultant knowledgeable about the states, was tasked with conducting this investigation. Warnecke synthesized and included appropriate material from her various documents, articles, and notes available for individual states. Her past documents, including the *State Geographic Information Activities Compendium*, and reports on conditions in the states for the U.S. Environmental Protection Agency, the U.S. Federal Emergency Management Agency, the USDA Forest Service, the National States Geographic Information Council, and the National Association of State Foresters were also used as background, and relevant material is included in this report.

Several external sources of information were contacted to obtain material about individual states before inquiries were made of state officials. NASA provided information on state recipients for MTPE remote-sensing applications grants. Some corporate representatives of EOSAT, SPOT, and ERDAS provided useful material about satellite data use in individual states. Information was also gathered about the NOAA's Coastal Change Analysis Project (C-CAP) and the Gap Analysis Program (GAP), now organizationally located within the U.S. Geological Survey's Biological Resources Division (see below). A search of related state legislation was conducted and provided by the Kentucky Legislative Research Commission. A review of recent literature was conducted to identify additional articles and activities. These materials were incorporated into this report.

This information was supplemented by telephone contact and queries of at least one official in each of the 50 states during 1994. When possible, contact was made with a statewide GI/GIS coordination organization in each state's executive branch. Additional individuals were contacted, particularly in the states where a GI/GIS coordinating office does not exist and other officials have satellite data use. All persons contacted were queried to identify and document current and future satellite data uses and users in each state. The information gathered and synthesized in 1994 was updated in part during 1996 and 1997, but a complete query of the 50 states was not conducted regarding satellite data.

3.2 Content of State Profiles

An individual State Profile was prepared for each of the 50 states; these may be found in Appendix B, including the following information.

3.2.1 State Contacts

Each State Profile provides the name, organization, address, phone number, and additional contact information for at least one person per state whom NASA can use and contact in its outreach efforts. The following individuals are included for each state as applicable:

- *Statewide GI/GIS Coordinator or Equivalent:* At least one key contact per state is identified, usually the official or informal statewide GI/GIS coordination contact(s) or equivalent for each state, regardless or not if any agency is using satellite data in that state.

- *Satellite Data Users:* For the states having some data use, the profile includes one individual or a few individuals using satellite data.

- *Gap Analysis Program Contact:* The GAP contact for each state is included, as provided by the National GAP Office in Moscow, Idaho (see below).

- *Others:* Other individuals influencing or using satellite data are included if information was volunteered by contacted state officials. These individuals are primarily located in academic institutions. Additional names and phone numbers of academic researchers are also provided in the profile text if full addresses were not provided.

The profiles for states with very limited or no use of satellite data may have only one contact (that of a statewide GI/GIS coordinator or equivalent), while other profiles have up to six names if the state has multiple agencies using data. Individuals contacted as part of this project are indicated with an asterisk (*). While some of these contacts were provided during the original data collection in 1994, the list of state GI/GIS coordinators and GAP contacts are current as of 1996.

3.2.2 State Context and Satellite Data Activities

The textual portion of each State Profile provides information about any statewide attention or direction regarding satellite data and identifies usage of satellite data by individual agencies. All organizations throughout the profiles are bolded and italicized the first time they are mentioned in that profile. The text includes the following information as applicable within individual states:

- *State Government Context:* A general description of GI/GIS coordination is provided for each state. If in existence, the state government organization with an official or informal statewide GI/GIS coordinator or "equivalent" is described, whether or not satellite data use is identified in that state. The incidence, authorization, and administrative location of GI/GIS coordinators for the 50 states are summarized in Figures 8 and 9 (see Section 5). Individual legislative actions or executive orders that specifically address satellite data are described if in existence. In addition, statewide GI/GIS coordination groups are identified, including specific attention to satellite data as applicable.

- *Satellite Data Use:* The majority of the profile text includes descriptions of identified past, current, and planned uses of satellite data that are either (1) part of a statewide effort or (2) within individual agencies. Specific applications areas are bolded in the text, identified for each of the 50 states in Figure 3, and summarized for all states in Figures 4 and 5. The descriptions also include some state activities using related technologies, such as GIS, and data sources, such as digital orthophotography and the use of GPS. This information is provided to exhibit related conditions and identify opportunities.

- *Gap Analysis Program Activities:* GAP is a nationwide program of the Biological Resources Division in the

Figure 3:
Current and Past Uses of Satellite Data in the 50 States

State	Current and Past Uses
Alabama	Wetlands and emergency management
Alaska	Land cover and emergency management
Arizona	Agriculture, forestry (and fire), public lands, water, and wildlife
Arkansas	Land cover, agriculture, archeology, forestry, water, wetlands, and highway planning
California	Vegetation, agriculture, coastal, forestry (and fire), water, wildlife, and emergency management
Colorado	Vegetation and wildlife
Connecticut	Land cover, coastal, and water quality assessment
Delaware	Agriculture and forestry
Florida	Agriculture, coastal, environmental assessment, forestry, public lands, water, wildlife, highway planning, and emergency management
Georgia	Land cover, wetlands, water, wildlife, and land planning
Hawaii	Land cover and environmental assessment
Idaho	Land cover, agriculture, forestry, water, and wildlife
Illinois	Land cover, air monitoring, water, economic development, emergency management, and education
Indiana	Limited
Iowa	Land cover, energy development, and emergency management
Kansas	Land cover and water
Kentucky	Land cover, mine reclamation, and wetlands
Louisiana	Coastal, wetlands, and emergency management
Maine	Forestry
Maryland	Land cover, coastal, forestry, water, wetlands, land planning, and revenue
Massachusetts	Limited
Michigan	Forestry and wildlife
Minnesota	Forestry
Mississippi	Land cover, agriculture, forestry, wetlands, and emergency management
Missouri	Land cover
Montana	Forestry, water, and revenue
Nebraska	Land cover, agriculture, natural resources and hazard assessment, water, and wildlife
Nevada	Limited
New Hampshire	Land cover, forestry, wetlands, and highway planning
New Jersey	Limited
New Mexico	Agriculture, forestry (and fire), mining assessment, and water
New York	Vegetation, coastal, forestry, public lands, and wildlife
North Carolina	Land cover, coastal, water, and wetlands
North Dakota	Limited
Ohio	Land cover, agriculture, coastal, mining assessment and reclamation, water, wetlands, and wildlife
Oklahoma	Forestry
Oregon	Vegetation, forestry, and wildlife
Pennsylvania	Limited
Rhode Island	Limited
South Carolina	Land cover, agriculture, coastal, forestry, water, wetlands, economic development, emergency management, and land planning
South Dakota	Limited
Tennessee	Vegetation, biodiversity assessment, wetlands, and wildlife
Texas	Vegetation, coastal, water, wetlands, wildlife, and emergency management
Utah	Vegetation, wetlands, and wildlife
Vermont	Land cover, forestry, and water quality
Virginia	Land cover, forestry, water, land planning, and highway planning
Washington	Environmental assessment, forestry, public lands, and wildlife
West Virginia	Land cover and water
Wisconsin	Land cover, forestry, water quality, and wildlife
Wyoming	Agriculture, water, and wildlife

NASA as a Catalyst: Use of Satellite Data in the States (Warnecke 1997)

Figure 4: Most Frequent Current and Past Uses of Satellite Data in the 50 States

Frequent Use	Amount
Land-cover inventories (and some land use)	22
Forestry	22
Water resources (including quantity and quality)	21
Wildlife management (usually for habitat assessment)	17
Wetlands assessment	14
Emergency management (such as spills, wildfire, and earthquakes)	13
Agriculture (often for irrigation water regulation)	12
Coastal resources management	10
Vegetation assessment	7
Land planning and economic development	5
General environmental/natural resources assessments	5
Public lands management	4
Energy (usually mining assessment and reclamation)	4
Highway corridor planning	4
Revenue generation through taxation	2
Air quality monitoring	1
Archaeology	1
Education	1

U.S. Geological Survey that uses satellite data and GIS to map land cover, vertebrate species, and lands that are managed to maintain biological diversity. GAP work has been conducted on a state-by-state basis in cooperation with agencies, universities, and others in more than 40 states. The status of these projects is described in the profiles and summarized in Figure 6, as provided by the National GAP Office in Moscow, Idaho, where GAP began in the late 1980s. GAP continues to receive Federal funding for these state projects, and the program is collaborating with other Federal agencies in the Multi-Resolution Land Characteristics (MRLC) Consortium to purchase Landsat TM images for the contiguous 48 states in 1997. These data will be used with Landsat TM data that was purchased in 1992 through MRLC for GAP and other efforts.

- *Nonstate Government Activities:* Satellite data activities of other organizations, such as academic institutions, that are working within a state is provided in the profiles if written material or other information was discovered or volunteered by state officials. The profile also includes information about applicable state-based work related to the Coastal Change Analysis Program (C-CAP), a nationally standardized database of land-cover and habitat change in the coastal regions of the country. Managed by the NOAA's Coastal Services Center in Charleston, South Carolina, C-CAP inventories coastal submersed habitats, wetland habitats, and adjacent uplands through the analysis of satellite data (primarily Landsat TM) and other data with GIS.

3.3 *Findings and Observations*

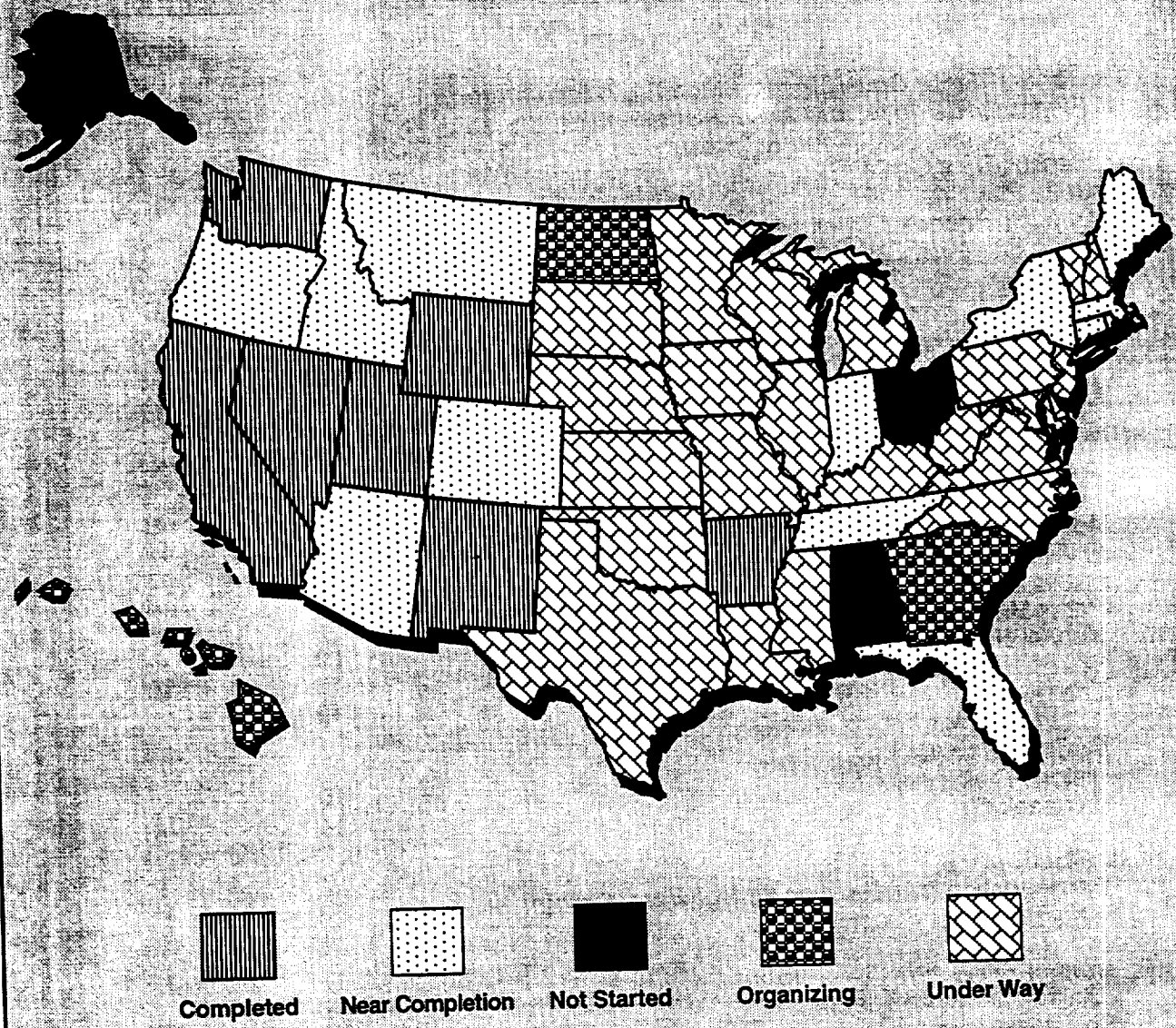
The information gathered through this investigation was aggregated and analyzed in several ways. The following general findings and observations can help NASA design and implement future efforts with state governments.

Figure 5:
Uses of Satellite Data and GIS in the 50 States: Classified by Government Function*

	GIS	Satellite Data
General State Government: Planning, Administration, Finance, Revenue, and Asset Management		
Revenue, including Property Taxation	13	2
Census Data Center	13	—
State Planning	12	4
Budget, Finance, Comptroller, Asset Management	9	—
State Surveyor, Cartographer, and Geographer	4	1
Library	3	—
Environment/Natural Resources		
Water—Quantity, Quality, Rights, or Drinking	49	21
Wildlife, Game, Fish or Biological Resources	42	17
Geology	39	—
Waste Management, including Solid, Low-Level	30	—
Air Quality	29	1
Forestry	27	22
Agriculture	27	12
Oil/Gas/Mining Regulation and Reclamation	24	3
Public Lands Management	22	4
Parks Management	22	—
Natural Heritage Program	20	—
Coastal Resources	18	10
Energy	12	1
Cultural Resources		
Historic Preservation	19	—
Archaeology	14	1
Infrastructure		
Transportation (satellite data for highway planning)	50	4
Utility Regulatory Commissions	9	—
Human Services		
Health (primarily epidemiology)	25	—
Social Services	6	—
Employment Security and Labor	5	—
Education	3	1
Other		
Public Safety, Emergency Management and Military	24	13
Economic Development	20	1
Community and Local Affairs, Planning Assistance	20	4

* Adapted from Warnecke 1995.

Figure 6: Gap Analysis Program Status in the 50 States (as of January 1997)*



* Figure courtesy of the National Gap Analysis Program in Moscow, Idaho. Alaska and Hawaii are not drawn to scale.

3.3.1 *Most States Have No Legal Direction Regarding Satellite Data*

A search of relevant legislation and executive orders in the 50 states was conducted in the fall of 1994 to determine the extent to which state officials are given direction regarding satellite data. This review found only six states with a directive that contains a specific reference to remote sensing or satellite data. No more recent state directives are known that specifically address satellite data. While few states have official direction regarding data, an increasing number of states have legislation and executive orders regarding geographic information or GIS as described in subsection 5.3 in Section 5.

3.3.2 *State Government Experience With Satellite Data Varies Widely*

Some state governments have continued to use satellite data since Landsat resources and NASA outreach programs were available in the early 1980s, some states have initiated data use after these programs ceased, and other states are essentially not using data at all. In general, states can be categorized into the following three groups, according to their level and type of experience with satellite data:

- Approximately one-third of the states has made extensive use of satellite data, such as providing multi-agency support for land-cover and other data that can be used for multiple purposes, or are applying data to multiple state applications, such as in forestry, water, or wildlife resources management.

- A second third of the states has used satellite data on an experimental or limited basis, usually with little commitment and resource utilization, as well as benefits that are realized by only one or a few program areas.

- The remaining third of the states has very limited knowledge or use of satellite data today. While some of these states have similarly low usage of GIS and have a limited geographic information coordination effort, some of these states have extensive GI/GIS efforts, but have not complemented this work with satellite data.

It is clear that various state agencies among the 50 states could make use of satellite data, but have not done so to date.

3.3.3 *States Use Satellite Data for Many Diverse Purposes*

An important focus of this investigation was to determine the applications and frequency of satellite data use in state governments. The State Profiles identify all state agencies known to be using satellite data and include discussion about these applications, as summarized below and in Figures 3, 4, and 5. Important findings of this work include the following:

- Considering all 50 states, few state agencies use satellite data, but many diverse applications are identified. Less than half of the state governments use data for the most frequently identified applications, and less than a quarter of the states for most applications. More than 40 states have GAP in their state, but this work is usually conducted at academic institutions or field-level Federal offices and not necessarily with all relevant state agencies.

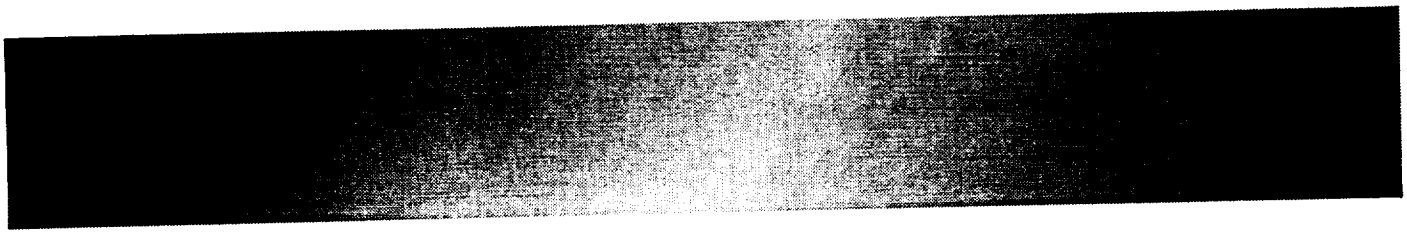
- Most state government data use to date supports specific natural resources functions within individual state agencies, most frequently including forestry, wildlife, and water resources, with growth also in agricultural, coastal resources, and environmental assessment applications.

- Satellite data are increasingly applied to a broader variety of state government functions and responsibilities, such as emergency management, land planning, economic development, transportation planning, revenue generation, and others.

- Some states are using data to develop statewide land-cover, vegetation, or wetlands data that are used by multiple state agencies and others. Some of these efforts are in collaboration with GAP and other external initiatives.

3.3.4 *Satellite Data Knowledge and Experience Differ Among State Officials*

Some state officials have extensive backgrounds and experience using data in their states or other organizations. Their knowledge and experience could be a valuable resource to help NASA develop and test future products. However, a greater number of state officials, and even some that work



regularly with GI/GIS, seem unaware about existing data resources, applications, and potential benefits. Concerns were expressed that data may not apply or be of appropriate resolution or price to meet their needs. Few of the contacted officials were aware about MTPE and EOS, although interest was expressed in learning more about future resources, opportunities, and costs.

The lack of awareness about satellite data is an issue at several levels within state organizations. Most state policy makers, agency directors, and program managers are even less aware of satellite data than the queried officials. Accordingly, they lack sufficient information to determine whether, how, and at what cost data can help meet agency missions in the future. In addition, most technical staff within individual programs that regularly use other data resources and methods also lack sufficient knowledge about satellite data to investigate or recommend data use.

3.3.5 *Only Some Federal Satellite Data Activities Are Conducted With States*

Federal agencies use satellite data to meet their missions, but these initiatives do not necessarily involve state governments. Some examples of Federal efforts that have stimulated and even funded state agency data use include the following:

- NASA provided direct grant funding to some state agencies, such as the California Department of Forestry and the Ohio Department of Natural Resources, for specific data development projects using satellite data, which ensures their use in these agencies and perhaps other state agencies.

- While often not organizationally located within a state agency, the national GAP is the first recent initiative to use satellite data in some states (see above). Work includes acquiring available data from the state fish and wildlife or other agencies, and some of these agencies are GAP participants and satellite data users. Satellite data analysis for GAP sometimes stimulates similar work by other agencies in some states.

- The U.S. Environmental Protection Agency's Region 4 (the southeastern states) funded and encouraged the states within its region to acquire and analyze satellite data to produce a wetlands data layer for use with GIS. The satellite data are being analyzed with similar approaches so that they can be used at a regional as well as a state level.

- The Forest Service uses satellite data to understand forest resources in several parts of the country in which it owns and manages public lands. This usage has helped stimulate some state governments to conduct similar work for neighboring lands, such as in the Pacific Northwest and the northeastern states.

However, this query of state officials discovered that in several cases, state agencies are not necessarily involved with or even aware of the satellite data work conducted by Federal agencies about the lands within their borders. For example, while GAP has stimulated and facilitated satellite data use in some states, GAP work is not coordinated well with related work in other states. Some state GI/GIS coordinators are not aware of or involved with satellite data activities because the data are not included in their state's GI/GIS coordination efforts.

3.3.6 *Some Academic Satellite Data Work Has Limited Impact on Individual States*

As with some Federal agencies, researchers at many academic institutions also use satellite data about the state in which they are physically located. This satellite data work is often funded by NASA or other Federal agencies. Virtually

the only satellite data usage or the most extensive data activity in some states is conducted at a university. Academic satellite data work sometimes educates state government personnel and stimulates agency-level data use, such as through the GAP program. Collaborative efforts have been experienced among state agencies, academia, and Federal agencies in some states.

However, some state officials remarked during this inquiry that they are not aware of or involved with satellite data work at universities in their state. Concerns were expressed that academic research sometimes occurs in a vacuum, even if about areas within the state. Mechanisms often do not exist for states to know about or benefit from academic research. In addition, research using satellite data may not be designed to be appropriate or relevant for state needs, and academic overhead charges are sometimes too expensive for state agencies to afford to participate.

Meeting of Representatives From States Experienced With Satellite Data

An important conclusion of the investigation of the 50 states was that some states and their officials are not aware of satellite data resources and opportunities. However, in direct contrast, other state officials have extensive knowledge and experience with satellite data and NASA programs. These individuals are a valuable resource for NASA. State officials are able to provide direct input for NASA's outreach strategy for states and other sectors, and they also provide practical feedback on programs and products.

NASA sponsored a meeting of experienced state representatives as an initial mechanism to learn about the broad range of state government applications and perspectives—and particularly the factors that can be unique compared to Federal agencies and academia. This meeting was also viewed as a key opportunity for NASA staff to interact personally with some state officials and to develop productive relationships for the future.

4.1 Meeting Attendees, Purpose, and Description

A small group of state representatives was invited to attend a meeting with Dixon Butler, Alexander Tuyahov, Jerry Garegnani, and others from the Office of Mission to Planet Earth at NASA Headquarters, as well as with John Estes and associates from the University of California at Santa Barbara who were developing the EOSDIS User Model for NASA. The meeting was held on March 29 and 30, 1995, at NASA Headquarters in Washington, D.C. The agenda for this meeting and a list of participants are provided in Appendix A.

Fourteen representatives of states were invited to the meeting, based on the results of the preliminary findings from the 50-state investigation, as well as past NASA relationships with states. These individuals were from states with extensive and varied data experience in several application areas—and often with other state and Federal agencies. They also represented states of several regions of the country, differing physical sizes and topography, and varying operational requirements. Twelve of the 14 invited representatives participated in the meeting.

The purpose of the meeting was defined to expand NASA's understanding of conditions in states and to determine the most effective relationship between NASA and state governments to extend the results of NASA's research and information to address state needs. More specifically, NASA desired assistance to answer the following questions:

- What kind of program should NASA plan and implement with state and local governments?
- How can NASA best evaluate the utility of EOSDIS data to the broader nonscience research and applications community in state and local governments?

The majority of the meeting consisted of interactive sessions in which state representatives described how NASA can best help states, how satellite data are currently used by states, how EOSDIS can be applied to make the greatest contribution to meet state needs, and what benefits and lessons learned were obtained from past NASA programs. The participants also provided suggestions on a strategic approach and program structure to facilitate NASA's beneficial involvement with states and the dissemination of NASA's data and research results to states. Presentations were made to update state representatives on NASA's plans and activities.

4.2 Leading Satellite Data Uses by Experienced States

Each state representative at the meeting provided a written list of their state's 10 highest priority uses of satellite data. These lists were summarized by similar categories as were used in the 50-state investigation to identify the most

frequent applications and an indication of the relative importance of these applications among one another. Figure 7 includes a summary of the list provided by each participant. Important findings from this work and as compared to the 50-state investigation include:

- All 12 states with representatives at the meeting are using satellite data to develop a land-cover (and sometimes land-use) data base that is increasingly used for multiple applications by one or more state agencies. This was also a leading application identified through the investigation of the 50 states.

- With findings similiar to that of the 50-state investigation, most of the 12 experienced states primarily use satellite data to support natural resource functions—usually for water, forestry, and wildlife–but a stronger interest in integrated environmental applications was also identified

- Attendees indicated a stronger interest in satellite data use for applications other than natural resources than was revealed from the 50-state investigation. For example, half of the 12 experienced states expressed interest in using data for land planning or economic development, transportation and utility corridor planning, and emergency management.

Figure 7: Leading Uses of Satellite Data by 12 Experienced States

Leading Use	Amount
Land cover/land use inventories (including wetlands, and so on)	12
Water resources	10
Forestry	10
Wildlife management	8
Land planning or economic development	7
Emergency management (such as spills, wildfire, and earthquakes)	6
Highway and utility corridor planning	6
Agriculture	5
Air quality monitoring	4
Coastal resources management	3
Environmental protection monitoring and regulation	2
Energy management	2
Revenue generation	1
Geology	1
Archaeology	1
Education	1

NASA as a Catalyst: Use of Satellite Data in the States (Warnecke 1997)

These results clearly indicate that as states become more experienced with satellite data, the benefits of using them to develop land-cover and land-use data for multiple applications become evident. These and other data derived from satellite data have many natural resources and environmental management applications in states, similar to the Federal Government. However, the 50-state investigation and the meeting results indicate that satellite data are increasingly applied to other state government functions that may not be relevant at the Federal level. These applications, such as land-use planning, economic development, transportation and utility corridor planning, and revenue generation, can provide additional tangible benefits for state governments. Moreover, local governments are likely to use satellite data for a similarly wide range of applications, particularly because these applications are among the most important local government functions. However, these applications are not necessarily initiated or researched by other data users at Federal agencies and academic institutions. This broader range of applications is important for NASA to consider in state and local outreach activities, as well as in planning EOSDIS efforts with others.

4.3 Future State Uses of Spatially and Temporally Enhanced Data

The state meeting attendees repeatedly reported that substantive benefits are realized from satellite data provided by existing sensor systems. Yet, technological advances are providing data with even greater utility to states and others. The attendees were asked to consider the potential impacts of spatially and temporally enhanced data on all states. An important discussion ensued, with state representatives reaching consensus on some of these impacts.

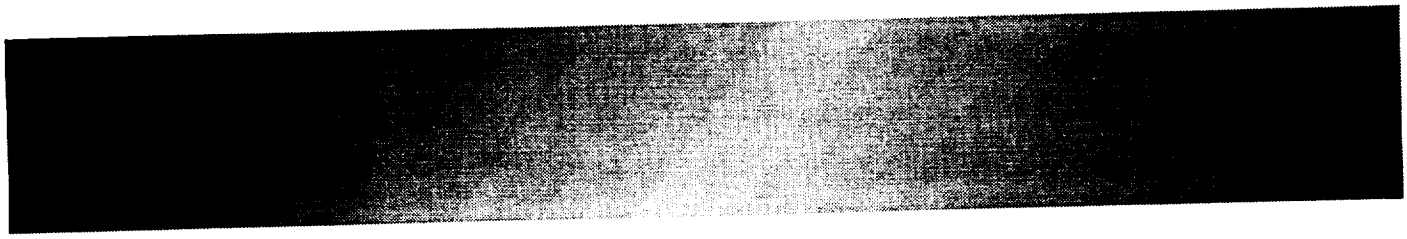
The attendees agreed that certain improvements, particularly in sensor spatial and spectral characteristics, would fundamentally expand the range of applications and change how satellite data are used by states. Higher resolution data with 1- to 3-meter accuracy would be more informative and useful for some applications than current resources. For example, data with greater resolution are needed for regulation and adjudication.

The state representatives indicated that essentially all state applications of satellite data would benefit from improved spatially enhanced data. In addition, they determined that such improved data could dramatically impact certain state applications, such as:

- Land-use inventories and planning
- Base mapping
- Transportation and utility corridor planning
- Economic development
- Emergency management

Potential applications of temporally enhanced data were also considered by the state representatives. They agreed that temporal improvements would be welcome for many applications in several respects, such as quicker data delivery and more frequent and available data products. States could benefit by more frequent overflights and images—and particularly with greater availability of images without clouds. The attendees did not reach a consensus on a prioritized list of applications to realize significant benefits because many applications are more important in some regions of the country, with greater applicability in some states than others. However, the following applications were identified as those that could realize particular benefit from the availability of enhanced temporal coverage:

- Emergency management (such as fire assessment and response)
- Agricultural irrigation



- Coastal monitoring

These views of representatives of the 12 states experienced with satellite data reinforce the conclusion that a growing number and wider range of state applications will benefit from the use of satellite data. The attendees also believe that the availability of spatially and temporally enhanced data will expand data use, particularly for emerging applications such as emergency management, land-use planning, transportation and utility corridor planning, and economic development.

State GI/GIS Conditions Relevant to Satellite Data and EOSDIS

The rapid and widespread growth of GIS applications and GI/GIS coordination in many facets of society, and particularly state governments, increasingly influences satellite data use. Unlike satellite data, GIS is used by at least one agency in each of the 50 states and by multiple agencies within most states. Moreover, increasing and maturing use of GIS has stimulated many states to authorize, direct, and facilitate the coordination of GI/GIS through interorganizational groups, coordination entities, and other mechanisms. Satellite data may or may not be included in these efforts as described below.

5.1 GIS Use in the 50 States

An analysis of the 50 states has found that as of 1990, each of the 50 states has used GIS for at least one application (Warnecke *et al.* 1992). Since then, as indicated in Figure 5 in Section 3, GIS has been applied to essentially all functions of state government (Warnecke 1995). In addition to GIS software usage, as included in Figure 5, at least one agency in each state uses computer-aided drafting (CAD) or related software, particularly the 50 state departments of transportation but also others, such as park or property management offices.

Figure 5 also reveals similarities between the frequency of satellite data and GIS use. However, the number of states using GIS for certain application areas is more than double the number of states using satellite data use for many applications. Several opportunities for future satellite data use are identified by investigating GIS use in states.

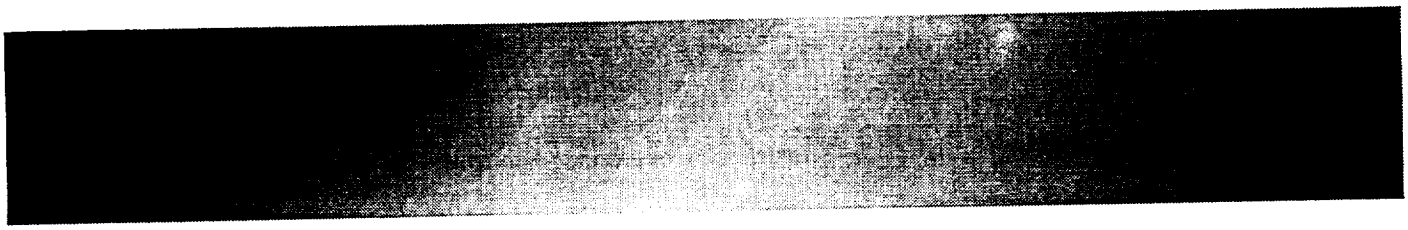
Among all governments, it is generally agreed that most GIS use has been for environmental and natural resources (ENR) and infrastructure applications, including transportation and utilities. Over time, most state government GIS use has been within ENR agencies, with multiple applications in the majority of states. GIS use is particularly strong in ENR areas for which states have greater jurisdiction than the Federal Government, such as water (49 states), wildlife (42), geology (39), waste management (30), air quality (29), forestry (27), and agriculture (27) (Warnecke 1995).

More recently, this and other research indicate GIS use in virtually all functions of government. Moreover, substantial GIS growth is indicated in several "emerging application areas" in recent years. For example, states use GIS for public safety and emergency management (24 states), economic development (20), community and local affairs (20), general government, such as administration, finance, and asset management (19), cultural resources management (19), human, social, or educational services (13), and planning and growth management (12) (Warnecke 1995). These functions have some of the greatest political and financial interest and support from government decision makers.

GIS use is also expanding from individual programs within an agency to serving multiple program areas and to central and support units as an information management, analysis, and planning tool across programs and for entire functions and agencies. GIS use by multiple agencies for multiple purposes promotes and facilitates the integration of otherwise disparate data, such as for natural resources, infrastructure, demography, and human services. Moreover, experiences show that GIS use encourages integrated approaches within and among state agencies. Accordingly, a satellite data set is becoming one of several sets of data that can be used in a coordinated manner for several applications by multiple agencies.

5.2 State GI/GIS Coordination Scope

The growing use of GIS and the increasing need for data resources have been the leading forces to encourage states and other organizations to coordinate several related efforts and activities. The initial focus of many of these efforts usually is on GIS and users of this software. However, as coordination efforts evolve, conceptualization and scope



often expand to include more data, technologies, applications, and participants. Technological improvements in remote sensing and the global positioning system (GPS) complement governing needs that encourage attention to additional and more accurate data.

Over time, only a few states have had statewide remote-sensing or GPS coordination efforts that were not somehow linked with GI/GIS. GI/GIS coordination approaches in states and other organizations increasingly incorporate a broadened focus, which may specifically imply attention to satellite data.

The changing definition of "state" in the context of GI/GIS and satellite data is another important evolution in states that is increasingly important for NASA and others. The geographic area of a state, not merely the state government and its agencies and programs, has become the scope of state coordination efforts. Thus, states seem to be defined as a community or collection of interests having a broader identity and involving more actors in and outside state government.

This changing definition means that other sectors, such as localities, Federal agencies, Native American tribal governments, the private sector, and nongovernmental organizations, have a greater role and impact on state GI/GIS direction, such as influencing state legislation and participating in state GI/GIS coordination groups (Warnecke 1993). This trend is in contrast to the Federal Geographic Data Committee, which until 1997 only had Federal members. This broader definition of "state" has important implications for NASA. For example, the needs and perspective of external organizations are increasingly reflected in overall state direction and funding, as well as data policies, architectures, requirements, and custodianship.

As state GI/GIS coordination evolves, it is increasingly affected and directed by policy and other high-level officials, including governors, legislators, department directors, and other state leaders. GI/GIS is also increasingly linked to important statewide, agency, and program missions that can ensure its continued use and financing. Moreover, while early state GI/GIS coordination efforts concentrated on executive branch agencies, the legislative branch has become more involved, and interbranch GI/GIS coordination has been established in some states.

5.3 *State GI/GIS Direction and Authorization*

While the investigation that is reported in subsection 3.3 in Section 3 found little mention of remote-sensing or satellite data in state statutes, an increasing number of states have authorized GI/GIS coordination and related direction through legislative or executive actions. A comprehensive inventory of state GI/GIS authorizations funded by the Mapping Science Committee of the National Research Council in 1993 identified 100 state directives related to GI/GIS among the 50 states (Warnecke 1993). These directives include (1) legislative actions such as statutes or resolutions, (2) executive actions such as executive orders or less formal directives, and (3) memoranda of understanding that mention or directly influence GI/GIS. Marking accelerating growth, 49 of these directives were authorized between 1991 to 1993 (Warnecke 1993). State statutory references can be classified as follows:

- Authorizing GI/GIS coordination groups or studies (17 states)
- Authorizing statewide or broad environmental GI/GIS offices, data bases, or funding (14)
- Directing GI/GIS use or data development for specific missions or needs, mainly natural resources management, environmental protection, or growth management (11)
- Providing for access and cost recovery for "GI/GIS data," often modifying open records laws that directly affect localities (10)

- Providing assistance to local and regional organizations
- Authorizing GI/GIS for legislative reapportionment
- Requiring compatibility of state-funded data
- Directing the private sector to develop compatible data (New Jersey)

While the number of statutory GI/GIS references is increasing, few omnibus statutes exist specifically for GI/GIS, fund offices, or require commonality or authorize oversight. In addition to these legislative actions, 15 state executive orders or related directives and five memoranda of understanding were documented that mention or directly influence GI/GIS, although two of the orders are now void (Warnecke 1993). While most of these directives do not explicitly mention satellite data or remote sensing, inclusion can be implied in numerous states.

In addition to authorizations, states are establishing GI/GIS direction through plans, policies, standards, and guidelines. Clearinghouses, metadata, and other mechanisms are developing to manage and provide access to data. However, few states have established programs, incentives, procedures, resources, or oversight mechanisms to ensure coordination or compatibility. Management monitoring, control, and accountability mechanisms are just beginning to emerge, both at statewide and agency levels. Most efforts encourage coordination; however, states with more experience seem to empower designated state groups or offices with some authority.

5.4 Coordination Groups

The growth in the use of GIS and related technologies (as well as GI/GIS direction) is leading to the institutionalization of statewide and departmental GI/GIS coordination. This is reflected by the increasing incidence and authorization of state GI/GIS coordination groups and entities. New formal and informal groups continue to emerge in the states, and most are called "GIS" or "GI" councils or committees. These groups may or may not specifically include satellite data, but as their scope expands, there is a growing assumption that satellite data are included.

All 50 states have at least one interorganizational group whose primary propose is to improve the coordination of GI/GIS among multiple agencies and organizations, and 88 independent GI/GIS groups were recently identified among the 50 states (Warnecke 1996). The growing number and strength of these groups indicate an important "first step" in GI/GIS institutionalization. For example, groups frequently build momentum and demand for data, services, and coordination mechanisms that generally require established offices, staffing, and funding.

These groups have different authorization, direction, resources, and participation, and they may or may not include satellite data. The authorization of GI/GIS groups varies, with more than 40 states having at least one group with some degree of official stature, via statute (11 states), executive order (13), memoranda of understanding (2), or some other method (Warnecke 1993). Whether official or not, state GI/GIS groups increasingly have formal and informal influence over the direction of GI/GIS in their states. There is a trend toward formalization of the roles of these groups, reflecting increased maturation and institutionalization.

There is also a wide diversity in the level of policy or technical issues addressed by groups in different states, although they usually have similar objectives (Warnecke 1993). The trend is toward multiple groups that work together, with a sanctioned policy-level group addressing state government and one or more technical groups focused on GIS, GPS, base mapping, standards, remote sensing, or other issues (Warnecke 1993).

Figure 8: Incidence and Authorization of State GI/GIS Coordinators

Year	Authorized Number	Authorized Percentage (%)	Unauthorized Number	Unauthorized Percentage (%)	Total
1985	10	59	7	41	17
1988	15	52	14	48	29
1991	30	75	10	25	40
1994	31	77.5	9	22.5	40
1995	33	80.5	8	19.5	41

Group participants increasingly represent several state government functions, multiple sectors such as local and Federal agencies, and higher levels within these organizations. Across the states, the organizational level of individual group participants varies considerably, ranging from agency directors to primarily GIS users. Some states differentiate between voting and nonvoting membership categories, with perhaps only state members as voting members. Other state groups are more informal, and virtually anyone is able to participate equally. Participants usually use or influence GIS, while others may plan to use GIS in the future. ENR agencies are usually involved, but additional agencies with transportation, human services, public safety, economic development, and other responsibilities are also becoming active in state GI/GIS groups. The membership also sometimes includes elected legislators or legislative staff.

Other sectors are increasingly involved in GI/GIS groups, including localities, Federal agencies, regional organizations, academic institutions, Native American tribal governments, utilities, nongovernmental organizations, and the business community. Localities seem to be the fastest growing sector represented in state GI/GIS groups, because they can be directly affected by state GI/GIS activities. Federal agencies participate in some state GI/GIS groups; however, some states have difficulty determining which Federal organization can represent all Federal agencies. To date, NASA officials have had limited involvement with these groups. However, state GI/GIS coordination groups can be important avenues for establishing linkages with a state, as well as other officials.

5.5 *Coordination Entities*

The growing incidence and authorization of statewide GI/GIS coordination organizations or entities are another example of increasing GI/GIS institutionalization. These "coordinators" serve as an important focal point for GI/GIS coordination and development within state government, often complementing and staffing state GI/GIS groups. They range in size from a single individual to up to 30 people in a definable organization, and they have a wide range of roles and activities.

Figure 8 shows that 41 of the 50 states have a statewide GI/GIS coordinator. The incidence of state coordinators has increased markedly over time—particularly since NASA's programs with states ended in the early 1980s. For example, the number of states with a coordinator increased from 17 to 40 between 1985 and 1991. While many early statewide GI/GIS coordinators were unofficial, these coordinators are increasingly considered to be official and "authorized" by legislative or gubernatorial action. Thirty-three of the 41 state coordinators in 1995 were authorized, as compared to only 10 authorized coordinators in 1985. This trend toward increasing authorization of state GI/GIS coordinators is even stronger than the growth in coordinators, indicating a maturation of GI/GIS institutionalization in states (Warnecke 1995).

State GI/GIS coordinators are important contact points for NASA and other organizations. While NASA's earlier state outreach programs primarily addressed agencies with natural

Figure 9: Administrative Location of State GI/GIS Coordinators

Year	PPA	IIT	ENR	State	Non	Total
1985	4	0	11	2	0	17
1988	9	4	14	2	0	29
1991	10	12	14	4	0	40
1994	10	15	12	2	1	40
1995	8	18	12	2	1	41

PPA Planning, policy, or administration agency
IIT Information policy or technology agency
ENR Environmental and/or natural resources agency
State Other state government agency
Non Nonstate government organization

resources responsibilities that could use data to meet program missions, consideration should also be given to statewide GI/GIS coordinators and their administrative location in state organizations. As shown in Figure 9, many state GI/GIS coordinators originated in natural resources agencies. However, they are increasingly located in central agencies with a statewide focus and roles addressing most or all state agencies. For example, the number of statewide GI/GIS coordinators in information or information technology agencies increased from 0 to 18 between 1985 and 1995, and those in planning, policy, or administration agencies grew from 4 in 1985 to 8 in 1995. Alternatively, the number of coordinators in natural resources agencies has remained stable at approximately 11 since 1985. Moreover, more of the coordinators in central agencies are authorized than those in line agencies (Warnecke 1995).

5.6 Coordination Roles, Activities, and Resources

State GI/GIS coordination groups and entities have a wide range of roles, activities, and resources. Responsibilities, support, level of effort, and effectiveness can vary dramatically, and they are often independent of authorization. For example, some GI/GIS coordinators concentrate on coordination-type roles, while others have primarily operational activities, such as service centers. The following roles and activities are known to be under way by one or more state GI/GIS coordinators or groups:

- Serve as a clearinghouse concerning activities, projects, and plans about GI/GIS in state agencies and possibly other entities, including providing directories, guides, annual reports, newsletters, and other materials with current information
- Provide data clearinghouse, access, and dissemination functions for data indexed and possibly maintained in a state GI/GIS data base, and perhaps providing customized data searches, manipulation, and interpretation to meet user needs
- Develop and implement data and metadata policies, guidelines, standards, and procedures to encourage data commonality and sharing, including accuracy and scale requirements to meet overall state needs
- Promote collaborative planning for future data development and other work, including helping prioritize and coordinate data work conducted by multiple organizations
- Develop data, sometimes with general appropriation or collaborative interagency funding, to ensure that the

data are useful for more than one purpose, project, or agency

- Provide contract GIS services for state agencies and others
- Provide GIS educational services for state agencies and others
- Provide funding or technical assistance programs for local government GI/GIS activities
- Staff GI/GIS coordination and user groups
- Hold GI/GIS conferences and meetings to facilitate information exchange

The level and success of GI/GIS coordination activities conducted by state groups and coordinators are largely determined by their resources. It is generally agreed that the allocation and use of resources for state GI/GIS coordination are increasing, but the determination and comparison of commitments are difficult. Official financial and personnel resource allocations and mechanisms for GI/GIS coordination vary greatly, and they are often supplemented by individual agencies, external organizations, and voluntary contributions. Most GI/GIS activities and some coordination efforts have been funded in the past as part of program missions. Other states fund coordination efforts with the proceeds of GIS service bureaus. However, an increasing number of states have appropriated general fund resources for data, clearinghouses, and/or coordination staffs.

The number of state personnel conducting GI/GIS coordination activities is also increasing, both officially and informally, but it is difficult to quantify these commitments because efforts are often conducted by numerous people. The staff of a central state GI/GIS organization can be one full-time individual or a portion of an employee's time or it can be composed of more than 30 individuals. Coordination work is also often accomplished by other employees whose primary function is not GI/GIS coordination or by volunteers outside state government.

State GI/GIS coordinators have a variety of backgrounds and experience, with markedly different, and often limited, awareness and knowledge of satellite data. To be most useful, outreach and education programs should be designed to meet the needs of people with both limited and extensive awareness and experience. The fact that states have dramatically different levels of direction, participation, coordination, and resources also has direct influence on state outreach programs.

Rationale for NASA Involvement Regarding Satellite Data

The existence of this report is evidence that NASA recognizes the increasing roles and responsibilities of states in the Nation's governance, particularly when compared to the Federal Government. Much can be learned from NASA's past programs with states and current satellite data conditions. State representatives at the 1995 meeting identified important issues regarding the future use of satellite data in states and other organizations, including some important implications for NASA.

6.1 NASA's Past State Outreach Effort Had Positive Impacts

As discussed in Section 2, NASA's past programs with states and other governments had a relatively brief existence between 1976 and 1982. These programs ceased because of policy and funding changes that affected many agencies in the Federal Government. Since then, no other NASA programs have provided direct outreach to states or localities until the efforts described in this report. NASA programs, funding, data, and expertise stimulated most early uses of satellite data in numerous states, localities, and other sectors.

While these early programs had a short duration, they continue to be significant today. State representatives at the 1995 meeting suggested that benefits continue because some state officials retained their interest, expertise, and use of satellite data, often despite significant obstacles since the programs ended. Satellite data usage initiated during this time has continued for more than 15 years in some states, and several state officials were educated to continue to use data in their or other organizations. NASA's stimulation of image-processing usage also cultivated the GIS use—particularly the use of grid data models—that continues today.

In addition to direct involvement with associations and individual states, NASA funded the earliest inventories of GI/GIS as well as satellite data use in state governments. Historical analyses of GI/GIS conditions in the 50 states before 1985 are almost solely based on this work. Among Federal agencies, NASA's outreach effort was one of the most extensive ever developed to empower state and local governments regarding geographic information. In retrospect, NASA leaders exhibited a valuable and unique degree of knowledge and sophistication in establishing an outreach program specifically for state and local governments.

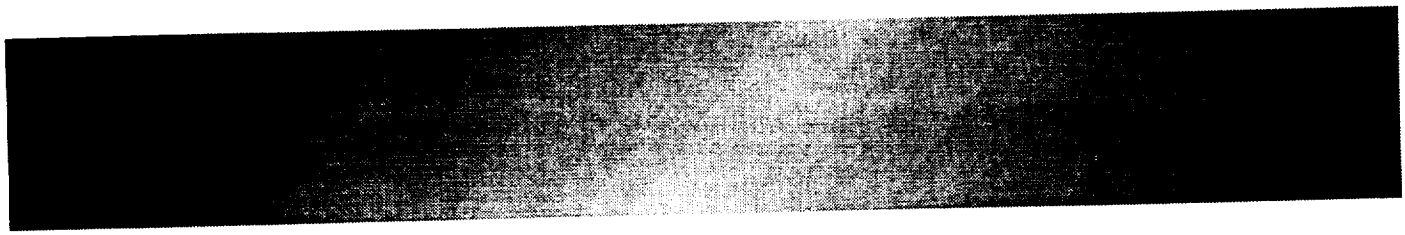
6.2 NASA's State Effort Had Limitations, but Lessons Were Learned

While some states benefited from NASA's state program, other states did not take advantage of NASA's programs or satellite data, or they abandoned their data activities after NASA support ended. A thorough analysis of the impact of NASA's state program has not been conducted in this report or elsewhere. However, state representatives at the 1995 meeting suggested some of the following reasons as to why NASA's outreach effort did not benefit more states in the long run and why more states have not used satellite data since then:

- The timing and duration of NASA's state program were critical factors. It existed when satellite data were just becoming available and useful, and it ceased in the early 1980s before many state applications could be developed or demonstrated.

- There was some overselling of the technology, and certain applications were promoted even though others may have better met state needs. In addition, a "one size fits all" approach was sometimes used, even though state needs and capabilities vary extensively.

- Some states became dependent on NASA funding, so state use of satellite data ceased in some cases when Federal funds were withdrawn. The high cost of data meant that it was not cost-effective for states to finance on their own.



- NASA's state program was discontinued just as more useful data for states were becoming available from a second-generation multispectral scanner, the thematic mapper (TM), which was available from Landsat 4 and Landsat 5, launched in 1982 and 1984, respectively.

It can be concluded that NASA programs ceased prematurely because satellite data use was not initiated or did not mature in the majority of states. Discontinued government support resulted in insufficient demand generated by states and others for the private sector to respond. Many fledgling state and local uses of satellite data did not thrive or expand to the extent that might have happened if NASA technology transfer efforts had continued with states and localities.

NASA learned several important lessons from its experiences with these programs. For example, it learned that outreach programs with states and localities need to be customized, focused, and designed differently than those for academic institutions, Federal agencies, or other organizations. NASA's approach to work with both individual states and state associations was a successful way for states to learn about satellite data resources and opportunities and about how other states apply this technology to meet similar state needs. This experience also revealed that each state needs to be addressed individually to maximize relationships, technology use, and applications with multiple state agencies. Moreover, NASA learned that for technology transfer and capacity-enhancing efforts to be successful, applications need to be determined and articulated by state and local government officials, rather than Federal agencies or others.

The elimination of these programs and lack of specific attention to states since the 1980s continue to affect satellite data use in some states. Many state officials lack sufficient awareness of data resources and opportunities to make appropriate and knowledgeable decisions. The commercialization of Landsat data resulted in negative consequences, such as higher costs for states and localities than for Federal agencies, and continues to deter some use today. Licensing and distribution restrictions also impede data use in state governments, even if Federal agencies have acquired relevant satellite data for a state. Accordingly, many states have experimental, limited, or no use of data today, and known beneficial uses in some states have not been applied in others.

6.3 *State GI/GIS Conditions Increasingly Impact Satellite Data Use*

Both satellite data and GIS capabilities were beginning to be available to states and others during the 1970s and early 1980s. Many early uses of remote sensing and GIS in states evolved together, largely because of NASA's initiatives in numerous states. Some of these early state efforts thrived, and GIS and remote-sensing activities matured together and now operate in an integrated manner. However, a lack of continuing support for NASA state outreach efforts has resulted in a significant disjuncture between satellite data and GIS use in some states today. The consideration of GI/GIS maturation over time provides further evidence that NASA's state outreach programs were discontinued prematurely.

Over time, satellite data use in states has grown at a much slower rate than GIS use, in part because GIS has been commercialized to a greater extent than satellite data. In addition, some Federal agencies have encouraged state GIS use through various programs and funding mechanisms. While some state governments have very little or no use of satellite data, GIS is used in multiple agencies in each of the 50 states (Warnecke 1992, 1995). In addition, several states use GIS for similar applications, unlike the limited diffusion of satellite data applications. There does not seem to be as strong a correlation between large and long-term users of GIS and use of satellite data as could be expected. Some states with extensive GI/GIS activities are initiating data use to meet the needs of multiple GIS users, such as for land cover, but these states are in the minority.

6.4 *Broadening GI/GIS Coordination Initiatives May Not Include Satellite Data*

Interorganizational coordination can catalyze the use of satellite data for multiple applications, as well as for cooperative financing for acquiring and interpreting these data. However, very few coordinated satellite data initiatives exist today that are not part of statewide GI/GIS coordination efforts.

Past NASA programs cultivated coordinating groups and integrated satellite data activities in some states, but most of these efforts were subsequently subsumed by GI/GIS coordination efforts or ceased. Virtually all states have some GI/GIS coordination initiative in response to increasing growth in GIS use and data needs. Accordingly, state GI/GIS coordination initiatives primarily address GIS and digital cartographic data. As GI/GIS coordination approaches evolve and mature, they seem to broaden their focus. For example, several state GI/GIS efforts have established base stations for the use of the global positioning system (GPS). States increasingly address parcel-level or land information systems needs of local governments.

NASA and others involved with satellite data should recognize that most state GI/GIS coordination initiatives have an imprecise definition of the scope of their efforts and that they do not specifically address satellite data. Attention to satellite data may be implied, but specific activities regarding these data do not exist in many states. Essentially, satellite data are not a priority of most state GI/GIS coordination efforts, if addressed at all, except in some states with extensive satellite data or GI/GIS experience.

In summary, if a state GI/GIS coordination effort does not address satellite data, and many do not, then a statewide satellite data effort probably does not exist. One exception is the nationwide coverage of Landsat data that is used in the Gap Analysis Program (GAP) of the U.S. Geological Survey's Biological Resources Division, although state data use is restricted under this program. GAP and other Federal organizations participate in the Multi-Resolution Land Characteristics (MRLC) Consortium, jointly funding the acquisition of Landsat data in 1992 and 1997. GAP uses these data on a state-by-state basis, and its collaborators often include one or more state agencies, but GAP licensing arrangements have limited the use of these data by other state agencies or for other state purposes.

6.5 *State GI/GIS Institutionalization Will Not Necessarily Catalyze Satellite Data Use*

While NASA's state program stimulated the early state use of satellite data and GIS, GI/GIS use and institutionalization will increasingly influence satellite data use in the future. Yet, satellite data use will not necessarily expand because of GI/GIS institutionalization. Direction, funding, policies, and other decisions are increasingly made about the focus of GI/GIS and how GI/GIS is being institutionalized, but satellite data may be essentially ignored. For example, while the review of state legislation described in subsection 3.3 in Section 3 identified few references to remote sensing or satellite data in statutes, an increasing number of states authorize GI/GIS through legislative or executive actions without mentioning satellite data. Directives and other important policies and standards may have narrow definitions that preclude the inclusion of satellite data.

Numerous state officials are not sufficiently aware or knowledgeable about satellite data to make informed decisions, much less catalyze or coordinate satellite data work. At the same time, several GI/GIS coordination mechanisms and activities are being designed and implemented by state groups and offices. For example, some Federal agencies encourage states to contribute funding for Federal high-altitude aerial photography programs. In addition, some states are establishing programs to assist state agencies, localities, and others in their use of GI/GIS. Conferences and

other educational programs are provided. Satellite data may or may not be included within the scope of these efforts. State GI/GIS actions will not necessarily expand satellite data funding, coordination, and use in the future.

In particular, as GI/GIS coordination matures, states usually inventory existing or needed data resources and develop data clearinghouses that are increasingly available in automated form, such as CD–ROMs and World Wide Web sites. With multiple agencies, localities, and other organizations facilitating the use of data, these efforts could reveal satellite data resources, needs, and opportunities, but satellite data are not necessarily included. Risks are growing that some state GI/GIS coordination leaders are not sufficiently knowledgeable to provide relevant information or referrals to potential state users or to incorporate satellite data in emerging statewide data clearinghouses that are made available to multiple users.

6.6 *Limited NASA Attention for More Than a Decade Justifies an Accelerated Approach*

NASA is developing an outreach strategy to educate, develop, and strengthen the overall nonglobal change remote-sensing market. Specific plans have been developed for the commercial and educational sectors. However, an outreach strategy for states has not been articulated to ensure that states are sufficiently aware of Earth Observing System (EOS) data, applications, opportunities, and potential benefits. Risks are growing that without a specific strategy to develop and maintain this client base, EOS opportunities and benefits cannot be fully realized.

NASA's involvement within most individual or groups of states since the early 1980s has been limited. For example, few NASA employees participate in GI/GIS state coordination groups or with state agencies, except the few agencies that have received grant funding. NASA has only participated in one meeting of the National States Geographic Information Council since it was formed in 1990. Jerry Garegnani represented NASA at the 1994 annual conference, and he met with some state representatives to learn about and improve conditions. He asked officials about existing NASA relationships with states. Examples were cited of how NASA has given substantial attention and funding to certain state agencies in recent years, but these funded agencies may have narrow or parochial interests. Furthermore, it was stated that NASA may not have established contact with all appropriate agencies and officials—in particular those agencies that have statewide coordinating roles influencing satellite data.

More generally, states and localities have been overlooked in some important satellite data policies and activities since NASA's outreach program for states ceased in the early 1980s. For example, while the state, local, and Federal governments share in governing the Nation, state and local government prices for Landsat data were established at the commercial, rather than the Federal Government, rate. Efforts are needed to "make up" for the lack of Federal Government attention to state and local government satellite data needs for more than 10 years.

Recent institutional conditions and trends also reveal that a state strategy could also improve the effectiveness of NASA's relationships and programs with localities, field-level officials of Federal agencies, academic institutions, private companies, and others, because these sectors increasingly participate in and benefit from state GI/GIS coordination efforts. A "state strategy" is, in effect, a "field approach" to reach a multitude of potential users throughout the country.

Recommendations to Maximize EOS Opportunities and Benefits

The findings summarized in this report and the specific input of state officials provide guidance for NASA to establish a strategy empowering states to maximize opportunities and benefits with the Earth Observing System (EOS). In particular, discussions by state representatives at the 1995 meeting sponsored by NASA clearly indicate that the use of satellite data by states is a way to help meet the growing information needs required for many components of state and local governance. State representatives concluded that NASA could make a substantial improvement in state governance by adopting a state strategy and the following set of specific recommendations. This strategy can also assist states in successfully accomplishing existing and emerging state responsibilities as their roles expand in the Nation's governance.

State representatives suggested that a multitiered and multifaceted approach is needed to develop state markets for EOS data and achieve results and benefits in all 50 states. Moreover, NASA needs dedicated communications linkages with individual and groups of states to maintain continuity and long-term, sustainable relationships. This strategy would stimulate growth in EOS data use in all states and in EOS applications in all potential areas of governance, and it would help develop the value-added commercial sector.

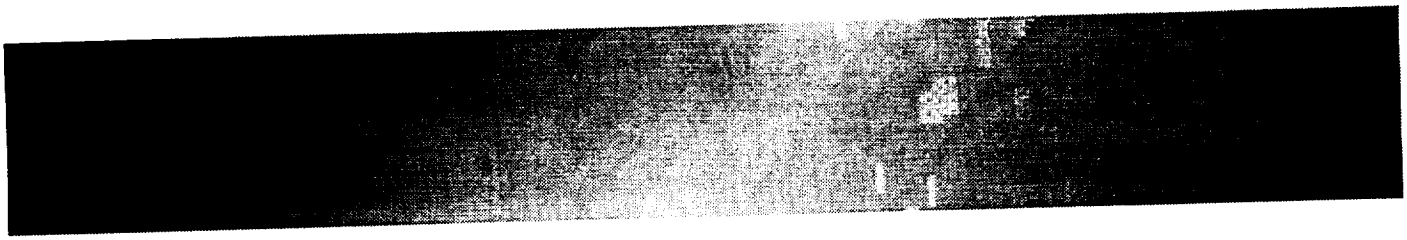
A customized approach to establish long-term working relationships and internal capacities and capabilities is needed in each state. With appropriate educational programs, user requirements analyses, applications projects, and other efforts, NASA can help each state develop its own institutional infrastructure to serve as an effective focal point and clearinghouse for EOS data to reach various users within states. Designated state contacts should be educated and supported so they can serve as effective liaisons to distribute EOS data and related information to other state officials, as well as adequately represent their state's interests, activities, and needs and relate these requirements to NASA and others.

The states should also be empowered to apply NASA technology and research to collectively define, prioritize, and address state satellite data and EOS needs, as well as to provide effective input and feedback on overall NASA and specific state outreach activities. A state's program should prove EOS data effectiveness, in terms of technical capabilities, applicability to state needs, and cost, with caution not to oversell. NASA should also support existing efforts, including multistate, thematic data and applications development, thus using individual states as an approach to test EOS data applicability and use under differing conditions. In addition, NASA could reengineer some internal activities and redeploy some existing resources to improve the effectiveness of its approach toward states.

7.1 Initiate Relationships With State Officials

NASA's approach toward states should involve each of the 50 states and consider their individual institutional, informational, and GI/GIS infrastructure. NASA has learned from its past state program and those of other agencies that a "one program fits all" approach does not address the diversity of regional, state, and local conditions and needs. The establishment of dedicated communications links with individual states can offer numerous benefits for NASA and the states. For example, states can be kept aware of and utilize NASA, EOS, and related activities, training, and data, while NASA can be provided with a feedback mechanism on system performance and data utilization.

Effective relationships with states require identifying and communicating with key individuals and their organizations in each state. NASA's earlier state outreach program primarily addressed agencies and individuals that use natural resources data to meet program missions. However, given today's circumstances in most states, additional interaction is needed with statewide GI/GIS coordinators that now exist in 41 of the 50 states. By using this existing network, NASA can be in contact with numerous potential users of EOS data



in a wide variety of agencies and other sectors, such as localities, academic institutions, and so forth.

It is also important for NASA to maintain contact with and educate policy-level officials, including governors and legislators and their advisors, such as state science advisors who can be important advocates for technology use. Other important state officials are those with departmental or policy leadership roles for individual state functions that could benefit from satellite data. These functions include multiple and individual environmental and natural resources responsibilities, as well as transportation, public safety, emergency management, economic development, and other areas identified as emerging satellite data application areas in Sections 3 and 4 of this report. Leaders of state information technology offices should also be kept informed, particularly if GI/GIS coordinators are located in other agencies. These officials have differing levels of awareness, expertise, and interest in satellite data, ranging from very experienced to limited exposure to satellite data. Accordingly, outreach efforts need to be designed and implemented for individual and differing officials, similar to individual states.

Relationships with national associations can complement and strengthen linkages with individual states. Three types of associations can be important participants in NASA's approach with states:

- National "umbrella" associations include the National Governors Association, the National Conference of State Legislatures, and the National Association of Counties. Programs with these associations were effective in NASA's past efforts.

- State representatives participate in more than 100 other state associations that usually address specific government functions and may or may not be affiliated with one of these umbrella state associations. Attention to selected state associations can complement EOSDIS efforts with groups having similar functions, such as the National Association of State Foresters with the Society of American Foresters.

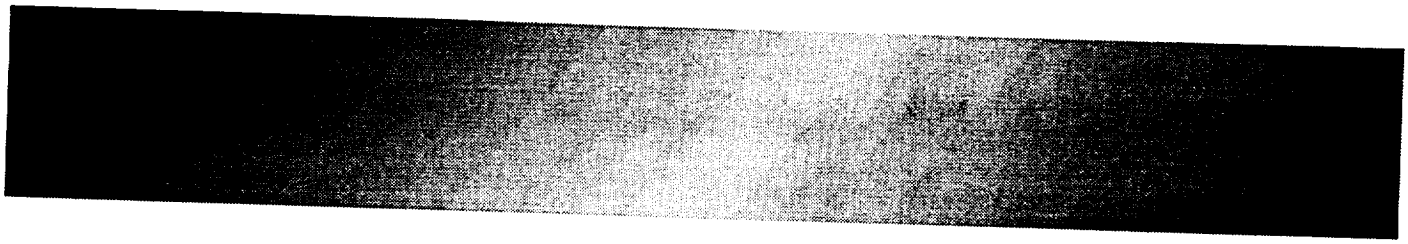
- Other state associations specifically address GI/GIS. The National States Geographic Information Council is the only state association with this focus. The American Society for Photogrammetry and Remote Sensing and the Urban and Regional Information Systems Association are also important because some state officials also participate in these groups.

Relationships with each of these groups can have important benefits and should be determined based on specific program objectives and needs. Several different opportunities can be pursued simultaneously. For example, by working with associations, NASA can empower the states to help design and provide feedback on NASA activities, prioritize overall state needs and opportunities, and provide a common voice to the commercial and Federal sectors.

While future NASA efforts should involve multiple state officials within each of the states, one of the first initiatives should be to identify and confirm specific state contacts who can serve as focal points for NASA's efforts. This process should include contact with each governor's office and state legislature, along with a method to confirm contacts to serve as the official liaison for each state.

7.2 *Conduct Initial Awareness and Educational Efforts*

State representatives at NASA's 1995 meeting strongly indicated that the states need to be sufficiently aware of and interested in satellite data before educational efforts can be successful. Accordingly, initial state contacts should be designed to establish NASA relationships and increase state awareness and interest, because many state officials are unfamiliar with MTPE or EOS. State officials also recommended



that NASA should show specific evidence that the agency understands the importance of states and desires to maintain relationships over time.

State representatives at the 1995 meeting specifically recommended that the selected contacts should be invited and funded to attend a dedicated session lasting at least a couple days to educate them about how to access and use EOSDIS. This educational session would be the critical first step to invest in long-term relations and EOS market development. It would stimulate EOSDIS use in states by encouraging officials to investigate for themselves how EOSDIS can aid their states. These officials could also be educated to determine how and why satellite data can be used to effectively meet their needs. NASA's research results could be disseminated in such a way to promote the utility of advances in technical development and the availability of data.

7.3 *Institutionalize and Maintain State Relationships*

A long-term educational and liaison program should be a key element of NASA's state strategy. The process of official selection and maintenance of contacts for each state means "training the trainers" and involving numerous other state officials. In addition to informing other state officials about satellite data, EOS, and new developments, these individuals can (1) inventory internal satellite data activities, (2) assess state satellite data needs and opportunities, and (3) provide feedback to NASA from the individual states.

NASA's long-term liaison program with states should be designed to provide continuing guidance and assistance, as well as build and maintain internal capacities and capabilities in each of the 50 states. A variety of methods could be used to regularly educate and communicate with state officials. These educational efforts will increase the capacities and capabilities of states to serve as effective liaisons with NASA and to carry out specific roles and responsibilities.

While conditions vary significantly by state, it is important that each state has a sufficient institutional infrastructure and capacity to enable the designated state contact(s) to disseminate information and data from NASA to other state officials on a regular basis, inventory and assess satellite data activities and needs for multiple state agencies, and provide appropriate feedback to NASA. Each state will also need sufficient staff capability and technical sophistication, including adequate knowledge of data resources, research results, best practices, software, and algorithms, to technically provide and use EOSDIS data themselves or be able to properly manage contractors who are performing remote-sensing–related work for them. NASA's relationships with states will need to be institutionalized and monitored within individual states to develop and maintain these capacities and capabilities and ensure that goals, objectives, and benefits are being realized.

7.4 *Empower States to Define Their Needs and Opportunities*

A key lesson learned from NASA's past state programs—and strongly recommended by state representatives at the 1995 meeting—is that NASA should avoid imposing applications on states. The investigation of the 50 states and the meeting results included in this report reveal that states have current and potential satellite data applications that do not exist in the Federal Government. Careful efforts should be taken to consider these applications in EOSDIS plans. Accordingly, state officials should be educated and empowered to define and prioritize how satellite data and EOS can help states, including specific needs and applications and even data and technology requirements, both for individual states and for states in general.

NASA's state strategy can utilize and build on the inventory of satellite data applications included in this report in several ways. NASA should invite state officials to supplement, provide examples of, and prioritize a list of applications

shared by all states, as well as those for selected or groups of states based on their geographic location or size. Some state officials should also be capable of defining data and technology requirements for these applications in terms of specific regions of the country. This comprehensive approach will help specify differences in data and technology requirements to develop individualized approaches and applications that take advantage of satellite data and EOSDIS opportunities, as well as NASA research results.

7.5 *Provide EOS Data in Usable and Affordable Formats*

To maximize the success of NASA's state strategy, EOS data must be provided in formats that are flexible and easy to access, disseminate, and use. State representatives at NASA's March 1995 meeting had several suggestions in this regard. For example, information about the properties of each sensor and appropriate use for detailed level mapping, such as for land cover, land use, and species composition, would be extremely helpful. Photo-interpreted data would be welcome. They also recommended that products be directly usable or have the ability to perform precision and bulk radiometric correction (georeferencing, atmospheric correction, and terrain correction). This would dramatically increase the use of satellite data, especially as a visual backdrop to other spatial data.

The state representatives also suggested that subproduct or subgranule extraction be provided to allow access to smaller pieces of satellite data scenes or large data sets. In addition, programming code and algorithms could be available in the public domain to allow sophisticated users to manipulate data or perform corrections. These tools could also be available to software vendors to incorporate into commercial software, thus making them available to additional users.

The representatives also recommended that specific work regarding classification refinement would benefit states and others. For example, they suggested that probability ratings could be developed for certain classifications if they are close. Additional work could be conducted in (1) guided clustering, (2) multiple categories and maximum likelihood, (3) repeat cover mapping (multitemporal classification), (4) advanced "automated" change detection, and (5) advanced "automated" feature extraction.

The state representatives urged that NASA learn from the Landsat commercialization experience and avoid privatization if it will have negative consequences, such as higher costs for states and localities than Federal users. The privatization of Landsat was at a cost to state and local governments, even though they have important roles in the Nation's governance. Any privatization should provide a product at a lower total cost across all levels of government. The total cost should be calculated by considering state and local expenditures, not just the cost to NASA or other Federal users.

7.6 *Validate EOS Data Usefulness Through Funded Research*

NASA's state strategy must include the requirement that EOS data are tested, demonstrated, and validated to be useful for state needs. State representatives at the 1995 meeting stressed that NASA should avoid overselling the technology and its utility for states. Instead, NASA should fund applied as well as basic research to prove EOS applicability and effectiveness. They also emphasized that EOS data will only be used if savings are generated and results are more cost-effective than other alternatives available to states.

NASA's applied research should be designed to effectively apply NASA's science products and research results to meet multiple state needs. Two types of projects are needed to validate EOS data for states. First, demonstration projects should be undertaken to accomplish specific state needs based on the comprehensive list of potential applications generated by the states. Second, joint application projects should be developed with states to refine the requirements, procedures,

benefits, resources, and technology necessary for states to effectively use EOS data. A particularly effective approach would be to enter into joint application projects with states that would apply MTPE's results in a problem-oriented setting or to conduct policy development or other decision making.

If designed accordingly, both demonstration and joint application projects can be incorporated within the same effort. State representatives suggested that funded research projects should:

- Translate EOSDIS science products to higher order products that meet state data needs, particularly in a format that is usable by state governments
- Demonstrate the ability to use and integrate appropriate EOS data products for specific state applications
- Develop implementation techniques for specific state applications
- Specify measurable improvements in quality, resolution, and cost or resource efficiency by using EOS data rather than alternative sources
- Demonstrate the applicability of EOS data for specific applications that require data with greater resolution than has been available from other satellite data, such as regulation and adjudication
- Demonstrate how EOS data can be used effectively with GIS, GPS, and other data sources commonly developed and used by states
- Identify specific state needs and tasks for which it has been found that EOS data may not be appropriate or are beyond the capabilities of existing information or available technology

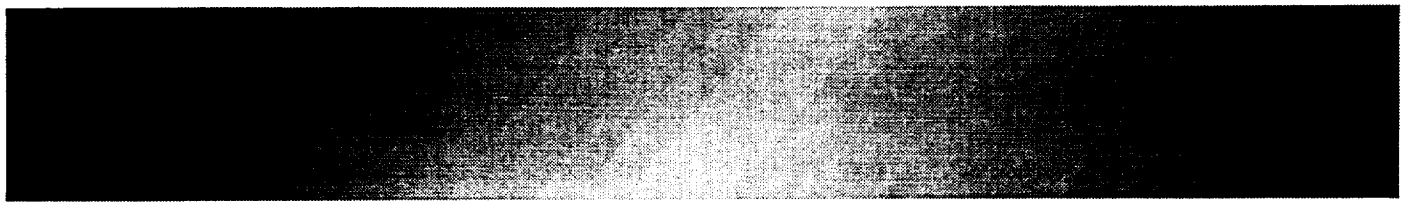
State representatives at the 1995 meeting provided other suggestions regarding NASA's applied research. They encouraged NASA to choose initial state projects that have a high probability for success and would demonstrate EOS effectiveness in a relatively short timeframe. If a NASA project developed public domain software that can provide increased capability, the state representatives suggested that NASA should work with commercial software companies to incorporate the enhanced capabilities because many states use commercial products.

These demonstration and joint application projects can produce numerous benefits. For example, the involvement of state officials in this research will contribute to building long-term state capacities, capabilities, and relationships with NASA, as well as a continuing client base for EOS data and services. Many of the projects will also probably apply to other sectors, such as local governments, Federal agencies, academia, and the private sector; the results should also be disseminated to these potential satellite data users.

7.7 Empower States to Use and Diffuse EOS Data and Research Results

NASA should communicate the benefits of this technology to extend the benefits of MTPE and EOS work and funded research. However, this information must be provided to states and others in a format that is easily understood, accessible, and usable. NASA, other Federal agencies, and the private sector have not sufficiently informed states about satellite data. State representatives at NASA's 1995 meeting emphasized that reports and papers can be informative, but they are not enough for states to put research results into practice.

Alternatively, NASA's project results should be repackaged for educational purposes in states using several formats and organs. For example, project results can be synthesized as applicable to state applications in "best practice" guides with referral and other information. This approach would help



ensure that policy makers, program managers, and staff with satellite data expertise become more aware and are regularly informed of advances in EOS applicability for states. Furthermore, publicity can invite feedback and participation, which can be utilized in future project design.

This approach will help ensure that states have sufficient interest, knowledge, capacity, expertise, and resources to understand, access, and use EOS data. Moreover, states would be empowered to determine their own uses—and analyze and utilize EOS data and research results themselves—or be able to properly manage contractors who are performing remote-sensing–related work for them. This strategy can also help state liaisons determine satellite data activities and needs for multiple state agencies within their own state.

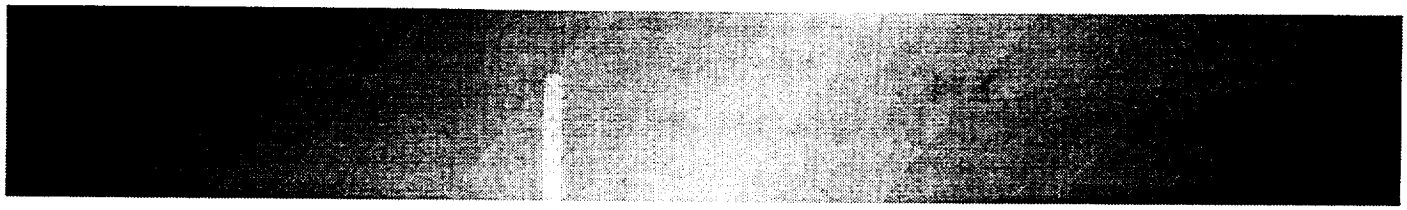
NASA is considering several distribution mechanisms for EOS data products. State representatives suggested that NASA carefully consider these distribution channels, avoiding the issuance of proprietary licenses for data distribution or other services—an approach that does not stimulate growth or promote competition but rather leads to an environment of poor services and high costs. They suggested that distribution systems in some states could be a feasible and efficient option for the diffusion of EOS data to additional state agencies and others using satellite data within and about states. In effect, as "arms" of NASA, state liaisons could regularly disseminate much information from NASA, including research results, project updates, and other information, to interested parties within their states. State liaisons could also help others understand, analyze, and use EOS data, as well as access NASA's knowledge, special products, and expertise as appropriate for certain state projects. By empowering states through existing channels, NASA can improve the effectiveness of its outreach programs and reduce the long-term costs of these efforts.

7.8 *Involve State Officials in Additional NASA Efforts*

NASA should involve state officials in the design, implementation, and evaluation of this state strategy and other MTPE efforts to enhance program benefits in individual and all states. A program with only a one-way flow of research results and technology will not take advantage of the ability of knowledgeable state officials to provide input back to NASA. Input, feedback, and response mechanisms will also enhance EOS usefulness; they should be incorporated into each aspect and component of this state strategy. Provisions are needed to solicit and incorporate input from individual state representatives for several topics, as well as to encourage states to work together to provide NASA with common and prioritized concerns and recommendations. This is particularly needed because NASA has not had a state program for more than a decade, and states have not had a forum to discuss satellite data or NASA relationships and products since then.

NASA can maximize the benefits of this state strategy by including knowledgeable state officials in several MTPE activities. Some state officials have excellent satellite data backgrounds and could provide useful advice for additional NASA efforts. State officials could voice needs, priorities, and recommendations for NASA's overall outreach and dissemination efforts. State representatives can also be active members of various working groups and advisory committees with which MTPE interacts, including those sponsored by NASA and otherwise. NASA has already included state officials on some committees; such individuals can suggest overall program recommendations and provide technical input and feedback. For example, some state officials have sufficient expertise and experience to provide insights into algorithm development.

NASA will derive numerous short- and long-term benefits from enabling state officials to have regular input into its



programs. This approach will enhance the goodwill and respect that states have for NASA and reinforce NASA's state strategy by further encouraging state participation. NASA's leadership would also provide states a mechanism and forum to communicate needs, priorities, and recommendations to other Federal agencies and the commercial sector, which would in turn enhance others' products and their usefulness with NASA programs and EOS data.

7.9 Develop Internal NASA Capabilities to Effectuate State Strategy

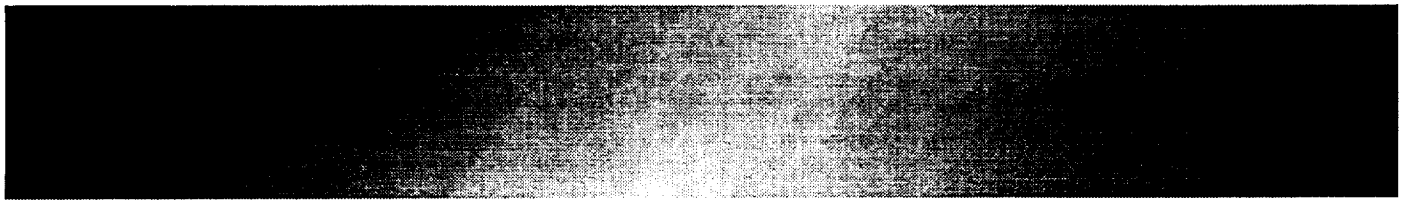
It is also critical that NASA staff be involved in this state strategy and program. State representatives at NASA's 1995 meeting specifically stated that NASA needs to develop its internal awareness and expertise regarding states and commit appropriate resources for the strategy to succeed. Because NASA has not had a specific approach for states since the early 1980s, the agency seems to have limited consideration and knowledge of states—and little interaction with them, except state agencies that are grant recipients.

NASA staff should be educated about American governmental institutions and functions, including the balance of power and the differing roles and responsibilities of Federal, state, and local governments. For example, the common and unique functions of government, as listed in Figure 5, should be described with examples of current and potential satellite data applications. Information about NASA's state strategy should be provided so that staff can answer potential questions. Many NASA employees could benefit from this orientation because it would encourage the consideration of actual government roles and applications as part of their research and evaluation of grant proposals and results. This education is also needed to facilitate the use of research and grant results by other practitioners.

An important central role for NASA is to serve as a clearinghouse and conduit of information about each of the 50 states, such as contacts, applications, and other activities, to determine best practices and lessons learned in individual states. This information could be disseminated on a regular and informal basis to ensure that the states and NASA benefit from state experiences. Central program staff would also represent the program to other parts of NASA and external entities, as well as ensure that findings and results are useful to other NASA efforts and programs. Some roles and activities could be contracted to state associations, particularly the clearinghouse function, but NASA expertise is needed for overall program management and oversight, as well as other components of the strategy.

As discussed above, an essential feature of this state strategy is a customized approach for each state to encourage long-term working relationships and maintain internal state capacities and capabilities. Designating a lead NASA employee to serve as a liaison for each state will help provide effective understanding, interface, and response to individual state needs. Staff at NASA field offices could serve as these direct contacts for nearby states and in individualized educational programs, as was done with the three Regional Remote Sensing Application Centers in NASA's first state program. Field staff could participate in individual state coordination efforts.

NASA staff should participate in several existing coordination mechanisms in individual states, such as GI/GIS coordination groups, although the agency has had limited involvement with them to date. These groups are the leading interagency mechanisms to effectuate collaborative approaches regarding satellite data, and they perform several coordination functions that could help NASA achieve its strategic objectives in individual states. NASA staff could participate in such groups to (1) initiate and develop avenues for coordination, (2) learn about state conditions and needs, and (3) educate and inform participants about satellite data opportunities and resources. For example, NASA could present briefings and learn from others at state



conferences and meetings sponsored by these groups. Outreach efforts by field-level staff can produce numerous benefits to increase the awareness, interest, and use of satellite data in states, as well as increase the practical value of research efforts.

However, NASA employees with state liaison responsibilities must have sufficient interest, expertise, and knowledge of the state strategy and program to be effective. For example, responsible staff should be aware of state issues, conditions, and needs within individual states and among all the states. Beyond the above orientation, these individuals will need additional education to conduct work in individual states, while others will need to be sufficiently knowledgeable to design, manage, and evaluate the program.

A final recommendation is for NASA to geographically organize its information and research so that it can be more useful for states and others. NASA awards many grants to researchers at academic institutions and other organizations, but it is difficult for states and others to benefit from or even know about these funded activities. For example, NASA does not categorize its grant awards and projects in such a way that a list can be generated of those in individual states or other political subdivisions.

Accordingly, NASA should reference its internal projects and grant contracts by geographic location and provide information about these activities to applicable states and elected Federal officials. For example, contact and project summary information could be provided in a list and map form according to applicable states and congressional districts. Providing information about existing efforts in this way would publicize existing NASA efforts and offer a wonderful resource for many state government practitioners and researchers to maximize benefits and collaborative opportunities.

8 Summary and Conclusions

Twenty-five years ago, NASA revolutionized our view of the world with the launch of the first satellite to enable us to see the Earth. Subsequently, a NASA program stimulated the use of Landsat data by states and led to the development of capabilities that exist today in some states. Since that time, technology has changed, and data needs have grown. NASA now has an important role in the information age to expand scientific knowledge, disseminate information about the Earth system, and go beyond science to enable and foster the productive use of Mission to Planet Earth (MTPE) science and technology in the public and private sector. By leading the global effort to study Earth from space, NASA is improving and helping preserve America's strategic position in information technology. In addition, newly available data from the Earth Observing System (EOS) could provide substantial benefits for many sectors of society.

The use of space-based remotely sensed data for governing is an area poised for expansion because of the expense of gathering ground-based data, the increased computational capability that is now commercially available at greatly reduced cost, and the almost universal use of the geographic information system (GIS), which allows the integration of images with other spatially referenced data. MTPE is uniquely positioned, by virtue of its experience from earlier outreach activities and their science base, to assist in the utilization of space-based remotely sensed data and associated emerging technologies.

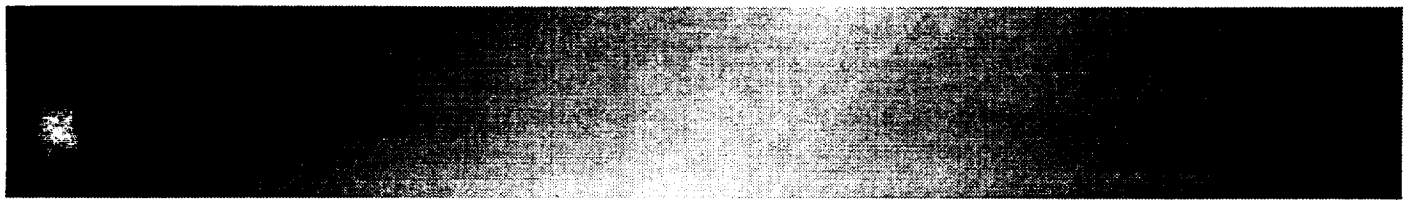
NASA is now developing an outreach strategy to educate, develop, and strengthen the overall nonglobal change remote-sensing market and to maximize the usefulness of EOS data. Specific plans have been developed for the commercial and educational sectors. Several additional opportunities are available when considering the variety of roles and responsibilities of all levels of government, particularly states and localities. States could be an important component of NASA's effort to ensure that all potential user needs are addressed in EOS plans, particularly for those applications that have been identified in states but have not emerged in investigations of the Federal Government.

This report has been prepared to present work conducted to date by MTPE to understand and meet the needs of state governments through the new data system, known as the Earth Observing System Data and Information System (EOSDIS). NASA conducted an investigation of current state conditions and convened a meeting of experienced state representatives in 1995 to learn about the needs, barriers, and perspectives of states that can be unique when compared to other users, such as Federal agencies and academic researchers. The discussions at the meeting clearly indicated that satellite data can help states meet the growing information needs required for many components of state and local governance.

The findings in this report and input from state representatives lead to the conclusion that NASA should establish a specific outreach strategy and program for states. Key reasons for this approach include the following:

- **State governments have increasingly important roles and initiatives in the Nation's governance.** This trend is expected to continue in many satellite data application areas, with even more dramatic changes expected as more Federal responsibilities are devolved to states. State agencies, however, are facing reductions similar to Federal agencies. New technologies and data sets from EOS/EOSDIS can help states work more effectively in fulfilling their growing responsibilities. Moreover, recent state initiatives can provide effective mechanisms for NASA's outreach efforts.

- **To date, some states have realized benefits from satellite data use, but most states have experimental or very limited use of satellite data.** State markets for satellite data have not developed to a level that might have been expected when NASA's program for states



ceased in the early 1980s. Furthermore, awareness and knowledge about satellite data resources and opportunities are limited in many states, so informed decisions are not necessarily made to even explore satellite data

- **While all 50 states have some GI/GIS coordination efforts, only a few states have interagency satellite data approaches, and satellite data may not be addressed in these GI/GIS efforts.** GI/GIS authorizations, groups, offices, and activities in several states do not officially or informally include attention to satellite data.

- **States and localities seem to have been overlooked in some important satellite data policies and activities for more than 10 years.** In particular, the commercialization of Landsat resulted in state and local prices being established at commercial, rather than Federal Government, rates. This direction is cited as a key cause of the limited growth in satellite data use today. Efforts are needed to "make up" for the lack of Federal Government attention to state and local governments.

- **A state strategy would also improve NASA's relationships with localities, field-level officials of Federal agencies, academic institutions, private companies, and others.** These sectors increasingly participate in and benefit by state GI/GIS coordination initiatives, which could become effective networks and channels for NASA's outreach strategy. A "state strategy" is, in effect, a "field approach" to reach a multitude of potential users throughout the country.

- **While EOS offers several potential satellite data applications for states, awareness of this resource is very limited, even among state officials currently using satellite data.** Risks are growing that without a specific strategy to develop and maintain this client base, EOS data will not be utilized fully or effectively in states and other sectors, and potential opportunities and benefits in several states will not be realized.

Looking to the future, NASA can catalyze new opportunities for emerging and expanded applications of EOS data if the growing functions and needs of state governments are specifically considered in outreach plans and efforts. NASA is uniquely positioned and has the experience necessary to establish a state strategy that can provide benefits for states and other EOS users. Such an effort can also provide NASA with useful input and feedback to maximize benefits from outreach efforts in many sectors of society. A state strategy and program can be designed and implemented with limited resource commitments, and many benefits can be realized through the redirection and redeployment of existing resources. Specific recommendations are provided by state representatives that they believe, if accepted and implemented in the short term, can have immediate beneficial impact on the use of NASA's remotely sensed data in states and other sectors of society, as well as maximize the benefits of the public's investment in this national resource.

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Warnecke, L., "State Geographic Information Coordination Efforts and Groups" in Proceedings of the conference sponsored by the National Governors' Association titled "Making Information Work," Washington, DC, January 18–23, 1992.

Warnecke, L., "Geographic Information Coordination in the States: Past Efforts, Lessons Learned and Future Opportunities," in Proceedings of conference sponsored by the National Governors' Association titled "Piecing the Puzzle Together: A Conference on Integrating Data for Decision-making," Washington, DC, May 27–29, 1987.

Warnecke, L., *et al.*, *State Geographic Information Activities Compendium* (Lexington, KY: Council of State Governments, 1992).

Appendix A
State Meeting Agenda and Attendees

March 29–30, 1995
NASA Headquarters, Washington, DC

Agenda

Wednesday, March 29

8:30 Welcome and Introduction
Dixon Butler, Director, and Alexander Tuyahov, Deputy Director, Operations, Data and Information Systems, NASA Office of Mission to Planet Earth

Survey of Leading Uses of Satellite Data

9:00 Participant Introductions and Review of Satellite Data in their States

10:15 Break

10:15 Context for NASA/State Relationship

Briefing on NASA's Past Involvement With States
Alex Tuyahov

Discussion on Benefits and Lessons Learned From Historical Perspective
Paul Tessar, Wisconsin Department of Natural Resources

Briefing on NASA's Mission to Planet Earth—Current Programs
Alex Tuyahov

12:00 Lunch and EOSDIS Demonstration
Kevin Schaefer, NASA

1:00 Summary of Satellite Data in States and Results of Morning Satellite Data Survey
Lisa Warnecke, GeoManagement Associates

Definition Study of EOSDIS User Needs
Jack Estes, University of California, Santa Barbara

Discussion About Future Satellite Data Applications in States

Thursday, March 30

8:00 Summary and Recommendations by State Participants—How Can NASA Provide the Greatest Future Impact in States?

9:30 Briefing on Plans for Extending EOSDIS Beyond Science Research Community
Alex Tuyahov

Briefing on State Organizational Conditions
Lisa Warnecke

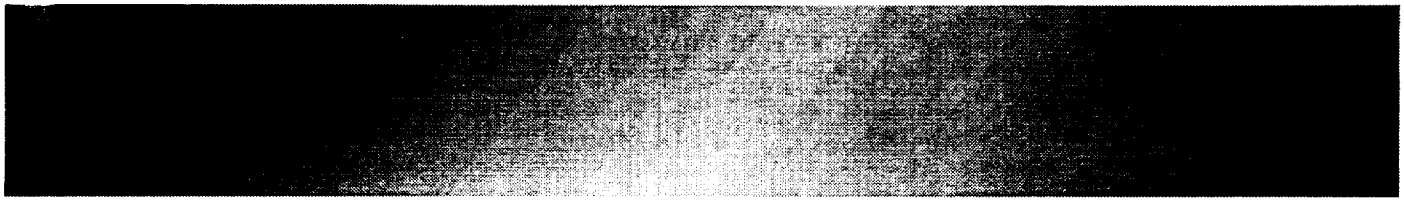
Discussion of a Program Structure to Facilitate NASA's Involvement With States, and the Dissemination of NASA's Data and Research Results to States

12:00 Lunch and Landsat Briefing
George Komar, NASA

1:00 Wrap-up and Summary

NASA Perspective
Alex Tuyahov

States' Perspective
Paul Tessar



State Participants

Dr. Fred Limp
Arkansas, Center for Advanced Spatial Technologies, University of Arkansas

Mr. Hal Anderson
Idaho, Department of Water Resources

Mr. William Burgess
Maryland, Department of Natural Resources

Mr. Michael Beaulac
Michigan, Department of Natural Resources

Mr. Paul Davis
Mississippi, Automated Resource Information System

Ms. Fay Rubin
New Hampshire, Complex Systems Research Center, University of New Hampshire

Mr. Michael Inglis
New Mexico, Earth Data Analysis Center, University of New Mexico

Mr. Thaddeus J. Bara
North Carolina, State Center for Geographic Information and Analysis

Drs. John Bossler and Carolyn Merry
Ohio, Center for Mapping, The Ohio State University

Mr. Richard Lacy
South Carolina, Department of Natural Resources

Dr. Charles Palmer
Texas, Natural Resource Information System

Mr. Paul A. Tessar
Wisconsin, Department of Natural Resources

Other Participants

Dr. Dixon Butler
Mr. Alex Tuyahov
Mr. Jerry Garegnani
NASA Mission to Planet Earth

Dr. John E. Estes
Mr. Joe Scepan
University of California at Santa Barbara

Dr. Lisa Warnecke
GeoManagement Associates

Appendix B
State Profiles

Alabama

State GI/GIS and Satellite Data Contacts

* Robert Grasser
Thomas Littlepage, GIS Coordinator
Office of Water Resources
Department of Economic and Community Affairs
401 Adams Avenue
PO Box 5690
Montgomery, AL 36103-5690
(334) 242-5496
(334) 242-0776 (fax)

* Barry H. "Nick" Tew
Alabama Geological Survey
420 Hackberry Lane
P.O. Box O
Tuscaloosa, AL 35486
(334) 349-2852
(334) 349-2861 (fax)
nick@sand.gsa.tuscaloosa.al.us

* Jerry McRay
Automated Data Processing
Alabama Emergency Management Agency
5898 County Road 41
Clanton, AL 36046-5160
(334) 280-2200
(334) 280-2410 (fax)

Gap Analysis Program Contacts

None reported.

State Government Context

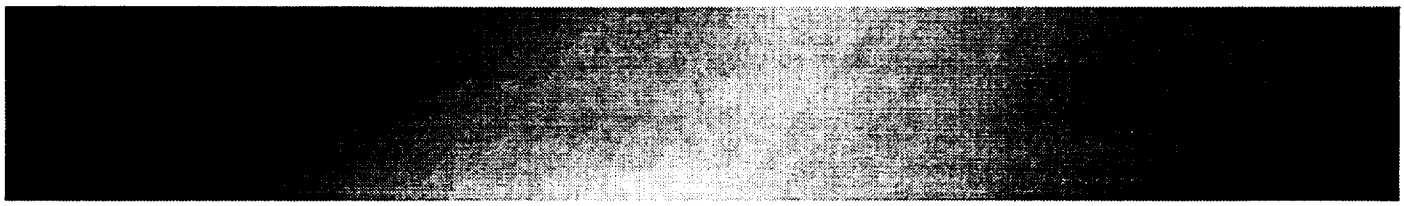
Alabama began to establish a new statewide GI/GIS coordination effort in 1996. Past state GI/GIS coordination groups had not continued, so efforts were recently initiated to establish a new approach. Representatives of some state agencies are organizing a new ***Alabama Geographic Information Committee*** that will build on past coordination efforts. The group does not have any resources or staff, and participation is on a voluntary basis. No state agency provides GI/GIS services to other agencies.

While no agency is the designated lead agency for GI/GIS, the ***Alabama Department of Economic and Community Affairs (ADECA)*** has been the unofficial GI/GIS coordinator for the state over the years. It is Alabama's planning and economic development agency, and it serves as the natural resources and environment planning entity for the state. ADECA and the ***Alabama Geological Survey*** are the leading agencies that are organizing the Geographic Information Committee.

Satellite Data Use

ADECA's Natural Resources Section serves as the natural resources and environment planning entity for the state. Other state agencies have operational natural resources and environmental programs. ADECA has been developing GI/GIS for its internal use since the late 1970s, particularly for water resources planning. Satellite data have been used in a few projects.

ADECA has been the lead state agency in Alabama working on the Gulf of Mexico Program with the ***U.S. Environmental Protection Agency (EPA)*** and other coastal states. These efforts include developing a data base for the gulf composed of data resources from various states and other sources. The program includes the Mobile Bay Demonstration Project, which began in 1989 with the objective of integrating information from a variety of sources to address **wetlands** and the bay. Tasks include the establishment of a wetlands digital data base using the National Wetlands Inventory, interpreted aerial photographs, and satellite data. The ***U.S. Army Corps of Engineers*** and the ***U.S. Fish and***



Wildlife Service have contributed data to the project. Some past land-cover work was performed using hydrologic units provided by the ***USDA Natural Resources Conservation Service.*** EPA's Region 4 (southeastern states) is working to apply data in the region to assess wetlands, and some effort has been under way to include Alabama.

The state is considering use of satellite data for future needs. According to EOSAT, Alabama has expressed interest in participating in their State Coverage Program. ADECA is considering more satellite data use to assist in water lawsuits.

The ***Emergency Management Agency (EMA)*** is using GI/GIS in all phases of emergency management, particularly for modeling. It is a leading state participant in the Chemical Emergency Stockpile Preparedness Program (CESPP). The ***Federal Emergency Management Agency (FEMA)*** provided most of the funding for acquiring and using software to participate in CESPP. EMA has developed its base data and is in the process of linking several data sets to other data bases, including Landsat data. These data have been used for **hurricanes, hazardous materials spills,** and **flooding.**

Gap Analysis Program Activities

None reported.

Alaska

State GI/GIS and Satellite Data Contacts

* Rich McMahon, Director
Land Records Information Section
Division of Support Services
Department of Natural Resources
3601 C Street, Suite 934
Anchorage, AK 99503
(907) 269-8836
(907) 563-1497 (fax)
richm@dnr.state.ak.us

Ed Christian, Analyst Programmer
Department of Environmental Conservation
410 Willoughby Avenue, Suite 105
Juneau, AK 99801-1795
(907) 465-5079

* Kathryn Lizik
Research and Analysis
Department of Labor
P.O. Box 25504
Juneau, AK 99802-5504
(907) 465-2437
(907) 465-4506 (fax)
kathryn_lizik@labor.state.ak.us

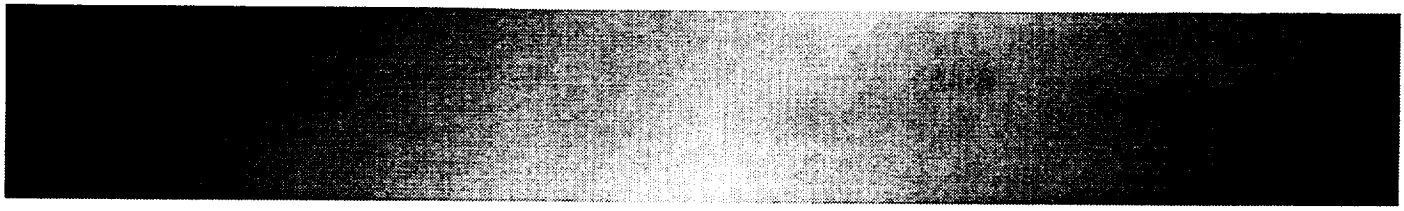
Gap Analysis Program Contacts

None reported.

State Government Context

Alaska has recently organized an approach to coordinate statewide GI/GIS activities, but it does not have an official or de facto focal point within the executive branch that serves as the state GI/GIS coordinator. However, Alaska does have a ***GIS Committee,*** which was established in the fall of 1995 and reports to the Telecommunications Information Council. Alaska also has a ***Geographic Data Committee,*** which is led by the ***U.S. Geological Survey*** and was created from the former state mapping advisory committee. These groups both help coordinate GI/GIS activities, and recent efforts are focused on strengthening relationships between the groups.

In addition, Alaska has some natural resources data coordination efforts, as well as various professional associations that facilitate GI/GIS coordination. No agency in state



government provides GI/GIS services for other agencies, although various agencies have related activities.

Satellite Data Use

Various agencies have GI/GIS activities under way, and there is some use of satellite data in coordination with these efforts. The ***Department of Natural Resources (DNR), Department of Environmental Conservation (DEC),*** and ***Department of Fish and Game (DFG)*** share responsibilities for natural resources and environmental management.

DNR has the largest GIS activities in state government and one of the largest levels of GIS activity of any state agency in the country. It is also the leading agency with satellite data efforts in Alaska state government. DNR has a few uses of satellite data under way; it acquired ERDAS software in 1994. For example, DNR, native corporations, and a mining group in the Tanana River Basin jointly purchased about 12 scenes of Landsat Thematic Mapper (TM) data that DNR is using for **land-cover mapping.** University students at the University of Alaska at Fairbanks are helping process the data.

The need for a coordinated response to the Exxon *Valdez* **oil spill** in 1989 prompted various agencies and private companies to strengthen their communications and work together regarding GI/GIS and satellite data. DNR and DFG enhanced their GI/GIS efforts and coordination as a result of the spill, which also was the impetus for DEC to obtain GIS capabilities to assist in its role as the primary responding agency for the incident. DNR and DFG were also involved and used their existing GIS capabilities to help respond to the disaster. Several agencies used GI/GIS to assist in understanding and mitigating environmental impacts, to support planning and communications with the public, and to support cleanup activities. For example, GIS was used in the field to collect data, including the location of oil and the results of water quality sampling. Both Landsat TM and Satellite Pour l'Observation de la Terre (SPOT) data were procured to assist in restoration efforts after the spill. For example, satellite data use reveals potential sites for public land acquisition. The data were also used in the damage assessment legal case, including by the ***Department of Law.*** DEC gathered and digitized data that were transferred to DNR for presentation for the case. A damage assessment model was developed by DNR and some Federal agencies.

DNR applied for a grant from **NASA** titled "Public Internet Access to Remote Sensing Images and Geographic Databases of Alaska." It was not funded, but DNR is still interested in pursuing the project, which would have acquired satellite data and processed data with GIS for the *Valdez* area. The goal was to maximize existing GIS data for the area, complement them with satellite data, and then provide access to the data and dissemination of them in various ways, including on the Internet.

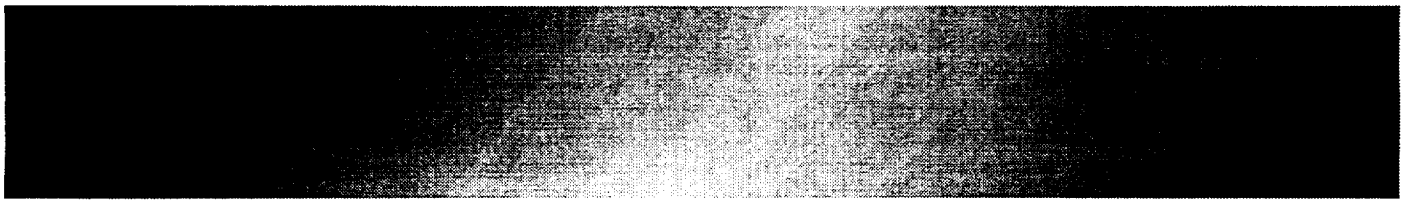
Gap Analysis Program Activities

None reported.

Nonstate Government Activities

According to DNR, the University of Alaska at Fairbanks' ***Geophysical Institute*** has the largest amount of satellite data work in the state. The institute and DNR have discussed developing some cooperative projects using satellite data (contact Rose Watabe at (907) 474-7487).

A Coastal Change Analysis Project (C-CAP) is under way with the National Oceanic and Atmospheric Administration's (NOAA) ***National Marine Fisheries Service***'s Auke Bay Laboratory. The project is monitoring **glacial movements** of the Hubbard Glacier. This glacier formed the world's largest glacier-formed lake, and change could damage a salmon fishery and village. A 1986 image is the only one available that meets C-CAP cloud-cover specifications, and efforts are under way to have another image. Image-



processing work has been conducted at the Department of Energy's ***Oak Ridge National Laboratory.***

Federal agencies developed some of the earliest applications of GIS in Alaska. The ***Committee on Northern Resource Information Management (CONRIM)*** has been involved with inventorying and making information about arctic areas available since the 1970s. CONRIM has a subcommittee that is advising the development of the Arctic Environment Data Directory (AEDD). One of the primary goals of the Interagency Arctic Research Policy Committee (IARPC), which is led by the ***U.S. Geological Survey,*** and the Interagency Working Group on Data Management for Global Change is the development of the AEDD, which is a subset of the Earth Science Data Directory maintained by U.S. Geological Survey. The working group worked on developing a prototype electronic publication series known as the Arctic Data Interactive, which is based on multimedia and compact disc technologies to enhance the use of the AEDD. It includes more than 300 data sets from Federal, state, and local agencies, as well as 10 other countries. The U.S. Geological Survey is leading this project, with state participants in this effort including DNR and DFG, as well as representatives of the University of Alaska.

Researchers at ***Pennsylvania State University*** have investigated the use of SPOT satellite data to produce digital elevation model data for the North Slope.

Reference

Sasowsky, K., Petersen, G., and Evans, B., "Accuracy of SPOT Digital Elevation Model and Derivatives: Utility for Alaska's North Slope," *Photogrammetric Engineering and Remote Sensing* 58 (June 1992): 815–824.

Arizona

State GI/GIS and Satellite Data Contacts

* Gary J. Irish, Program Manager
Arizona Land Resource Information System
State Land Department
1616 West Adams
Phoenix, AZ 85007
(602) 542-4061
(602) 542-2600 (fax)
girish@lnd.state.az.us

Gené Trobia, State Cartographer
State Land Department
1616 West Adams
Phoenix, AZ 85007
(602) 542-4060
(602) 542-2600 (fax)
gtrobia@lnd.state.az.us

* Tom Elder, GIS Coordinator
Information Technology Division
Department of Water Resources
500 North 3rd Street
Phoenix, AZ 85004
(602) 417-2400, ext. 7178
(602) 417-2401 (fax)
tomelder@aztec.asu.edu

Sally Lanier, GIS Coordinator
Habitat Branch
Wildlife Management Division
Arizona Game and Fish Department
2221 W. Greenway Road
Phoenix, AZ 85023
(602) 789-3609
(602) 789-3928 (fax)

Gap Analysis Program Contacts

Dr. Charles van Riper III
Colorado Plateau Research Station
Northern Arizona University
Box 5614
Flagstaff, AZ 86011
(520) 556-7466
cvr@nbs.nau.edu

Dr. Bill Halvorson
Cooperative Park Studies Unit
USGS Biological Resource Division
University of Arizona
Tucson, AZ 85721
(520) 621-1174
halvor@srnr.arizona.edu

State Government Context

Arizona has had a statewide approach to coordinate GI/GIS and satellite data for more than a decade. The ***Arizona State Land Department (ASLD)*** has served as the official lead state agency for these statewide activities since 1982, and it is one of Arizona's oldest users of GIS technology and satellite data. The ***Arizona Geographic Information Council (AGIC)*** serves as an omnibus group to encourage GI/GIS coordination. AGIC prioritizes user requirements for geographic data and systems and recommends spatial data standards and guidelines.

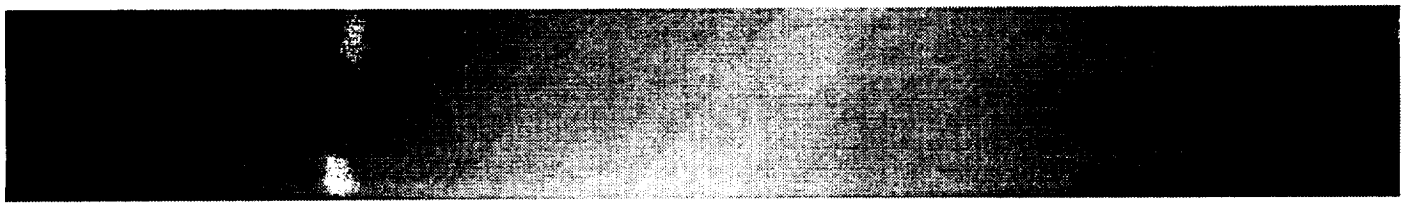
According to state statute, ASLD is the parent agency for the ***State Cartographer's Office (SCO)*** and the ***Arizona Land Resource Information System (ALRIS)***. The statutes directing ASLD's Resource Analysis Division specifically address satellite data and remote sensing. Arizona is unique compared to other states because few states have specific statutory direction regarding satellite data. It is directed that a clearinghouse and repository of information, such as map and satellite data products and digital cartographic data, should be developed and that access to maps, aerial photographs, land resource information, and other remote sensing data should be provided and monitored over time to help analyze natural resources conditions.

SCO was established by the legislature in 1988, but funding was not authorized until 1995. The State Cartographer position was filled in the fall of 1995, and two additional staff help constitute the office staff. SCO serves as the official statewide GI/GIS coordination office for Arizona, including coordination and development of data and a clearinghouse for GIS.

ALRIS is Arizona's state GIS service bureau. It served as the lead state agency for GIS between 1982 and 1995, including providing support to AGIC until SCO assumed this role. ALRIS conducts substantial data development and maintenance work for many statewide and other multipurpose data bases. ALRIS's data development efforts include design, development, and maintenance of statewide multipurpose spatial data bases for use by as many agencies as possible. ALRIS provides GIS training and consulting work for users outside the agency, as well as supports ASLD's internal uses of GIS technology. Some of the work conducted for statewide needs and for others is under the direction and auspices of AGIC. ALRIS maintained a clearinghouse for distributing digital spatial data and data documentation, and it is now conducting this work with SCO.

Satellite Data Use

Several agencies in Arizona use satellite data. ASLD has used satellite data to help serve in its data development and clearinghouse role for the state. For example, efforts are under way to use data as background to a GIS-based land query system. Satellite data have also been used to meet some departmental needs to help manage state-owned lands because such data can cover these lands at a relatively low



cost per acre. Spectral information has been important to classify these lands, particularly for the discrimination of vegetation and land-use information.

ASLD's ***Forestry Division*** has been one of the largest users of GIS technology and satellite data within ASLD. It is one of the few state forestry organizations to have used satellite data to conduct the **forest resources inventory** effort that is conducted with the ***USDA Forest Service*** for all states.

In the late 1980s, the division created a **vegetation** data base of Arizona's forest areas using Landsat Multispectral Scanner (MSS) data for 75 percent of the state, including lands managed by the state and others. This project was conducted in coordination with the USDA Forest Service as part of that agency's national forest resources inventory effort for Arizona, with help from the ***Bureau of Land Management*** and the ***Bureau of Indian Affairs.*** ASLD used ELAS and ARC/INFO software to process and analyze the data. The DTAP (digital terrain applications package) software was developed by ASLD and also utilized. In addition, the division has used Landsat data and GIS as an aid in its important forest firefighting mission. The division has used GIS to track location, size, agency responsibility, and other factors related to **wildfires.**

Arizona has various agencies with environmental and natural resources responsibilities in addition to ASLD. The ***Arizona Department of Water Resources (ADWR)*** has had perhaps the most extensive history of using remote sensing and integrating remotely sensed data with GIS. The agency was formed in 1980 to provide comprehensive groundwater use regulation and planning and to halt or minimize groundwater depletion. ADWR began using GI/GIS and satellite data to help meet this need in 1984. ADWR now utilizes GI/GIS and satellite data for a wide variety of **water resources applications** to help management and protect Arizona's limited water resources, as described below. Multitemporal (change detection) capabilities have been found to be particularly important for water use and agriculture monitoring work, but costs have been an impediment to more extensive use of satellite data.

Delineation, analysis, and monitoring of **surface and groundwater rights and usage** for maintaining compliance with irrigation requirements make up one of the department's largest uses of GI technology. ADWR has developed a spatial data base, consisting of irrigated groundwater rights for all irrigated fields more than 2.5 acres that are administered under the Groundwater Management Act of 1980. The data base is created from applicant filing data, transcribed to 7.5-minute quadrangle maps and then digitized. This water rights data base is then used for several applications.

The CropWatch Program began as a pilot project in 1985 and was institutionalized in 1986 to enforce limits on irrigated acreage expansion and to provide **crop acreage** information for water resources planning (see Figure B1). Landsat MSS data were first used in the program, but SPOT XS Level 1B scenes are now used to monitor irrigated agriculture acreage limit compliance and to create crop maps. SPOT data are used because of more frequent repeat acquisition opportunities to minimize cloud cover and because they show more detail on the ground. Other sources of satellite images have also been evaluated. The crop maps are created with ERDAS software and are combined with the water rights data base, maintained in ARC/INFO. Irrigated areas with no water rights are flagged for inspection by field personnel. ADWR also uses satellite data to develop crop history statistics to help monitor water use reporting compliance and assess the efficiency of irrigation water use. Historic crop production and water use statistical trend comparisons are used for water conservation and water resources planning for agricultural lands.

These data are also used by ADWR to support the court-ordered surface water rights adjudication process. In the adjudication process, GIS is used to map surface water rights

Irrigated Agriculture in Arizona

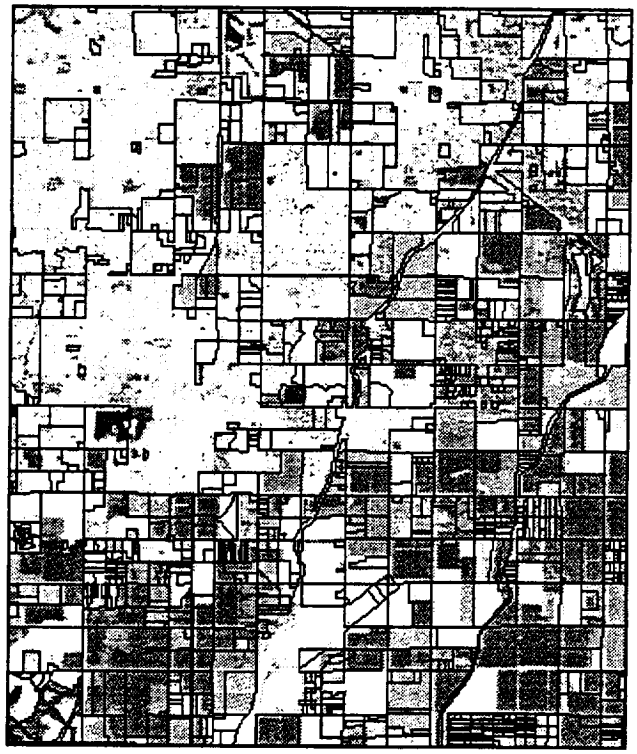


Figure B1

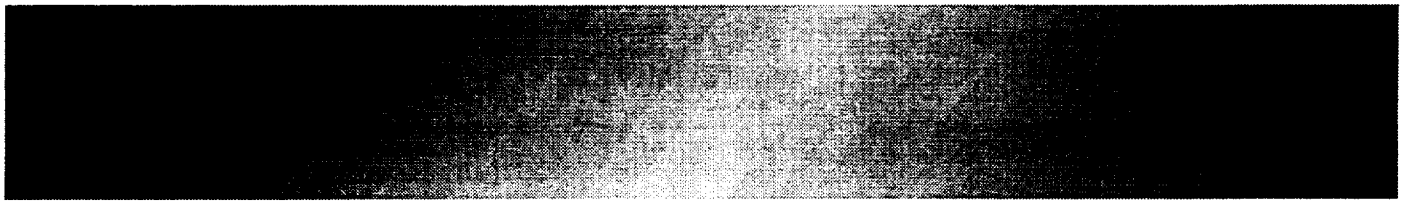
This map illustrates the final crop field maps produced by the Arizona Department of Water Resources CropWatch Program for Chandler, Arizona, during the summer of 1994. The different shades indicate crops that can be irrigated using groundwater, crops growing outside established water rights, and vegetated areas in urban or desert areas. (courtesy of Tom Elder, GIS Section Leader, Arizona Department of Water Resources, (602) 417-2400, ext. 7178, *tomelder@aztec.asu.edu*)

claims for each adjudicated watershed. This mapping produces a hydrographic survey report for each watershed. Such reports contain an atlas of maps showing the locations of all surface water claims and information about the claimant. Crop irrigation claims, stock pond impoundments, and special-use maps are delineated in the atlas. To date, ADWR has processed the San Pedro River Basin and portions of the Little Colorado River Basin. The survey reports and maps are usable by the courts to decide water rights and priority of rights for all surface water in Arizona.

ADWR also uses GIS technology and satellite data to exam ine water and nearby resources, including statewide water-use assessment and planning. GIS technology and satellite data have also been used to help identify and conserve **riparian vegetation areas** (see below for University of Arizona).

Another project using satellite data is in the Lower San Pedro River Basin. It includes the participation of local governments, businesses, and citizens. This area is a designated conservation area of the Bureau of Land Management. GIS has been used in conjunction with hydrologic models to help determine the effects of pumping of groundwater on the river. Some data layers being used include locations of wells, potable water service areas, Census geography, and others. Part of the purpose of the project is to determine the effects of groundwater pumping on instream flow.

The ***Arizona Game and Fish Department (AGFD)*** began using GI/GIS in 1983 and has used satellite data to develop data for Arizona's riparian areas, a decreasing habitat type of great significance for wildlife in the state. Early activities included mapping wildlife distribution, density, and habitats, sometimes including sightings and survey location data. Satellite data were used in studies of large areas because other methods would not have been as cost-effective. Over the last several years, AGFD has used GIS to examine the species/habitat questions for a variety of different kinds of animals and evaluated the impact of land ownership and administration on them. GI/GIS and satellite data have also been used to determine potential water rights acquisition needs to help wildlife. AGFD will use satellite data with the Gap Analysis Program (GAP) to conduct further habitat assessments. Additional plans are to use satellite data to support efforts to inventory and study old-growth forest locations, including the evaluation of timber management practices on wildlife. AGFD is also an active participant in the GAP work in the state (see below).



Gap Analysis Program Activities

Project teams at the ***University of Arizona*** in Tucson and ***Northern Arizona University*** in Flagstaff are responsible for GAP in Arizona. Work has been funded to complete accuracy assessment and analysis and to develop a final report after all primary GAP data layers were completed in the spring of 1995. This work is expected to be completed in 1997. In addition, Arizona is part of two four-state ecoregion projects. The Four Corners Project is being coordinated by Northern Arizona University and includes parts of New Mexico, Colorado, and Utah comprising the Colorado Plateau and Southwest Highlands ecoregions. The Mojave Ecoregion Project includes California, Nevada, and Utah and is under way. The assessment of the vegetation map is partially funded by AGFD, which is an active cooperator in the project. The data set will be shared with the state and others through the ***U.S. Geological Survey's Biological Resource Division***'s National Biological Information Infrastructure, with funding provided by the Division of Information and Technology Services.

Nonstate Government Activities

In addition to the GAP work, the University of Arizona has a Remote Sensing Center located in its Office of Arid Lands Studies. Several projects have been conducted using satellite data and aerial photography. For example, recent changes in riparian habitat of the Tanque Verde Creek in Tucson prompted an investigation of native plant communities, hydrology, and climate in this area. Landsat MSS data were used to develop indices of **vegetation** condition between 1983 and 1989. A wide array of multitemporal comparisons were constructed between the vegetation indices and well water levels, temperature, and precipitation. The ***City of Tucson*** and ***Tucson Water*** provided funding for the project.

Northern Arizona University also has used satellite data for several projects. For example, its School of Forestry has expertise in and has used GIS, computer decision support systems, and remote sensing for **forestry.**

Arizona State University is working with the ***U.S. General Services Administration*** to develop information technology pilot projects to help implement the National Information Infrastructure. In one of its three funded projects, Arizona State University will carry out the proposal by the ***U.S. Environmental Protection Agency*** for bringing "EarthVision" activities into Arizona's high schools.

The ***City of Scottsdale*** has a unique project using satellite data that is funded by ***NASA,*** the ***U.S. Department of Energy,*** and Public Technology Inc.'s Urban Consortium, along with partnerships with private industry. The project has included a review of the potential applicability of satellite data to municipal operations in Scottsdale and related cost savings. Some satellite data have been procured and were processed by Arizona State University's Mars Global Surveyor Space Flight Program for use in the city's GIS. The project has focused on developing and commercializing an advanced **stormwater permitting** system. Software was developed that uses satellite data to help generate an individualized stormwater permit, which includes the percentage of area that is permeable and impermeable with regard to water absorption for each defined land parcel. Estimates are that the system could reduce permitting costs by a third. There are plans to test the system in additional cities.

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Arkansas

State GI/GIS and Satellite Data Contacts

Jami Lockhart, GIS Coordinator
Arkansas Archeological Survey
P.O. Box 1249
Fayetteville, AR 72702
(501) 575-3556
(501) 575-5453 (fax)

Shelby Johnson, President
Arkansas GIS Users Forum
Center for Advanced Spatial Technologies
University of Arkansas
12 Ozark Hall
Fayetteville, AR 72701
(501) 575-6159
(501) 575-5218 (fax)
shelby@cast.uark.edu

Gap Analysis Program Contact

* Dr. W. Fredrick Limp
Center for Advanced Spatial Technologies
University of Arkansas
12 Ozark Hall
Fayetteville, AR 72701
(501) 575-6159
(501) 575-5218 (fax)
fred@cast.uark.edu

State Government Context

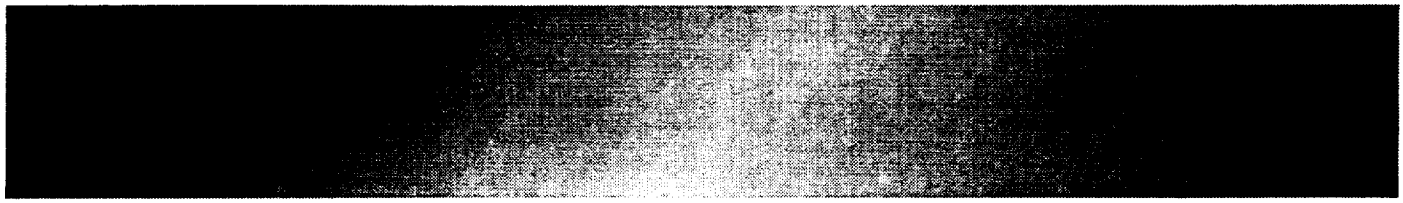
Arkansas has had an active and growing statewide GIS coordination initiative. However, recent political conditions are having an adverse impact on official coordination efforts. The legislature created the ***State Land Information Board*** in 1995 to provide direction for GI/GIS and related activities in Arkansas. This legislation was passed following the efforts and recommendations of the ***Mapping and Land Records Modernization Advisory Board,*** which was created by statute in 1993. The legislation provided that staffing support and GI/GIS coordination be conducted by the ***Department of Computer Services.*** It also stated that the advisory board would have a similar membership as the former advisory board. Certain state agencies are identified to be voting members, and other agencies could serve as nonvoting members if they expressed interest for membership to the governor.

The Department of Computer Services served as the de facto statewide GI/GIS coordinator during the early 1990s, and this role was made official in 1995 by the legislature. However, the department ceased work in this role in May 1995 because the Governor's Office has not filled positions in the new State Land Information Board and has not expressed any plans to make these appointments.

While the official board has not been activated, Arkansas has a ***GIS Users Forum.*** It currently serves as the only active statewide GI/GIS coordination group because the board membership and staff do not exist at this time.

Satellite Data Use

GI/GIS and remote-sensing activities are still early in their developmental stages in most state agencies, but there is a



substantial and growing amount of activity. Many state agencies have natural resources and environmental responsibilities in Arkansas and are involved in these activities.

A recent statewide initiative is actively using satellite data to address **wetlands and water resources** issues. A multiagency state task force, composed of the ***Soil and Water Conservation Commission,*** the ***Department of Pollution Control and Ecology,*** the ***Arkansas Game and Fish Commission,*** the ***Forestry Commission,*** and the ***Natural Heritage Commission,*** developed a statewide wetlands strategy that employs remote sensing and GI/GIS. The legislature appropriated $700,000 to the Soil and Water Conservation Commission in 1995 to develop digital map products in support of its water resources and wetlands efforts. One-third of the funds were allocated toward the development of county-level soils digitization, and most of the remainder of the funds has been designated toward producing map products that are derived from remotely sensed data sources.

Fourteen state and Federal agencies entered into a statewide satellite data consortium and purchased statewide Landsat TM coverages in support of this and other state efforts. Using a formal cooperative agreement signed by all agency directors, the group jointly obtained two season statewide TM data sets. The ***University of Arkansas Center for Advanced Spatial Technologies (CAST)*** serves as the statewide repository of the raw data and has provided it to the agencies as requested in coordination with its related satellite data work (see below).

Products developed for this initiative include a detailed map of **agricultural land use and land cover** to be developed using multiseason Landsat TM data. A potential farmed wetlands base map has also been developed from the satellite data for the eastern third of the state. Another product is a hydroperiod map, which will use multiple TM images correlated with the river gauging stations of the ***U.S. Army Corps of Engineers*** to map **hydrological conditions,** particularly the extent and intensity of flooding and water ponding.

This initiative and legislative funding has significantly increased the GI/GIS and satellite data activities at the Soil and Water Conservation Commission. It has recently installed software and hardware for GI/GIS and satellite data use, and staff are being trained to use it.

Other individual agencies are also involved in the use of GI/GIS and satellite data. The ***Archeological Survey,*** located at the ***University of Arkansas in Fayetteville,*** has used satellite data longer than any other state agency. It has perhaps developed use of geographic information technologies for **archeology** further than any other state archeological survey. For example, it has had contracts with the ***U.S. Environmental Protection Agency (EPA)*** to develop locations of endangered species and with the U.S. Army Corps of Engineers to evaluate cultural resources in the corps' eight-state southwest region. This latter effort included evaluating U.S. military installations for environmental assessments and resource management, as well as specific site assessments from an archeological perspective.

Unlike many state archeological surveys, the Arkansas survey data use GIS with various data layers, such as geology, elevation, political boundaries, soils, transportation, and hydrography, with its 20,000 archeological site records from the Automated Management of Archeological Site Data in Arkansas (AMASDA) data base. Satellite data have been used for specific sites and needs, including wildlife management and sensitive environmental areas.

Other state agencies are increasing their GI/GIS and satellite data activities to meet internal needs. For example, the ***Highway and Transportation Commission*** is using Landsat TM products in the development of **highway environmental impact** statements for new construction. The Forestry Commission is using data derived from Landsat TM in some

forestry applications, including the development of a statewide fire hazard mapping product. It is also working with the ***University of Arkansas at Montecello,*** the ***USDA Forest Service,*** and some private firms in various forest management programs.

Agencies participating in the wetlands initiative described above are also becoming active users. For example, the Department of Pollution Control and Ecology and the Natural Heritage Commission are training staff and have installed software and hardware to use satellite data and GIS. These and other agencies frequently involve state universities and private remote-sensing contractors to perform the large-scale analysis and deliver derived products that are then used in daily operations by the agencies.

Land Cover in Arkansas

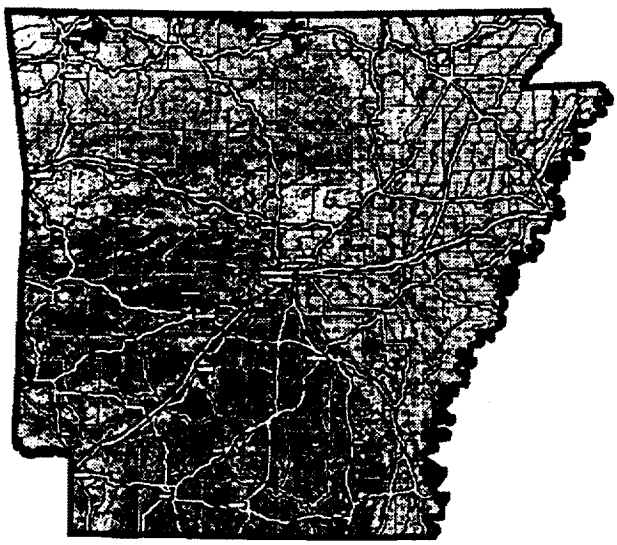


Figure B2a

This statewide vegetation map was derived from TM imagery as part of the Arkansas GAP project. Interactive maps such as this for any location in Arkansas are available via the World Wide Web. (courtesy of Fred Limp and Jim Farley, Center for Advanced Spatial Technologies, University of Arkansas at Fayetteville, (501) 575-6159, *info@cast.uark.edu*)

Gap Analysis Program Activities

CAST is conducting the Arkansas GAP (see Figure B2a). Statewide land-cover, land ownership, and management status maps have been completed, and Arkansas is considered to be one of the first six states in the country to have GAP work completed. The land-cover map has been aggregated, and accuracy assessment is now under way. The land-cover data have been aggregated using the "Montana" method, which has worked well, given the spectral classification procedures used initially. Data have been aggregated at 2-, 10-, 40-, and 100-hectare levels, with the 100-hectare level to be provided to the national GAP effort.

Increased discrimination for the urban mapped areas has been obtained by integrating GAP spectral data with TIGER and STF (Standard Tape Format) data to isolate urban classes from bare rock and similar spectral signatures that are not urban. Cartographically appealing hard-copy products have been developed in addition to the digital maps. Land-cover classes have been assigned to the spectral classes using a variety of data sources, including USDA Forest Service and state agency data. Twenty percent of the Arkansas Game and Fish Commission's plot data (3,000 plots) and a similar percentage of the USDA Forest Service's stand/compartment data were excluded for consideration in the information class assignment phase. These plots and stands/compartments were reserved on a random selection basis and were used later in the accuracy assessment phase.

In addition, an important accuracy assessment data set was developed by selecting 2,000 random field plot locations and providing them to the Arkansas Forestry Commission. The Arkansas GAP team developed an innovative method for site selection based on the Utah project and a software application that produces a small hard-copy map for each quad. These maps were given to Forestry Commission field staff along with disposable cameras. The field staff recorded the forest types based on the Arkansas GAP land-cover

classification and made their own comments, along with sample photographs, for a permanent record.

Land ownership and management status mapping was also conducted in close cooperation with participating agencies. Less than 10 percent of the state is under public management or owned by natural heritage groups. For the state, less than one-half of a percent is in GAP management class one, less than two percent is in class two, seven percent is in class three, and the remainder is in class four (or is unknown). As the land ownership/management effort went forward, it became clear that large portions of the state are managed for various natural and/or wildlife purposes, such as hunting clubs, but are in private ownership. Unfortunately, the location and character of these private lands are unknown and could not be included in the current GAP effort.

Vertebrate distribution maps have been developed for all terrestrial species and subjected to accuracy assessment, and all report elements are completed. The project emphasis is now on production of a CD-ROM-based final report. In addition to the text report, the CD will include a series of map products in an Adobe Acrobat PDF format (TM). Maps of each of the state's 914 7.5-minute quadrangle areas (at a map size of 8.5 by 11 inches or an effective scale of roughly 1:65,000), along with the 1:100,000 map areas, and county and state maps will be on the CD. It will also include county-based vertebrate maps, Landsat TM-derived vegetation, tasseled cap-hyper spectral cluster, and color infrared products (see Figure B2b). Similar maps will also be accessible via the World Wide Web *(www.cast.uark.edu)*.

Nonstate Government Activities

The University of Arkansas at Fayetteville established CAST in 1991. CAST focuses on research, education, spatial data distribution, and technology transfer in GIS, remote sensing, GPS, and digital photogrammetry. CAST also serves as the southwest office of the National Center for Resource Innovations and is the lead for the GAP work in

Color Infrared Imagery of Arkansas

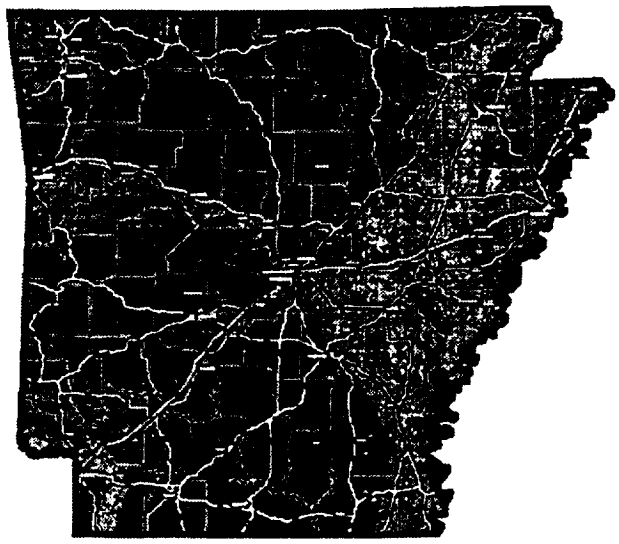


Figure B2b

This seamless statewide color infrared imagery of the State of Arkansas was developed with NASA funding. Interactive maps such as this for any location in Arkansas are available via the World Wide Web. (courtesy of Fred Limp and Jim Farley, Center for Advanced Spatial Technologies, University of Arkansas at Fayetteville, (501) 575-6159, *info@cast.uark.edu*)

the state (see above). It has received funding from numerous sources, including a **NASA** grant to develop satellite data methods and GIS technology. CAST is making the results of this external funding useful to governmental agencies. For example, it developed an unsupervised, classified Landsat TM mosaic of the entire state (see Figure B2c) and a statewide **vegetation** map, as well as a *Catalog of Arkansas Digital Spatial Data*. Under NASA grant NAGW-4117, seamless statewide Landsat TM-derived products, such as a tasseled cap map, color infrared maps, and vegetation maps, can be accessed via an interactive World Wide Web on-line mapping package. Users from agencies can access the system and create maps of any selected location in the state, including a variety of map elements such as transportation routes and the Public Land Survey System.

CAST has customized its efforts to aid several state, regional, and local agencies in their use of satellite data. It

Arkansas Spectral Diversity

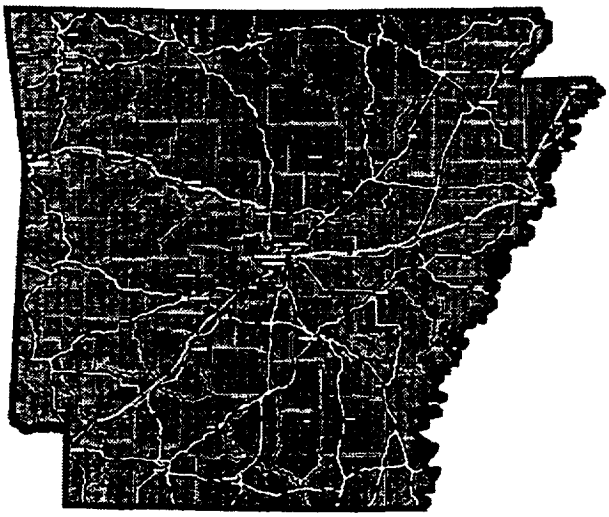


Figure B2c

This shows almost 3,000 spectral classes indicating the tremendous variation of land surfaces in the state as derived from TM imagery. Interactive maps such as this for any location in Arkansas are available via the World Wide Web. (courtesy of Fred Limp and Jim Farley, Center for Advanced Spatial Technologies, University of Arkansas at Fayetteville, (501) 575-6159, *info@cast.uark.edu*)

has participated in several state government applications of satellite data, including **forestry, pest removal, wetlands inventory, transportation,** and **demographic projections.** CAST has also conducted satellite data work to help **local and regional land-use planning** efforts. For example, it developed land-use and land-cover data to help a regional planning agency conduct planning studies for four counties in the central part of the state, and it has an initiative to assist in the use of these technologies in rural jurisdictions.

Other state universities are also active users of satellite data. The University of Arkansas at Montecello has developed an active program in remote-sensing applications in **forest management.** Work is under way with the state Forestry Commission, the USDA Forest Service, and some private firms to use satellite data in various forest management programs.

Arkansas State University at Jonesboro also has developed an active remote-sensing program that focuses on detailed analysis of **wetlands.** While much of these efforts involve satellite data, aircraft based data are also used.

California

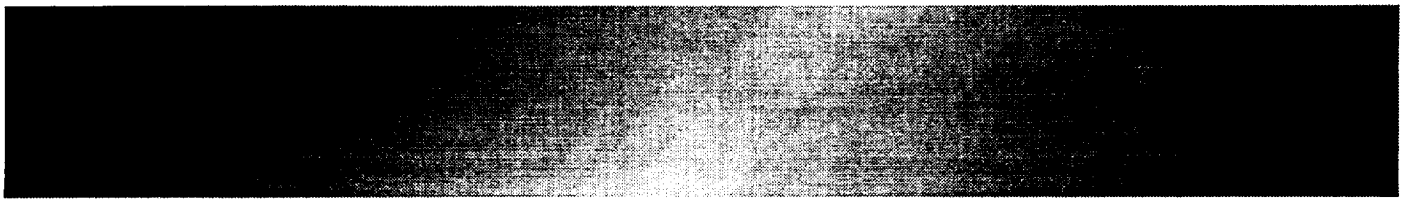
State GI/GIS and Satellite Data Contacts

* Randall Moory, GIS Manager
Teale Data Center
GIS Technology Center
2005 Evergreen
P.O. Box 13436
Sacramento, CA 95813-4436
(916) 263-1886
(916) 263-1346 (fax)
randy@gislab.teale.ca.gov

Gary Darling, Chief Information Officer
California Resources Agency
900 N Street, Suite 250
P.O. Box 942837
Sacramento, CA 94237-0001
(916) 653-4279
(916) 654-5829 (fax)

Robin Marose, Manager
Janine Stenback
Forest and Rangeland Resources Assessment Program
Department of Forestry and Fire Protection
1920 20th Street
Sacramento, CA 95814
(916) 227-2656

John Ellison
Department of Fish and Game
1416 Ninth Street



Sacramento, CA 95814
(916) 323-1477

Muffet Wilkerson
Department of Pesticide Regulation
1220 N Street, Room A-331
Sacramento, CA 95814
(916) 654-1354

Jonathan Van Coops
California Coastal Commission
45 Fremont Street, Suite 1940
San Francisco, CA 94105
(415) 904-5464

Gap Analysis Program Contact

Dr. David Stoms
Department of Geography
University of California
Santa Barbara, CA 93106-4060
(805) 893-7655
(805) 893-3146 (fax)
stoms@geog.ucsb.edu

State Government Context

The lead state organization regarding GI/GIS coordination in California is located in the ***Teale Data Center's GIS Technology Center,*** established in 1988, which serves as a service bureau on a cost-recovery basis similar to other computing services at Teale. It is developing and maintaining a geographic digital data library, fosters interagency coordination, and provides contract services. The GIS Technology Center has provided GI/GIS services and data for several state agencies, but it does not have a coordinating role regarding satellite data.

Data coordination is led by the ***California Resources Agency (CRA).*** CRA is working with several state, Federal, and local agencies, as well as academic institutions and community groups, to develop the California Environmental Resources Evaluation System (CERES). It was initiated to facilitate access to satellite data, digital data for use with GIS, aerial photography, and other data from multiple source to improve environmental analysis and planning conducted by a variety of users. For example, statewide SPOT data were recently purchased in coordination with CRA (see below).

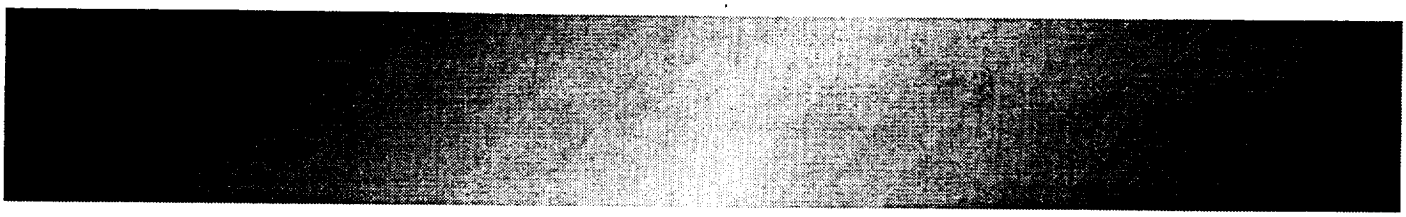
Statewide GI/GIS coordination is accomplished through the ***California Geographic Information Association.*** This group has approximately 400 members, but it does not have an official stature in state government. Teale's GIS Technology Center provides some staff support for the group.

Satellite Data Use

California has several agencies that use satellite data. The California Resources Agency (CRA) has taken a leading role in coordinating data acquisition and activities. It includes many of the state government's natural resources agencies, such as the ***California Department of Forestry and Fire Protection (CDF)*** and the ***Department of Fish and Game.*** CRA and other organizations in the state are developing CERES, which is increasing the access and use of GI/GIS by a variety of users, and it includes satellite data, aerial photography, and other data from multiple sources to improve environmental analysis and planning.

Ten state and Federal entities collaborated to purchase SPOT panchromatic digital ortho-images with 10-meter resolution in 1995. These data are being used as a base map for several GI/GIS efforts in California. Some applications of this and other satellite data are discussed below.

CDF was one of the earliest users and is still a leading user of satellite data in California. It is responsible for carrying out the state's forest policy, including managing forests and rangelands owned by the state. CDF also enforces forest



practice regulation, including timber harvesting on private and state lands. Approximately 90 percent of its budget is used for fire protection and fighting purposes for wildlands. In recent years, CDF has had a stronger role in responding to, understanding, and predicting fires that impact populated areas.

CDF's Forest and Rangeland Resources Assessment Program (FRRAP) has used satellite data, aerial photography, and other data with GIS for a variety of forestry and wildfire programs and purposes. CDF has historically served as California's lead agency to develop the state's vegetation cover data. It began these efforts in 1978 with image interpretation and development of a statewide vegetation classification using 1977 Landsat data. These data were developed to support monitoring land-use changes, biodiversity analysis, and modeling efforts to simulate future economic activity and environmental quality affected by biological processes as well as land-use activities. CDF subsequently purchased GIS software in 1986. FRRAP is collocated with the ***USDA Forest Service***'s Remote Sensing Laboratory to facilitate coordination of vegetation mapping. A list of CDF's GIS-remote sensing projects is available upon request.

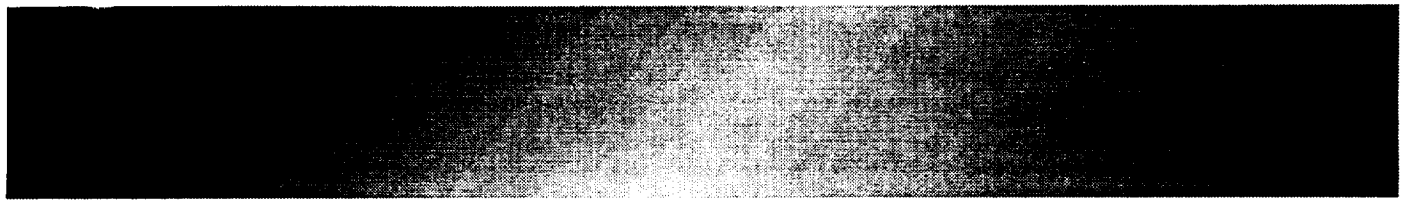
For example, vegetation mapping was conducted in the Klamath Province region of the Sierras using 1990 Landsat data, and then expanded to the entire region. (see NASA grant below) The satellite data was developed to help classify and analyze vegetation types related to wildlife habitat and to serve as a pilot project to demonstrate the capability to classify forest lands vegetation for the entire state. Vegetation mapping has also been used in such applications as fire protection and wildlife habitat monitoring.

CDF's Fire Protection Section is developing and using many data resources, such as satellite data with GIS to support wildfire prevention, fire protection planning, firefighting, and mitigation efforts. CDF is implementing GIS at the ranger units for fire protection. Satellite data have been used to help determine and analyze the impacts of human settlement on fire to prepare for future fires before they happen. For example, areas at risk for wildfires are being identified by examining locations throughout the state that have a similar constellation of potential firestorm conditions, such as slope, surrounding vegetation, roof composition, types of windows and siding, and building density. Satellite data have also been used to determine where housing density exceeds the density parameters of specific jurisdictions. CDF has used GI/GIS in several wildfire incidents, with two examples described below.

CDF, the ***City of Oakland,*** and others used GIS, satellite data, GPS, and other data during and after the Oakland fires in 1991. For example, these resources were used to monitor the fires during burning. Helicopters with GPS receivers were used to determine the fire perimeter during the fire. These resources were also used to assess damage and coordinate the rebuilding effort after the fires.

Satellite data and related technologies were also used to respond to the Laguna Beach fires in 1993. These resources were used to assist in inventorying and mitigating further damage, rapid processing of permits, and erosion and flood control. A unique consortium of companies and organizations provided the ***City of Laguna Beach*** with GIS capabilities. In addition, the California Natural Diversity Data Base was entered into the GIS to map the location of rare, endangered, and threatened species habitat in the area. Nine threatened species were found to be affected by the fire. Vegetation loss was estimated using GAP and other data (see below). Emergency access is being evaluated using GIS. Lessons learned included formalizing general and data relationships and standards before a disaster occurs.

Other California state agencies used satellite data prior to and since the joint purchase of SPOT data in 1995. The Department of Fish and Game is another growing user of satellite data. It has been used to assist in planning for and



managing the state's **wildlife** resources, including habitat protection and **oil spill management** assistance. For example, satellite data have been used to help determine how to best approach and contain spill areas and to evaluate the impact of oil spills on the state's wildlife.

The ***Department of Conservation's Division of Mines and Geology*** has used Landsat and SPOT images, aerial photographs, digital elevation models, and orthophotography with GIS to help predict, understand, and respond to **earthquakes** in California. Seismic Hazards Studies Zone maps have been developed to comply with the Seismic Hazards Mapping Act of 1990. In addition, these data have been used to understand surface patterns and conduct interactive modeling and interpretation of surface geology, faulting, strike, and dip, including three-dimensional views. Pilot efforts began in 1992 in the San Francisco/Santa Cruz area; plans call for 70 percent of the project to be completed by 2010.

The department and others have used satellite data with GIS and GPS to help respond to earthquakes such as in Northridge on January 17, 1994. For example, these resources were used to develop custom maps showing the exter of damage, location, and number of structures destr ed. Damage assessment maps were used to monitor progress and prioritize efforts in the cleanup.

In addition, the ***Department of Water Resources*** is using SPOT data to increase the accuracy of **vector maps** and to assist in calculating future **water resources** needs based on land use. The ***Department of Pesticide Regulation*** is using the satellite data to increase the accuracy and currency of vector maps derived from aerial photography, helping delineate fields used for **agriculture** and modeling and **regulating safe pesticide applications.** In addition to these agencies, the ***Resources Agency*** and the ***Coastal Commission*** have participated in remote-sensing projects funded by **NASA** with application to areas discussed above, as well as **coastal resources** planning and management. These projects include:

- Using Landsat Data to Monitor the Effectiveness of Salmon Habitat Protection in a Large Pacific Coast Watershed (Sierra's Klamath River Basin), contact: Ronald Iverson, ***U.S. Fish and Wildlife Service***

- Image Application for Coastal Resource Planning (Elkhorn Slough), contact: Gary D. Sharp, ***California Institute for Research***

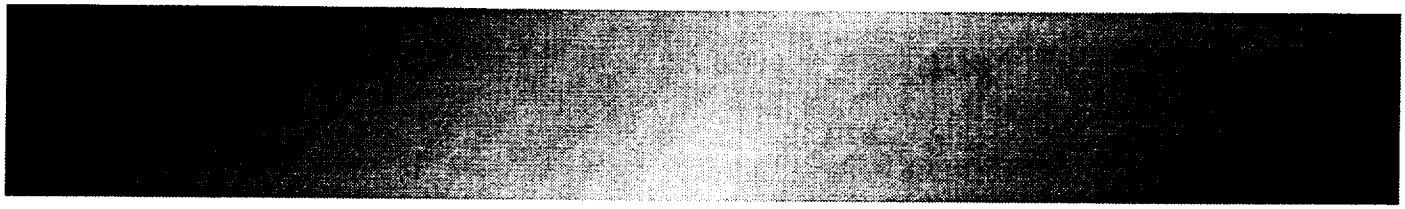
- Imaging California: South Coast Pilot, contact: Janine Stenback, California Department of Forestry and Fire Protection

Gap Analysis Program Activities

The California GAP is nearing completion by the ***Department of Geography*** at the ***University of California at Santa Barbara (UCSB).*** Land-cover and land management mapping have been virtually completed for all ten planning regions of the state. Attention is now being shifted toward data analysis and distribution. Revisions were incorporated in the land-cover data suggested by reviewers beginning in 1996, and efforts are under way to publish a final report. The current plan is to distribute the data base and regional reports on both the World Wide Web and a CD–ROM. These two media would be used both for locating and transferring data and for common queries of the data base. Discussions are still under way to determine who within the state should be responsible for long-term maintenance and distribution of GAP data.

The Universal Resource Locator (URL) addresses for California GAP data are:

- *http://www.biogeog.ucsb.edu* (for information about GAP and other related research projects at UCSB)



- *ftp://lorax.biogeog.ucsb.edu* (for accessing GAP data as they are completed)

In 1995, one Ph.D. dissertation was completed, and another is in draft. Papers have been delivered at GAP symposiums, and several peer-reviewed articles relating to GAP were published or accepted for publication in 1996.

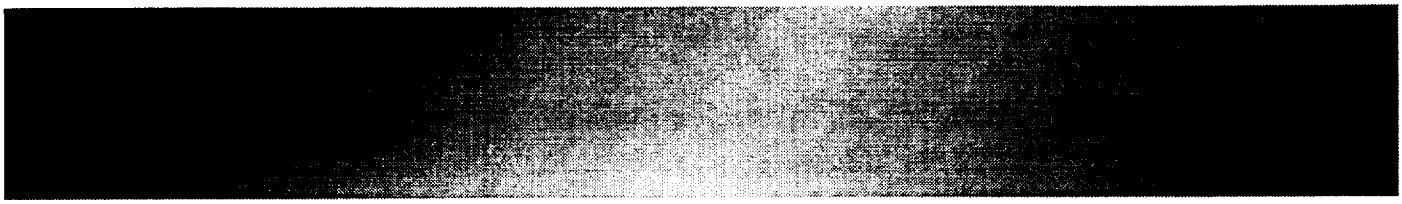
The California GAP participated in the Sierra Nevada Ecosystem Project (SNEP) funded by the USDA Forest Service. The mission of SNEP was to (1) define the spatial extent and dynamics of key structural, functional, and compositional features of the ecosystem; (2) identify the benefits humans draw from it; and (3) identify management alternatives and their effects on ecosystem integrity and its sustained capacity to provide the full range of benefits. A Gap Analysis of plant communities was one of several analyses of regional biodiversity. Others included late-successional/old-growth forests, aquatic species and habitats, and significant ecological areas, although these were generally limited to public lands because of data availability. Because of the vast amount of spatial data compiled for SNEP, the standard GAP management class definitions were refined to include permitted land uses on public lands, such as grazing allotments and commercial timber harvest from forest plans. The final SNEP report to Congress is in press, including the chapter on GAP.

The ***Biogeography Laboratory*** at UCSB undertook two additional studies of reserve selection algorithms to select biodiversity management areas. The first study reformulated the reserve selection models in the conservation literature as a classical Maximal Covering Location Problem (MCLP), as described in the operations research and regional science literature 20 years ago. The MCLP can be solved optimally (that is, no better solution exists), and most problems of the size described for reserve selection can be solved with reasonable computer resources. The MCLP model was solved for a real application using vertebrate distribution data prepared for the Gap Analysis of southwestern California. The areas are defined by each of the 280 7.5-foot quadrangles, and the regional species pool contains 333 native vertebrates. Therefore, the species-site matrix consists of 280 columns by 333 rows. A maximum of 12 sites are required to cover all species at least once, although 327 species can be covered in just seven sites. "Solutions" on an IBM RS–6000 workstation took an average of 2.8 seconds of CPU time over the 12 solutions, with none taking more than 9 seconds. This analysis is being published in *Biological Conservation* (see Church *et al.* below).

The second study recognized the limitations of the simple "covering" model. An optimization model was developed for SNEP (in collaboration with researchers at UCSB and ***Oregon State University***) that selects new areas for biodiversity management. The model, known as BMAS (Biodiversity Management Area Selection), minimizes total area and maximizes overall suitability of the selected sites while meeting predefined levels of representation (for example, 10 percent) for each community type (or wildlife species). Suitability was defined for this study by habitat quality (road density and human population density) and management factors (proportion of private ownership and the degree of fragmentation of land ownership). These factors were chosen for their potential impact on biodiversity management as well as the availability of data across the entire ecoregion. The SNEP study was not authorized to make formal management recommendations. Instead, BMAS was used to explore the dimensions of the problem by looking at a number of alternatives. The alternatives varied by their assumptions (which lands are considered currently protected), target levels of representation, biodiversity elements (communities versus vertebrate species), and suitability factors. This study will be included in the SNEP report to Congress, and two journal articles are in preparation.

Nonstate Government Activities

The University of California at Santa Barbara is an active user of satellite data, including conducting the GAP work



for the state (see above). Nonstate participants in the acquisition of statewide SPOT coverage in 1995 include the ***U.S. Environmental Protection Agency,*** the USDA Forest Service, and the ***Metropolitan Water District of Southern California.*** The ***Los Angeles Department of Water and Power*** used SPOT data to monitor changes at Mono Lake.

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Turner, Lisa, "Mapping California's Disaster Potential," *Government Technology* (August 1992): 26, 49.

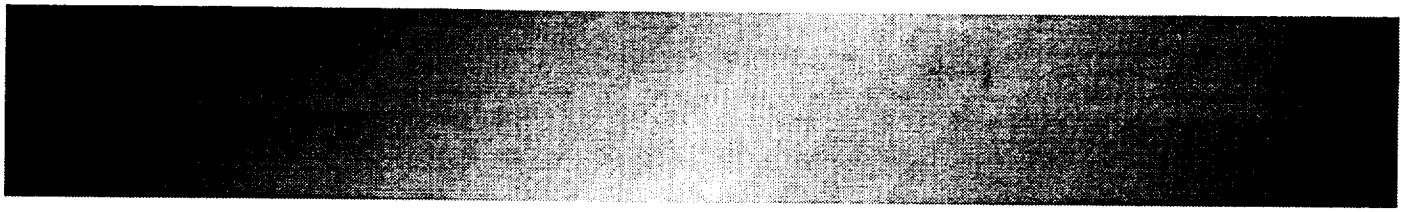
Colorado

State GI/GIS and Satellite Data Contacts

* Michael Whatley, GIS Coordinator
Larry Schuford, Director
Management Information Systems
Department of Natural Resources
1313 Sherman Street
Denver, CO 80203
(303) 866-2337
(303) 866-3415 (fax)
mike.whatley@state.co.us

* Marv Koleis
Division of Local Government
Department of Local Affairs
15075 South Golden Road
Golden, CO 80401-3979
(303) 273-1802
(303) 273-1795 (fax)

Donald L. Schrupp
Division of Wildlife
Habitat Resources Section
Department of Natural Resources



6060 N. Broadway
Denver, CO 80216
(303) 291-7277
(303) 291-7456 (fax)
hqwris@lamar.colostate.edu

Gap Analysis Program Contact

Donald L. Schrupp
Division of Wildlife
Habitat Resources Section
Department of Natural Resources
6060 N. Broadway
Denver, CO 80216
(303) 291-7277
(303) 291-7456 (fax)
hqwris@lamar.colostate.edu

State Government Context

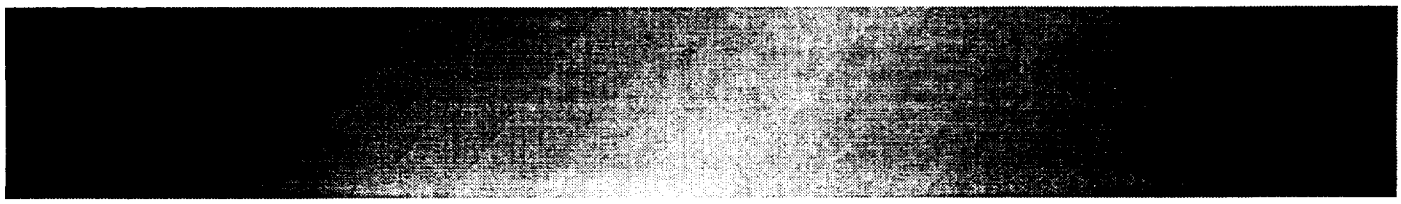
Colorado's state government does not have an official statewide GI/GIS coordination focal point or service center; however, the GIS coordinator of the ***Department of Natural Resources (DNR)*** has served as the de facto state GI/GIS coordinator since 1996. In February 1996, the governor signed Executive Order B00396, which reauthorized the ***Colorado Geographic Information Coordinating Committee (GICC).*** It had been originally created by an executive order in 1989. The 1996 order designated DNR as GICC's chair; the Department of Local Affairs was the chair according to the 1989 order. The GIS manager in the Division of Local Government served as the de facto lead person for statewide GI/GIS coordination until 1996. GICC has encouraged statewide GI/GIS coordination, including the production of a resource guide and sponsorship of annual conferences. Another state GI/GIS coordination group is the ***Colorado Counties GIS/LIS Committee,*** which is composed of county officials.

Satellite Data Use

Colorado's state government has had limited use of satellite data to date. DNR has most of Colorado's natural resources programs, while the Department of Health has its environmental protection programs. DNR is implementing an agencywide approach to GIS and has made the most use of satellite data of any agency in state government. A full-time GI/GIS coordinator was designated in 1995.

DNR's ***Division of Wildlife*** was the first state government user of GIS, as well as one of the earliest state wildlife agencies in the country to use this technology. The division began to use an early form of GIS in 1972 in preparation for the statewide wildlife plan, using 1:250,000 scale land-use/land-cover data from the ***U.S. Geological Survey*** as a base. The division identified distributions for more than 60 species of big game, small game, and furbearing species at this scale. Following this effort, GIS applications and data were integrated with other wildlife systems to create the Wildlife Resource Information System (WRIS). The division, the ***Colorado Cooperative Wildlife Research Unit at Colorado State University (CSU),*** the ***U.S. Fish and Wildlife Service*** in the 1970s, and the ***National Park Service*** in the 1980s were the primary developers of the software, which was bundled into the public domain software package known as the System Application Group Information System (SAGIS). Since then, the division acquired ERDAS and GRASS software.

The division's system is used for **wildlife habitat planning** purposes at state, Federal, and local levels. More recently, the division is working on the GAP project for the state, including the correlation of information from the division's data bases with GAP work (see below). The division has used satellite data to help develop a statewide **vegetative** layer and a habitat classification data set. Data are used for various purposes. Composite maps showing significant wildlife habitat are provided for **local government land-use planning.**



Both hard-copy and digital maps have been provided to some counties. Data transfers have been made with a variety of federal and state agencies.

DNR's ***Division of Water Resources*** has a satellite-linked water resources monitoring system, which provides real-time data on a continuous basis from key gauging stations across Colorado. It is used to monitor and evaluate current hydrologic conditions. It is a primary tool for the state and division engineers, as well as water commissioners in water rights administration, hydrologic records management, flood warning, and water resources management. Irrigation companies are also using the system as a management tool. The computerized system can be accessed by terminal or telephone from any location. The system began in 1984 with first-year funding of $1.8 million provided by the Colorado Water Resources and Power Development Authority and approved by the legislature. Colorado was the first state in the Nation operating a monitoring system of this type, and it has received numerous awards, including one of the top ten projects of the National Society of Professional Engineers in 1985 and one from the Council of State Governments in 1986.

Gap Analysis Program Activities

DNR's Division of Wildlife is conducting the GAP work for Colorado. The final draft of the land-cover layer for Colorado was completed and under review during 1996, and the project is expected to be completed in 1997. Current efforts are edge-matching data with Utah, Wyoming, and New Mexico, as well as the development of the data dictionary as part of a manual explaining the processes used in the project. The land-cover layer will be further reviewed by field biologists and vertebrate modelers in the subsequent months for revision during the final six months of the contract period. Accuracy assessment began in 1996 in coordination with Wyoming GAP work, and this work will use aerial video.

Meanwhile, Colorado Gap Analysis vertebrate modeling efforts began in earnest with the assembly of the modeling team. A team of six biologists and ecologists has joined Division of Wildlife staff. Efforts are under way to build links between data sets and coverages available through the Division of Wildlife's Wildlife Resource Information System (WRIS) and the land ownership and vegetation data coverages developed specifically for Colorado's GAP.

The main data fields being linked from the Division of Wildlife's species data base for GAP modeling efforts relate to county-based distributional records, wildlife habitat relationship information, and physical habitat descriptors related to species' environmental requirements and life histories. Ancillary information from other WRIS data bases will provide more site-specific information from the Scientific Collections Permit Database (SCICOLL), the Herptiles Observations Database, the Colorado Raptor Database (CORAPTOR), the Aquatic Database Management System (ADAMAS), and the Colorado Latilong Distribution Studies (WILDATA).

Additional information from partnering groups will come from the Colorado Bird Atlas Project (CBAP) and the

Colorado Wildlife Heritage Database (with the Colorado Natural Heritage Program). The ***Natural Resources Ecology Laboratory*** at CSU will provide integration opportunities with the Division of Wildlife's Species Ranking Project and provide additional information for GAP project use in evaluating management considerations relative to the protection of Colorado's biodiversity. GAP participants in Wyoming and Utah provided observations from their similar endeavors, and those in New Mexico evaluated of the commonality of land-cover mapping efforts in New Mexico, Colorado, Arizona, Utah, and Wyoming.

Nonstate Government Activities

CSU's ***School of Natural Resources*** has extensive facilities,

a teaching laboratory, various courses, and a degree program in remote sensing. Several projects are under way using satellite data.

Connecticut

State GI/GIS and Satellite Data Contacts

* Jonathan Scull
GIS Coordinator
Natural Resource Center
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106
(860) 424-3597
(860) 424-4058 (fax)
jonathan.scull@po.state.ct.us

* Robert Dixon
Office of Information and Technology
Office of Policy and Management
80 Washington Street
Hartford, CT 06106
(860) 418-6257
(860) 418-6491 (fax)

Gap Analysis Program Contact

For Connecticut and Rhode Island, see under Massachusetts.

State Government Context

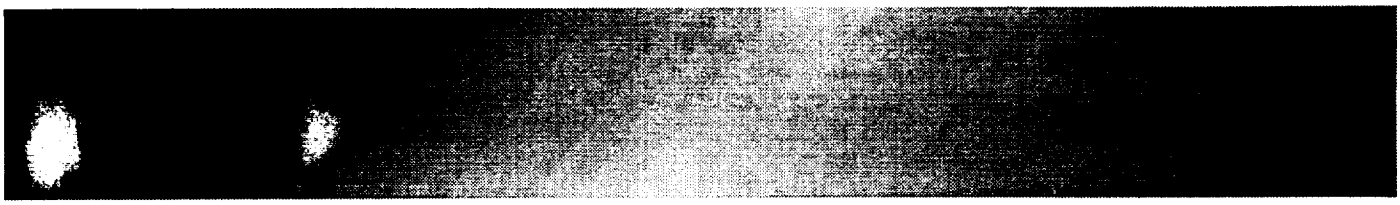
Connecticut began to establish a new statewide GI/GIS coordination effort in 1996, including the formation of a new interagency group, now known as the ***State Mapping Advisory Committee/Geographic Information Council.*** The ***Department of Environmental Protection (DEP)*** is leading this initiative. These efforts are being undertaken because a previous coordination effort, known as the Connecticut Map Project, was substantially revised when much of its funding was eliminated.

The legislature had provided authorization and funding for this project in 1994. Its purpose was to develop statewide digital orthophotos in coordination with localities to support property tax administration and other purposes. Staff in the ***Office of Policy and Management (OPM)*** were designated to implement the project and to essentially serve as the state GI/GIS coordinator. GI/GIS coordinating groups were also established to lead and coordinate the effort. However, funding and staffing for this project were canceled in 1995. While some efforts have continued for specific mapping efforts, related coordination efforts and groups were not continued after that cancellation.

No central state entity provides GI/GIS services for state or other entities, except that project support is provided by OPM for the remaining orthophotography through the Connecticut Map Project. This work is primarily being conducted for the Hartford metropolitan area with its Metropolitan District Commission.

Satellite Data Use

Most of Connecticut's GI/GIS and satellite data activities have occurred in and with DEP's ***Natural Resources Center (NRC).*** DEP is Connecticut's omnibus environmental and natural resources agency, with management, planning, regulatory, and research programs. DEP's ***Bureau of Environmental Services*** includes NRC, which was created in 1972 at the same time as DEP. NRC serves as DEP's research arm, and it is the primary location of GI/GIS work and natural resources information resources in the state. It includes Connecticut's Geological and Natural History Survey, as well as sections for various functions, including Earth materials, hydrology, and biological sciences. NRC's ***GIS and Cartography Section*** provides GIS services for NRC and



DEP, including the maintenance of a standardized digital cartographic data base used by DEP and by municipalities, regional planning agencies, other state agencies, Federal agencies, and others. The GIS and Cartography Section's major efforts have concentrated on developing digital data for the state, known as the Connecticut Standardized Digital Cartographic Data Base, with the 1:24,000 scale adopted as the state's base scale and DLGs as a standard.

DEP has sponsored the development of statewide data for **land use** and **land cover** using satellite data. This work has been conducted primarily in coordination with the ***University of Connecticut (UConn).*** The ***U.S. Environmental Protection Agency (EPA)*** helped fund this work through the Long Island Sound Study. This project began with the development of the statewide land-use/land-cover coverage using Landsat TM data. These data were made available at NRC in both raster (ERDAS) and vector (ARC/INFO) formats. These satellite data are being used for **coastal resources** and **water quality** analysis and management. After this coverage was completed, DEP contracted with UConn in 1995 to conduct initial research and development to use SPOT data for finer applications than the Landsat data. Efforts are expected to continue until the end of 1997, when it is anticipated that UConn will have completed this second land-use/land-cover coverage.

Additional efforts are under way to develop statewide digital orthophotos and other vector data, such as road centerlines, hydrography, and utilities. DEP is considering the amount of work needed to merge the Landsat and SPOT data with digital orthophotos and vector data to enable users to get the "best of all worlds."

Gap Analysis Program Activities

For Connecticut and Rhode Island, see under Massachusetts.

Nonstate Government Activities

UConn's College of Agriculture and Natural Resources has a ***Laboratory for Remote Sensing.*** It has worked with DEP and EPA to prepare statewide land-cover and land-use coverage using Landsat TM and SPOT data (see above). These satellite data has been used at UConn for various projects, such as biodiversity analysis (contact Dan Sivco at (860) 486-2840 or 5239). In addition, faculty at UConn are working with faculty at the University of Rhode Island on a Coastal Change Analysis Project (C-CAP) with the ***National Oceanic and Atmospheric Administration*** to examine issues concerning coastal land-cover classification and change detection in the Northeast (see under Rhode Island).

Delaware

State GI/GIS and Satellite Data Contacts

* Rick Collin
Planning and Data Administration Manager
Office of Information Services
801 Silver Lake Boulevard
Dover, DE 19901
(302) 739-9621
(302) 739-6251 (fax)
rcollin@state.de.us

Debbie Sullivan, Assistant to the Secretary
Rick Truitt, GIS Coordinator
Department of Natural Resources and
Environmental Control
89 Kings Highway
Dover, DE 19901
(302) 739-6308

Michael McGrath
Aglands Preservation Manager

Department of Agriculture
2320 South DuPont Highway
Dover, DE 19901
(302) 739-4811

Sandy Schenck
Geological Survey
Cartological Center
University of Delaware
Newark, DE 19711
(302) 451-2833

Gap Analysis Program Contact

For Delaware and New Jersey, see under Maryland.

State Government Context

Delaware has had several efforts to develop a statewide approach to GI/GIS in the 1990s. The ***Office of Information Services (OIS)*** has served as the state GI/GIS coordination focal point during this time, but coordination efforts have been cyclical. In 1993, a coordination group was authorized by the legislature, and a plan was prepared to facilitate statewide GI/GIS coordination. However, actions were not taken to establish the group or its membership because efforts to establish an executive order in this regard were unsuccessful.

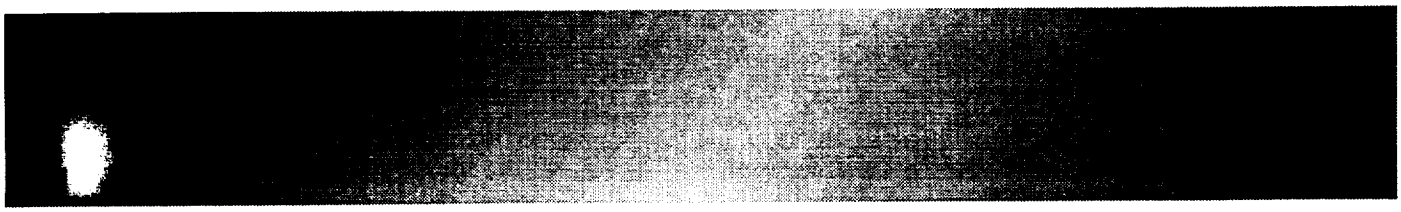
Interest in GI/GIS and its coordination resurfaced during the fall of 1995 and 1996. A GI/GIS pilot project was conducted for the Governor's Committee on State Planning Issues. In addition, the Joint Finance Committee asked OIS to conduct an inventory of GI/GIS activities in state agencies. OIS provided this information and also hired a consultant to develop some data and metadata standards and other mechanisms to facilitate GI/GIS use and coordination. In addition, OIS reinitiated its sponsorship of meetings of state agencies using GIS in the reconstituted ***Ad Hoc GIS Committee.***

Delaware does not have a central agency providing GI/GIS services to state agencies. However, some agencies have GI/GIS activities, and the ***Department of Natural Resources and Environmental Control (DNREC)*** has conducted GIS work for some agencies and projects outside DNREC.

Satellite Data Use

DNREC is responsible for most of the state's natural resources and environmental programs. The ***Management and Operations Division*** includes the agency's central ***GI/GIS Unit.*** It conducts GI/GIS clearinghouse activities and provides GIS services for some agencies and projects in and outside the agency. DNREC has the largest amount of GIS activities of any agency in state government, and it has been developing an agencywide approach to GIS. However, DNREC has had very limited use of satellite data.

The GIS Unit has been conducting GIS work for a variety of agencies and projects in and outside DNREC. Its GI/GIS activities began in 1986 with the Multimedia Advance Identification System for Delaware's Inland Bays (MAIS), which was one of the earliest uses of GIS in the state. MAIS was initiated to create an advance identification system for the Inland Bays Watershed, consisting of 13 quadrangle maps. It is a joint effort of DNREC, the ***Department of Agriculture,*** and the ***Department of Transportation,*** with some funding provided by the ***U.S. Environmental Protection Agency (EPA).*** The project determined and mapped areas least suitable for development, considering such factors as wetlands and Superfund sites. Various data have been developed and used for MAIS, including land use and land cover through the use of aerial photography. MAIS has been used to help coastal managers accurately assess impacts of proposed **land- and water-use** actions on natural resources. It also has been used to provide for **oil spill** emergency response if such a disaster were to occur in the area.



The Department of Agriculture also has an agencywide effort regarding GI/GIS. Unlike DNREC, this department has used satellite data. It has used statewide SPOT coverage with GIS to assist in the department's agricultural planning and resource management efforts. These satellite data have been used for acreage inventory and monitoring studies, such as agricultural assessments, including evaluating the loss of prime farmland and conducting farmland preservation efforts. The data have also helped the state's *Forest Service* inventory and the tracking of forest resources, including identifying areas for reforesting around the state's bays. A Terra-Mar system has been used to process the satellite data. DNREC's GIS Unit has provided some data in an automated format to assist in this effort.

Gap Analysis Program Activities

For Delaware and New Jersey, see under Maryland.

Nonstate Government Activities

Faculty at the *University of Delaware* have had a lead role in developing the interagency land-cover classification system used by the Coastal Change Analysis Project (C-CAP) of the *National Oceanic and Atmospheric Administration.* The system was developed during joint meetings with representatives from key Federal agencies. More recent faculty efforts include developing remote-sensing and field techniques for measuring indicators of wetland condition and functional health over large wetland areas. An overview of wetland health assessment techniques was prepared, with special emphasis on wetland condition and functional health indicators that can be monitored with remote sensors. A joint study is under way with investigators at Louisiana State University and EPA to work on impaired and healthy pilot test sites in Louisiana marshes. Field data are being correlated with Landsat TM data to assess biomass and stress indicators over large areas with the help of modified models and techniques developed during previous studies. Data derived from this work are crucial to C-CAP for the early detection of functional change in habitat.

Florida

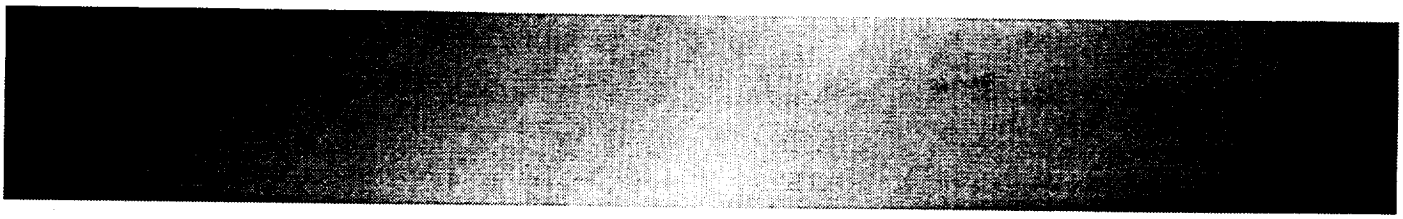
State GI/GIS and Satellite Data Contacts

* David Stage, Staff Director
Geographic Information Board
Department of Management Services
Building 4030, Suite 180
4050 Esplanade Way
Tallahassee, FL 32399-0950
(904) 488-7986
(904) 922-5929 (fax)
staged@dms.state.fl.us

Ruth Roaza, GIS Coordinator
Bureau of Information Systems
Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, FL 32399-2400
(904) 488-0892
(904) 922-6041 (fax)
roaza_r@dep.state.fl.us

Ken Haddad, Chief
Chris Friel, GIS Manager
Marine Research Institute
Department of Environmental Protection
100 Eighth Avenue, Southeast
St. Petersburg, FL 33701-5095
(813) 896-8626
(904) 823-0166 (fax)

Randy Kautz, Biological Administrator
Game and Fresh Water Fish Commission
620 South Meridian Street, Room 235



Tallahassee, FL 32399-1600
(904) 488-6661
(904) 488-6988 (fax)

Sam Patterson, Systems Project Administrator
Division of Administration
Department of Agriculture and Consumer Services
Mayo Building, Room B-10
Tallahassee, FL 32399-0800
(904) 488-5796
(904) 487-4776 (fax)

Gap Analysis Program Contact

Leonard Pearlstine
Cooperative Fish and Wildlife Research Unit
University of Florida
117 Newins-Ziegler Hall
Gainesville, FL 32611-0450
(352) 846-0630
(352) 846-0841 (fax)
lgp@gnv.ifas.ufl.edu

State Government Context

Florida has had an official statewide GI/GIS coordination effort under way since 1985. This effort has been in accordance with overall data management efforts to meet growth management needs as authorized by the legislature that year. It created the Growth Management Data Network Coordinating Council at that time to lead statewide GI/GIS coordination efforts.

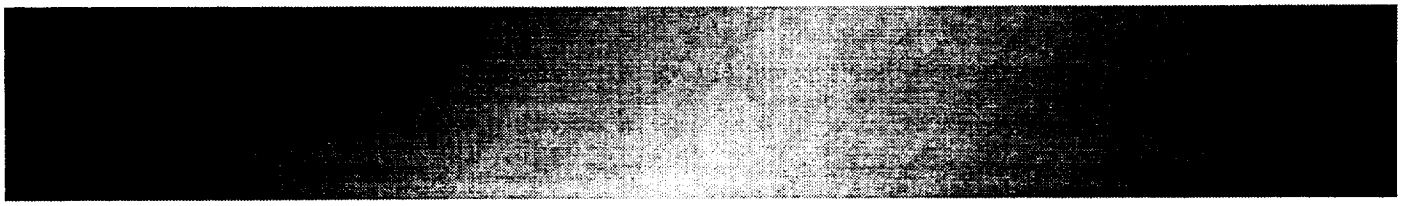
The legislature renamed that council the ***Geographic Information Board*** during its 1996 session and subsumed the former Florida Base Mapping Advisory Committee to serve as the new ***Technical Advisory Council*** to the board. Staffing for the council was originally provided by the Governor's Office, but this role was later transferred to the ***Information Resource Commission (IRC).*** The 1996 legislation designated that the staffing for the board would be conducted by IRC. However, IRC and the ***Department of Management Services (DMC)*** subsequently signed a memorandum of understanding providing that DMS would be responsible for staffing the board. This change was also established through the budget.

Florida does not have a central state agency that provides GI/GIS services. However, several agencies have GIS activities, and the board's staff conduct extensive data clearinghouse services. Several committees have focused on data acquisition for the state. Several state agencies also belong to the ***Landsat Steering Committee*** and have jointly acquired statewide Landsat TM coverage to enable multiple state and local agencies to access these satellite data at a reduced cost.

Satellite Data Use

Florida's state government has used GI/GIS and satellite data for over a decade. For example, Florida's project titled "Determining Land Cover by Using Data from Satellites" was selected as one of the eight most innovative state programs in the Nation in 1987 by the Council of State Governments. It now has some of the most extensive uses of these technologies compared to any state, both for statewide and substate needs.

State and regional agencies have worked together regarding satellite data acquisition on multiple occasions. Belonging to the Landsat Steering Committee, eleven state agencies joined together to purchase statewide Landsat TM coverage in 1992, 1994, and 1995 through EOSAT's state purchase program. Agencies participating in the program include the ***Department of Environmental Protection (DEP),*** the ***Game and Fresh Water Fish Commission,*** the ***Department of Agriculture and Consumer Services*** and its ***Division of Forestry,*** several regional water management districts, and others. Florida is also participating in the National Aerial



Photography Program (NAPP) to develop large-scale data resources and has one of the most densified GPS networks of any state.

Various programs in these and other agencies have used satellite data. An updated land-cover layer is under development to monitor growth and change. Examples of satellite data uses include monitoring agriculture, forest regions, and coastal resources, optimizing land acquisition and other efforts to protect wildlife habitat, planning and protecting water resources such as rivers, regulating activities impacting the environment, and creating emergency management plans. Some examples of satellite data uses are described below for applicable agencies.

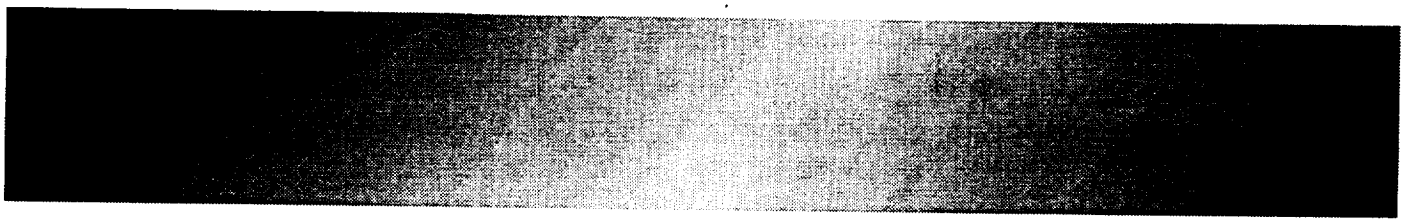
Most of Florida's natural resources and environmental programs are located in DEP. It was formed in 1994 from a merger of the former Department of Natural Resources and Department of Environmental Regulation, both of which were extensive users of GI/GIS. DEP now has a departmentwide approach, with a GIS coordination staff located in its ***Department Support Division.*** DEP has several GI/GIS and satellite data activities for multiple purposes, and it is in the process of developing several data layers for use with GIS, such as wetlands, soils, and hypsography.

One of Florida's first uses of satellite data was by DEP's ***Division of Marine Resources' Marine Resources Institute (MRI)*** in St. Petersburg. Since then, MRI has become one of the largest users of GIS in DEP and state government. It developed the Marine Resources GIS (MRGIS) in 1981 as a raster-based system using Landsat TM data and aerial photography to map estuarine and marine fisheries habitats. MRGIS was developed to monitor, assess, and protect coastal resources as part of the Coastal and Marine Resource Assessment (CAMRA) program. Efforts have been under way with the ***National Oceanic and Atmospheric Administration***'s Coastal Zone Management Program, the ***U.S. Fish and Wildlife Service,*** the ***U.S. Environmental Protection Agency (EPA),*** Florida's ***Department of Transportation,*** and others. MRI has developed a base inventory on Florida's marine and estuarine fisheries habitats and developed trend analyses for fisheries habitats for more than 50 years.

Much of MRI's satellite data work has been conducted in the Florida Keys with the ***Florida Keys National Marine Sanctuary,*** which was authorized by Congress in 1990. The sanctuary is encouraging multidisciplinary teams from various Federal, state, and local agencies to collaborate in their GI/GIS and other activities. These technologies have been used to select sites for explosives testing and protect sensitive shorelines, with particular attention to avoid oil spill damage. Underwater photogrammetry and monitoring of boat and diver use patterns have also been conducted.

MRI's other satellite data work has focused on Florida Bay, an estuary between the Florida Keys and the Everglades. It became increasingly evident that habitat conditions have declined in the bay beginning in the late 1980s, resulting in a coordinated effort among several state, Federal, and regional agencies. As part of this effort, MRI initiated a suite of investigations in 1993 to determine the distribution and composition of Florida Bay's discolored water. GIS, satellite data, GPS, and related technologies and data are being used in this effort. Activities initiated in 1995 include an investigation of the historical status and trends of estuarine wetlands fringing the northern bay and the feasibility of using remote-sensing data and techniques as a tool for routine monitoring of water quality, as well as continuing GIS integration and analyses of physical and chemical observations.

Submersed habitats in the Florida Keys, Florida Bay, Biscayne Bay, and Tampa Bay are being mapped in a cooperative Coastal Change Analysis Project (C-CAP) with the ***National Oceanic and Atmospheric Administration (NOAA).*** Photographs were collected by the NOAA Photogrammetry Branch. The effort in the keys is being



coordinated with the Florida Keys National Marine Sanctuary program. The keys were photographed at 1:48,000 because of cost considerations and will be used to demonstrate the resolution of signatures of submersed habitats at a scale smaller than acceptable with the current C-CAP protocol.

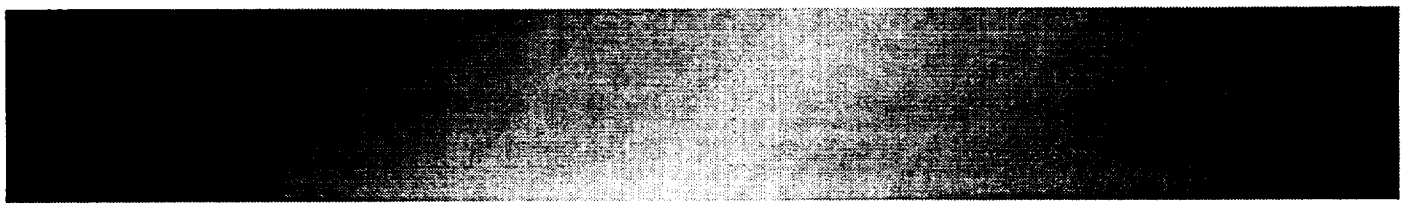
MRI also had a leading role in responding to **chemical spills.** One of MRI's mandates is to provide the DEP ***Office of Coastal Protection*** with the capability and technical support to facilitate oil spill contingency planning, response, and damage assessment responsibilities. The Exxon *Valdez* spill in 1989 increased the state's attention to the potential for oil spill disasters. The governor appointed a task force, which concluded that better maps and the use of GIS were needed to facilitate information updates and real-time analysis. In 1992, CAMRA received legislative appropriation and began developing the Florida Marine Spill Analysis System (FMSAS), a specific application built on the MRGIS. It was initiated to monitor environmentally sensitive areas using GIS and image-processing software.

FMSAS was tested on August 10, 1993, when an outbound freighter collided with two inbound tugs in Tampa Bay. A barge burst into flames and burned for more than 14 hours before the blaze was controlled. Various chemicals leaked to some of Florida's most sensitive habitats and popular beaches. CAMRA had a leading role in responding to the emergency. GIS, satellite data, and GPS were used in various ways. CAMRA's initial role was to provide responding agencies with maps depicting existing natural and cultural resources relative to the oil slick outlines and to predict the path of the oil movement. Information on these maps included bathymetry, habitats, and areas with threatened or endangered vegetation and wildlife. GPS receivers in helicopters were used several times per day to record the locations of vessels and the changing perimeter of the spill. The best air-to-plot time was 3.5 hours using GIS. As the spill neared land and washed ashore, the type and scale of needed maps changed for different participants and purposes.

Maps with spill boundaries, resources at risk, shoreline rankings, and more annotation were required to coordinate volunteers and contractors. These maps included road networks, navigational aids, and the locations of temporary rescue centers, such as schools and municipal buildings. Other maps were prepared to determine environmental sampling strategies for response and damage assessment efforts. Many data resources were used from several sources. In addition to MRI's data, data were obtained from the ***Marine Spill Response Corporation,*** the ***U.S. Geological Survey,*** and others. Landsat data and TIGER data from the ***U.S. Census Bureau*** were also used. These resources were also used to assess environmental and other damage and risk, to monitor change, and to simulate various scenarios, with much work conducted in real time.

The Florida Keys were the original test region for FMSAS, but the project area was expanded to the entire state after this disaster. Under contract to MRI, *ESRI* provided a plan for implementing the system for the entire state. Efforts have been under way to involve other organizations in developing data sets that were prioritized in the plan as being needed for similar disasters.

Others within DEP have used and supported satellite data to meet their program needs. One of the largest efforts is by the ***Division of State Lands*** for **state land management** of more than 20 million acres located in approximately 11,000 parcels. Increased activity and land acquisition were authorized in 1990 when the legislature adopted the Florida Preservation 2000 Act. This act provides that "acquisition of public lands should be based on a comprehensive assessment of Florida's natural resources and planned so as to protect the integrity of ecological systems and to provide multiple benefits, including preservation of fish and wildlife habitat, recreation space, and water recharge areas." It also authorizes an "ongoing computerized information systems program to modernize its state lands records."



DEP has also used satellite data for other applications. For example, it has been used to help monitor **water resources,** such as plant encroachment into lakes. DEP has also been actively involved in encouraging and funding the state's five water management districts to use GI/GIS and related technologies (see below).

The Game and Fresh Water Fish Commission's ***Office of Environmental Services*** began developing a comprehensive Statewide Wildlife Habitat System in the mid-1980s using Landsat TM data as a base. The system was designed and is primarily used to help protect **wildlife resources** by mapping and modeling habitat. This information is then used to help determine which properties should be acquired to protect habitat for endangered species. Landsat TM data from the late 1980s were used to develop a vegetation map of the entire state between 1987 and 1990. Staff of the commission and the Florida ***Department of Transportation (DOT)*** used the satellite data to map and categorize the state into 17 vegetation types, in coordination with the then Department of Natural Resources (now DEP). A data base of known locations and potential habitats of 133 species of wildlife has been assembled to help develop a map of potential habitats used by wide-ranging species. This information is being used to identify lands that should be purchased through the Florida Preservation 2000 program. It has also been helpful in aiding local planning and growth management efforts (see DEP). Expenditures to date have been more than $1 million for the commission's data development efforts, with funding provided by the Nongame Wildlife Trust Fund. The commission has also been working with the Gap Analysis Program (GAP) for the state and provided funding to assist this effort (see below).

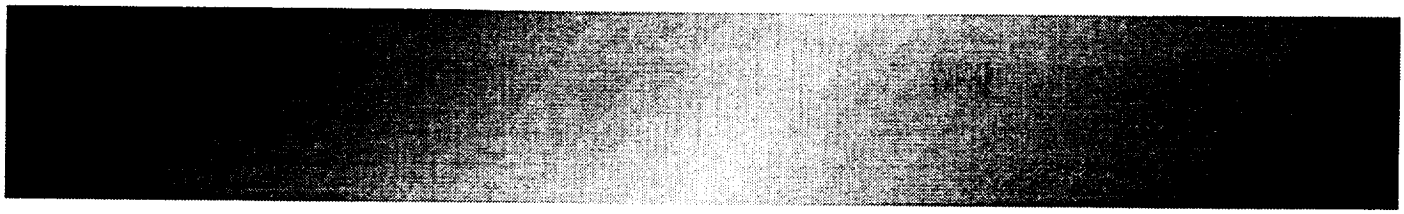
The Department of Agriculture and Consumer Services' ***Agricultural Management Information Center*** has used satellite data with GIS and other software to interpret and map habitats for endangered species, monitor **agricultural** practices, and protect groundwater resources from pesticide contamination.

DOT conducted satellite data work with the Game and Fresh Water Fish Commission to develop a statewide vegetation cover map as described above. DOT has also used satellite data for internal purposes. For example, SPOT data were used to help produce a current wetlands and land-cover map for a **highway siting** project northwest of Jacksonville.

Gap Analysis Program Activities

The Florida GAP is being conducted at the ***Cooperative Fish and Wildlife Research Unit.*** Plans are to have this work completed in 1997 or 1998. Land-cover classification has been completed for most of the southern portion of the state, and this area is being reviewed for a final iteration of the classification. ***The Nature Conservancy***'s Southeastern Region classification scheme was used to delineate classes to the alliance level or better. Analog videography played a major role in providing the volume of ground data necessary for a detailed classification at the alliance level. About half of the state (all lands south of Orlando) was completed in 1996. This effort is being greatly assisted by additional funding from the Florida Game and Fresh Water Fish Commission. Ground-truthing and mapping assistance has also come from a variety of agencies and individuals, most notably the ***U.S. Army Corps of Engineers.*** GAP is being conducted in Florida in coordination with the ***National Oceanic and Atmospheric Administration***'s Coastal Change Analysis Project (C-CAP) to comprehensively map Florida's land-use and land-cover change. Auxiliary mapped information (existing land use, U.S. Fish and Wildlife Service National Wetlands Inventory, and USDA Natural Resources Conservation Service county-level soils) is being prepared ahead of classification. Coverages for more than half the state have been reviewed, cleaned, and/or modified.

All native and exotic terrestrial vertebrate species in Florida have been mapped and modeled, as well as butterfly, skipper, and ant species. Breeding and wintering birds in the state are being treated separately. Distribution maps for all species are now being externally reviewed for accuracy. Distributions



were determined from museum and other records and published literature, with interpolation and extrapolation used as necessary. The data bases of species' habitat use are complete for all species except birds, which are nearly complete. Habitat information was compiled from more than 1,000 sources.

The next step will be to generate a matrix of species with habitat, utilizing the TNC classification scheme. Information necessary for species-specific modeling, where available, has been collected for most species. This information includes home range size and dispersal distances.

Nonstate Government Activities

Florida has five water management districts authorized by the legislature to protect and manage Florida's rivers and lakes in coordination with DEP. As part of this effort, DEP has encouraged and helped them use GI/GIS, satellite data, and related technologies. The water management districts have also participated in the acquisition of SPOT data during the 1990s (see above). For example, the ***South Florida Water Management District*** purchased SPOT data in 1990. They have been used with GPS to develop a baseline **vegetation** map for **water resources management** within the district, including 16 counties.

The South Florida Water Management District and others have also used satellite data and GI/GIS to help respond to **hurricanes and tropical storms,** particularly Hurricane Andrew in August 1992. GIS, satellite data, and GPS were used in various ways, including assessing damage, monitoring response, managing resources, and coordinating and assisting in the distribution of goods and services to victims. For example, GIS was used to locate the best sites for supply delivery, kitchens, tent cities, disaster application centers, hazard mitigation locations, and other facilities. At one point, more than 30 maps were produced daily to show the location of services, progress in terms of service restoration, and cleanup efforts from the previous day.

Other water districts have used satellite data. For example, the ***Suwannee River Water Management District*** has used both SPOT and Landsat TM data to create a **land-cover** data base. Local governments have also used satellite data. For example, ***Martin County*** used SPOT data to update and correct **road and hydrology** data in DLG and TIGER files as part of its interdepartmental GIS. ***St. Johns County*** used SPOT data to develop a land-use/land-cover map as part of its comprehensive master plan. The ***City of Jacksonville*** created **vegetation and land-use** maps using Landsat TM images acquired between 1990 and 1993. These maps are being used to create several data layers, including soils and wildlife habitat and utilization, and to determine changes in vegetation and land use. This effort is supporting the city's comprehensive planning efforts.

The Institute of Science and Public Affairs at ***Florida State University*** has the Florida Resource and Environmental Analysis Center (FREAC). The legislature's Florida Preservation 2000 Act provided that FREAC develop a plan for a public lands GIS, and it also serves as a service center. Other universities also have GI/GIS activities, including the ***University of Florida***'s Departments of Geography and Urban Affairs and the ***University of South Florida.***

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Rutchey, Ken, and Vilcheck, Les, "Development of an Everglades Vegetation Map Using a SPOT Image and the Global Positioning System," *Photogrammetric Engineering and Remote Sensing* (June 1994): 767–775.

Georgia

State GI/GIS and Satellite Data Contacts

* Dr. William McLemore, State Geologist
Geological Survey
Department of Natural Resources
Room 400
19 Martin Luther King Jr., Drive, SW
Atlanta, GA 30334
(404) 656-3214
(404) 657-8379 (fax)

Mike Hale, Chief Information Officer
Information Technology Policy Council
47 Trinity Avenue, Suite 315
P.O. Box 38391
Atlanta, GA 30334
(404) 657-1350
(404) 657-1355 (fax)
mhale@itpc.state.ga.us

Dr. Steven P. French, Director
Center for GIS
City Planning Program
College of Architecture
Georgia Institute of Technology
Atlanta, GA 30332-0155
(404) 894-2350
(404) 894-1628 (fax)
steve.french@arch.gatech.edu

* Dr. Ray Argo, Director
Information Technology Outreach Center
University of Georgia
Chicope Complex
1180 East Broad Street
Athens, GA 30602-5418
(706) 542-6297
(404) 542-6535 (fax)
argo@igs.cviog.ugs.edu

Gap Analysis Program Contact

None reported.

State Government Context

Georgia's state government is in a period of transition regarding GI/GIS coordination. A new effort began in 1996 following the establishment of a ***Chief Information Officer's Office*** and an Information Technology Policy Council. The council has a ***GIS Subcommittee.*** This subcommittee receives recommendations from a new ***GIS Advisory Committee,*** also established in 1996, which is chaired by the director of Information Technology Outreach Services at the ***University of Georgia.***

Georgia does not have an office within state government that provides GI/GIS coordination and services to multiple agencies, although GIS activities exist within various agen-

cies. However, both the University of Georgia and the ***Georgia Institute of Technology (Georgia Tech)*** have provided GI/GIS services to state agencies and others. An outcome of the committees' work was the establishment of the state GIS Clearinghouse in 1996. It is responsible for the collection and distribution of geographic information generated by state agencies, and approximately a total of $400,000 has been allocated on an annual basis for this work. The clearinghouse is being administered by the University System of Georgia, with central staff at Georgia Tech's Center for GIS and a node at the University of Georgia in Athens.

Earlier GI/GIS coordination efforts were conducted to support the implementation of the Georgia Planning Act of 1989. The ***Department of Community Affairs*** and the ***Department of Natural Resources (DNR)*** were placed in leading roles to develop GI/GIS to support the planning objectives of the act. Interagency GI/GIS coordination was strengthened as a result of this direction and activities. Georgia also had a State Mapping and Land Records Modernization Advisory Board that was created by the legislature, but it ceased in December 1994 according to the sunset requirements in the original legislation.

Satellite Data Use

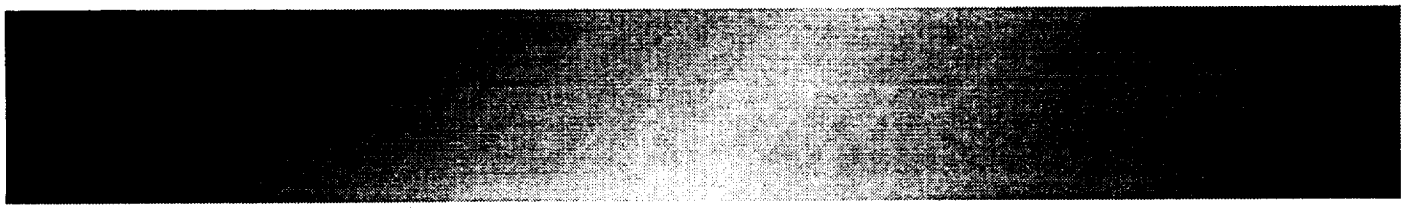
Satellite data have been used by Georgia's state government to help meet its missions. DNR is responsible for most natural resources and environmental functions in state government. It has a departmentwide approach to GI/GIS, including satellite data, with data managed and made accessible by the ***Geological Survey.***

DNR's ***Environmental Protection Division*** initiated the use of GIS and satellite data in the department in the mid-1980s. DNR served as a leading comprehensive data management pilot project with the ***U.S. Environmental Protection Agency (EPA)*** during the late 1980s. The purpose of the project was to develop and implement data management systems to better support the environmental management objectives of both the state and EPA. It was also designed to provide model concepts, approaches, and systems to enhance state-EPA partnerships, reduce redundancy, and simplify reporting obligations. The ***U.S. Geological Survey***'s Water Resources Division subsequently joined the project because the division was also developing water data.

DNR developed a statewide land-cover classification using Landsat TM data. It contracted with ERDAS Corporation to develop a digital version of 1989–1990 data to form a **wetlands/land-cover** data layer. The raster files were converted into ARC/INFO format to create 7.5-minute quadrangle maps. These satellite data have been used for various purposes, with a major reason being to meet the requirements of the Georgia Planning Act of 1989. These maps were provided to regional associations and localities to comply with the act, particularly in **land-use plans** and to identify and protect wetlands. The effort also complemented past work with the ***U.S. Fish and Wildlife Service***'s National Wetlands Inventory. In addition, the satellite data were used to assist in **water resources management,** such as to determine optimal site locations for water reservoirs. It also aided Georgia's natural heritage program.

More recently, DNR's management of GI/GIS and satellite data has belonged to the Geological Survey, which is responsible for being the repository and distribution source for satellite data purchased from EOSAT. The survey is also responsible for managing and conducting quality control and assurance work for DNR's other data used with GIS. The primary current use of satellite data is for **wildlife resources management.**

A voluntary project was undertaken by ***Pacific Meridian Corporation*** to demonstrate to the ***Department of Revenue*** and the ***Georgia Association of Assessing Officials*** how satellite data could help increase their efficiency and accuracy in generating **tax revenue from timber** activities. Georgia only taxes forested land as trees are harvested. An



increasing number of trees are being cut down without taxing authorities or landowners knowing about these activities. Accordingly, the company showed how satellite data would help identify clear-cutting practices to increase tax revenues (contact Ed Downing at (770) 499-1093).

Gap Analysis Program Activities

None reported.

Nonstate Government Activities

Both the University of Georgia and Georgia Tech are actively involved in GI/GIS and satellite data, including providing services to state government. For example, Georgia Tech and the ***Georgia Wildlife Federation*** worked with researchers in South Carolina to use remote sensing to detect coastal change along the coasts of Georgia and South Carolina (contact Nicholas Faust at Georgia Tech). Both universities are becoming more actively involved in the state's GI/GIS activities than before, because they have roles in the new state clearinghouse of data used with GIS (see above).

Reference

James, Fred, "Georgia Takes Resource Inventory from Space," *Government Technology* (November 199): 26–27.

Hawaii

State GI/GIS and Satellite Data Contacts

* Craig Tasaka, Planning Program Manager
Office of Planning
Department of Business, Economic Development and Tourism
State Capitol, Room 409
P.O. Box 3540
Honolulu, HI 96811-3540
(808) 587-2894
(808) 587-2899 (fax)

Joy Toyama, GIS Manager
Information and Communication Services Division
Department of Budget and Finance
1151 Punchbowl Street
Honolulu, HI 96813
(808) 586-1940
(808) 586-1922 (fax)

Ronald Cannarella
Division of Forestry and Wildlife
Department of Land and Natural Resources
1151 Punchbowl Street, Room 325
Honolulu, HI 96813
(808) 587-0166
(808) 587-0160 (fax)
roncan@hgea.org

Gap Analysis Program Contact

Ronald Cannarella
Division of Forestry and Wildlife
Department of Land and Natural Resources
1151 Punchbowl Street, Room 325
Honolulu, HI 96813
(808) 587-0166
(808) 587-0160 (fax)
roncan@hgea.org

State Government Context

The ***Office of Planning*** in the ***Department of Business, Economic Development and Tourism (DBEDT)*** serves as the lead coordination agency for GI/GIS in the state. This role includes satellite data and related technology and data.

In addition, the ***Information and Communication Services Division*** has provided GI/GIS services for other agencies and has served as a data repository agency for several state agencies. GIS activities began in the late 1980s with a strong direction and effort to conduct this work with a coordinated and statewide approach. Initial efforts focused on coastal management. Hawaii has a ***GIS Task Force*** that was created by the legislature in 1987.

Legislation was adopted in 1996 that placed the Office of Planning in DBEDT and established the office's duties. It states that the office is the lead agency responsible for planning and coordinating a multi-agency, statewide GIS, as well as the development of planning applications, including spatial analyses to enhance decision making. Efforts are under way to accomplish this directive.

Satellite Data Use

Hawaii has used satellite data in various efforts. The ***Department of Land and Natural Resources (DLNR)*** and the ***Department of Health*** are the primary environmental and natural resources agencies in the state. DLNR has been the leading agency to use satellite data, although these efforts are in coordination with other agencies, such as the Office of Planning in its statewide GI/GIS coordination role. Its ***Division of Forestry and Wildlife*** is developing a statewide **vegetation and land-use/land-cover** map using SPOT data acquired of the major islands of Hawaii. DLNR received a grant from the National Biological Service (now the ***U.S. Geological Survey's Biological Resource Division***) in 1995 to conduct this work. Twenty-five state, Federal, and private participants jointly purchased and are using these satellite data. UNESCO (1973) classifications are being used for the vegetation data. The project will result in both digital and hard-copy maps. This work is being conducted in coordination with the Gap Analysis Program (GAP) work that is also under way for the state by DLNR (see below). All data will be made accessible with the state GIS maintained by the Information and Communication Services Division.

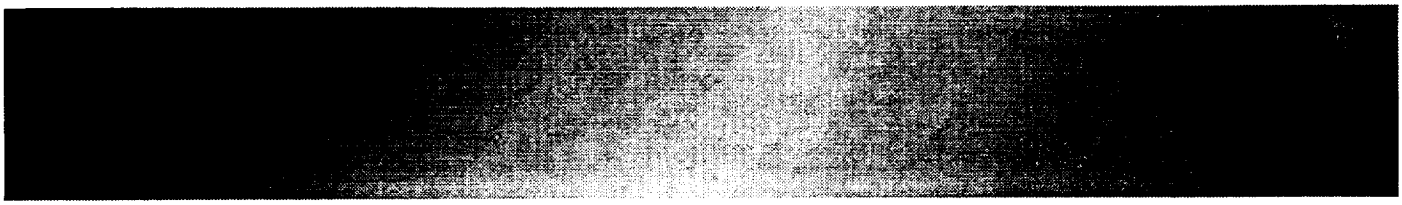
The state has also received funding from and worked with ***NASA*** to apply satellite data. NASA funded a project in 1993 titled "The Application of Remote Sensing Data to GIS Studies of Land Use, Land Cover, and Vegetation Mapping." This project is being conducted for the north side of the Big Island. The Office of Planning and DLNR worked with the ***University of Hawaii*** on the project (contact Daniel Ishii at the University of Hawaii's Office of Technology Transfer).

NASA also helped Hawaii respond to Hurricane Iniki in September 1992. NASA's Ames Research Center provided high-altitude photographic assistance using ER-2 aircraft. The ER-2's TM low-resolution simulator provides data that will allow Landsat data to be calibrated to actual ground conditions, which will improve future analyses of Landsat data.

Another project that successfully employed satellite data helped monitor and manage East Maui's **tropical rain forest health.** The East Maui Watershed Partnership was formed in 1992 by seven landowners to maintain the health of the East Maui Watershed. A pilot monitoring program was initiated in 1995 and coordinated by ***The Nature Conservancy of Hawaii*** to design monitoring protocols for collecting, converting, and integrating data from the ground, air, and space and incorporate these data into a common data base for use with GIS. Most of the data were generated by the Office of Planning or the ***Hawaii Natural Heritage Program.*** Remote-sensing data from NASA's aircraft-based TM simulator, Landsat, and SPOT were also utilized. GPS coordinates were used to link relational data base transect data to the GIS spatial data base. The program has helped monitor and manage Maui's rain forests.

Gap Analysis Program Activities

The Division of Forestry and Wildlife of the Department of Land and Natural Resources is conducting the GAP work for



the state. It was also given a grant by the U.S. Geological Survey's Biological Resource Division to fund the use of satellite data for vegetation and land-use/land-cover classification and mapping. A major objective of this funding was to encourage the reestablishment of GAP in Hawaii (see above). GAP participants have been setting the groundwork for the project in anticipation of the delivery of Landsat TM data.

Nonstate Government Activities

The University of Hawaii has used remote sensing for some activities in addition to the above project funded by NASA. For example, a project is under way to monitor volcanic activity using remote sensing.

Reference

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Idaho

State GI/GIS and Satellite Data Contacts

* Hal N. Anderson, Chief
Technical Services Bureau
* Anthony Morse, Manager
Idaho Geographic Information Center
Division of Policy and Planning
Department of Water Resources
1301 N. Orchard Street
Statehouse Mail
Boise, ID 83720-9000
(208) 327-7888
(208) 327-7866 (fax)
handerso@idwr.state.id.us

Gap Analysis Program Contact

Dr. Michael Scott
Cooperative Fish and Wildlife Research Unit
University of Idaho
Moscow, ID 83844
(208) 885-6336
(208) 885-9080 (fax)
mscott@uidaho.edu

State Government Context

Idaho has a long history of GI/GIS use and coordination, including the analysis of satellite data. The ***Idaho Department of Water Resources (IDWR)*** is responsible for maintaining the natural resource GIS for the state, according to the Idaho Ground Water Protection Act of 1989. An executive order signed in 1992, and again in 1996, authorizes IDWR to be the lead state agency regarding GI/GIS, defining "geographic information activities" to include remote sensing, digital cartography, GPS, and GIS. Idaho is one of the few states with a directive that specifically mentions remote sensing.

The executive order also specifies that IDWR's ***Idaho Geographic Information Center (IGIC),*** formerly known as the Idaho Image Analysis Facility, should promote the use of digital image analysis and GIS, as well as provide assistance, technical support, and coordination in this regard, both within IDWR and for other state agencies. IDWR began to serve in this capacity in the late 1970s, and more recently it has had this role on a formal basis according to executive order.

The ***Idaho Geographic Information Advisory Committee (IGIAC)*** serves as the state GI/GIS coordination group. IGIAC was authorized in the same executive orders; it coordinates GI/GIS and related activities among state, Federal, local, and other agencies. A new provision of the 1996 executive order is that IGIAC is a subcommittee of

the *Idaho Technology Resource Management Council (InTeRMaC)* that was formed earlier in 1996 by the legislature. InTeRMaC also has a working group co-chaired by the chair of IGIAC that is making longer term recommendations about the future approach to geographic information development and coordination in Idaho.

Satellite Data Use

IDWR has been the leading user of GI/GIS and remote sensing in Idaho's state government. It is responsible for water resources management, while other state agencies have other environmental and natural resources responsibilities and GI/GIS activities. GIS, remote sensing, and image-processing projects have helped accomplish the agency's mission regarding **water resources** and **agricultural water rights and irrigation use** for over a decade. IGIC is the official state center of GI/GIS coordination and activities; it provides related technical support and assistance to other state agencies. IGIC has a complete library of Landsat MSS scenes of Idaho from 1986, as well as many other MSS and TM scenes.

Several of IDWR's internal projects have used remote sensing. Applications include monitoring water use, adjudicating water rights, and estimating evapotranspiration from irrigated agriculture. The Snake River Basin Adjudication Project used remote sensing, GIS, and image processing to help adjudicate water rights in the Snake River Basin of Idaho, representing almost 90 percent of the state's land area and the Nation's largest water rights adjudication (see Figure B3a). The most recent work on this project mapped points of irrigation return flow into the river. Information from a variety of sources, including satellite data, U-2 photography, 35-mm aerial slides, 1:100,000-scale clear mylar maps, cadastral survey plats on microfiche, and 1:24,000-scale orthophoto quads, were used in this project.

Water Rights Adjudication in Idaho

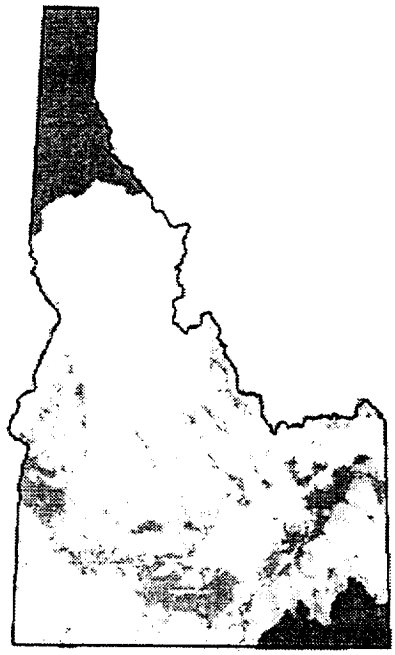


Figure B3a

These land-use data were developed for Snake River Basin from image processing of Landsat MSS data and are used in water rights adjudication. (courtesy of Anthony Morse, Idaho Geographic Information Center, Department of Water Resources, (208) 327-7888, *amorse@idwr.state.id.us*)

IGIC also has conducted several cooperative remote-sensing projects involving the image processing of Landsat data. These projects have been conducted with and under contract to other entities as part of IDWR's role as Idaho's lead agency for GI/GIS. It used Landsat data to develop a statewide digital mosaic to commemorate the state's centennial in 1989 (see Figure B3b). IGIC has used its satellite data resources for several vegetation and land-use/land-cover projects and for applications in such areas as **forestry** and **wildlife habitat** monitoring, in addition to

monitoring water resources and agricultural water rights and use.

IGIC has also used Landsat data to produce a vegetation cover and forest maturity map for the *USDA Forest Service*'s Boise National Forest. A vegetation map was also created for the *U.S. Department of Energy*'s National Engineering Laboratory using Landsat data. A general land-use/land-cover map was produced for the Payette River Basin using Landsat data. IGIC is developing detailed land-use data for the Boise Valley in cooperation with and under contract to the Federal *Bureau of Reclamation* to determine changes in irrigated land that have occurred in the valley. The project is using scanned 1:12,000-scale color infrared photography, which will be geometrically rectified. Interpretation is being accomplished interactively on the computer, with primary emphasis on changes that have occurred relative to the conversion of historically irrigated agricultural lands. The project is expected to be completed in 1997.

Land Use and Cover in Idaho



Figure B3b

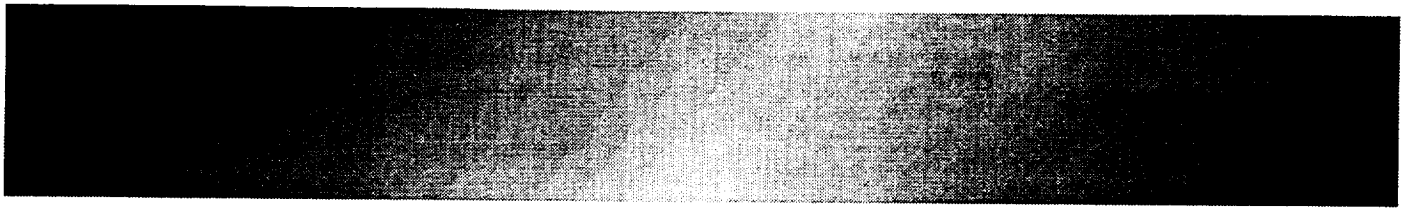
This statewide digital mosaic was developed for the Idaho Centennial. Individual scenes in this mosaic have been analyzed to develop land-use and land-cover information for several GIS projects. (courtesy of Anthony Morse, Idaho Geographic Information Center, Department of Water Resources, (208) 327-7888, *amorse@idwr.state.id.us*)

Gap Analysis Program Activities

The Gap Analysis Program (GAP) was conceived and developed in Idaho at the U.S. Fish and Wildlife Service's ***Idaho Cooperative Fish and Wildlife Research Unit,*** and Idaho was the first state in the country for which a Gap Analysis was conducted. Idaho's effort included the development of appropriate procedures for data collection and development, and many of the methods applied elsewhere were originally developed for this prototype. However, this project was conducted at the 1:500,000 scale, and subsequent states are being completed with an accuracy of 1:100,000. The research unit was the original and continues to be the lead organization for the national GAP.

The Idaho Gap Analysis group is continuing to analyze the original 200-hectare MMU data set while remapping the state using a minimum mapping unit (MMU) of 2 hectares. This land-cover remapping is a cooperative effort of the USDA Forest Service and other GAP offices in Montana and Utah. The GAP group at Idaho is revisiting the vertebrate models using ecological themes unavailable in 1989. Work is being conducted in conjunction with the ***Idaho Heritage Program.*** Plans are to compare maps of predicted vertebrate ranges at different levels of spatial and thematic detail.

Several researchers have published articles on the use of the Idaho GAP maps for assessing what additional protec-



tion of cover types and vertebrate species is obtained under various proposals for new national parks and wilderness areas (Merrill *et al.* 1995). The Idaho vegetation map has been edge-matched with the Oregon and Washington maps, including 95 cover types in three states, mostly at the undifferentiated level.

The distribution of cover types is being investigated within special management areas to assess representation across the entire geographical and ecological range of each cover type. Work is under way with the USDA Forest Service's ***Natural Areas Program*** to conduct a conservation assessment of Forest Service Research Natural Areas by comparing their distributions and sizes with GAP data. Another project is determining which biological and ecological processes can be accommodated on differently sized management areas and, if areas are too small, what ex situ or transboundary management activities are required to maintain the biological objectives of the area.

GAP land-cover maps and maps of human activity have also been used to predict habitat suitability in areas of potential conflict between bears and humans. These maps are being used to help design conservation strategies for grizzly bears in Idaho.

As part of the second-generation GAP effort in Idaho, collaboration is under way with the ***Idaho Department of Fish and Game,*** the Idaho Heritage Program, and ***The Nature Conservancy*** to revise the vertebrate distribution maps using hexagons as the unit of geographical occurrence. Plans are under way for a collaborative effort with adjacent states and The Nature Conservancy to produce a monograph of the ecological and cultural features of Bailey's ecoregions.

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Illinois

State GI/GIS and Satellite Data Contacts

* Sheryl G. Oliver, GIS Manager
Office of Realty and Environmental Planning
Department of Natural Resources
Lincoln Tower Plaza
524 South Second Street
Springfield, IL 62701
(217) 785-8586
(217) 785-8575 (fax)
soliver@dnrmail.state.il.us

Mark Joselyn, GIS Data Administrator
Department of Natural Resources
607 E. Peabody Drive
Champaign, IL 61820
(217) 333-8907
mjoselyn@dnrmail.state.il.us

Donald Luman
State Geological Survey
Department of Natural Resources
607 E. Peabody Drive
Champaign, IL 61820
(217) 333-6880

Gap Analysis Program Contact

Dr. Patrick W. Brown
Center for Wildlife Ecology
Illinois Natural History Survey
Department of Natural Resources
607 E. Peabody Drive
Champaign, IL 61820
(217) 244-4289
(217) 333-4949 (fax)
pbrown@denr1.igis.uiuc.edu

State Government Context

Illinois has an official statewide GI/GIS coordination approach, as authorized by legislation adopted in 1994. The ***Department of Natural Resources (DNR)*** is the leading natural resources agency in the state, and it is the oldest and most extensive user of GI/GIS in state government. DNR was formed in July 1995 from a merger of the former Departments of Energy and Natural Resources, Conservation, and Mines and Minerals. Its ***Realty and Environmental Planning Office*** provides GI/GIS coordination for DNR and for the state.

Statewide GI/GIS coordination is directed by the ***Illinois Geographic Information Council,*** which was formed by the legislature in 1994. According to the legislation, the council was formed within DNR. It is co-chaired by the director of DNR and another member elected by the membership. DNR provides support for the council through its GIS coordinator. The state also has a GIS users group known as the ***Illinois Geographic Information Systems Association,*** as well as a ***State Mapping Advisory Committee*** and a ***Geologic Mapping Advisory Committee.***

Satellite Data Use

Most of the satellite data and GI/GIS activity in Illinois state government is in DNR. It also the main natural resources agency in the state, including the management of several programs and significant research related to natural resources. DNR entities include the Natural Resource Management Office, the Mines and Minerals Office, and the Scientific Research Analysis Office, which includes the Natural History Survey, the Water Survey, the Geological Survey, the State Museum, and the Hazardous Waste Information Center. In addition, DNR has a Realty and Environmental Planning Office, which serves in a coordinating role for GI/GIS within DNR and as the informal state GI/GIS coordinator. Environmental

regulations are carried out by another state agency, the ***Illinois Environmental Protection Agency,*** which has some GIS capability. The Illinois Pollution Control Board serves as an adjudicating and appeals entity for the state.

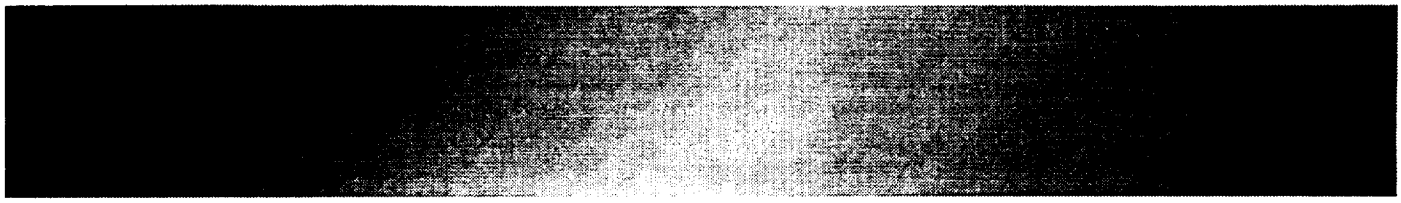
DNR manages the Illinois GIS (IGIS) that was initiated in 1982. IGIS is used by several divisions and offices of DNR, as well as other agencies. IGIS has evolved into an agencywide system and has grown with the incorporation of the former Departments of Energy and Natural Resources, Conservation, and Mines and Minerals into DNR in 1995. DNR's GIS activities are among the largest of any state agency in the country, in terms of technology, data, financial expenditures, and staff. The IGIS data base is maintained on all of DNR's facilities that use GIS. It includes, for example, more than 200 data layers at the 1:500,000 scale and other data at larger scales. DNR issued a CD-ROM containing natural resources, infrastructure, and socioeconomic data for the state in 1994, with a second edition released in 1996.

Satellite data have been used by various parts of DNR since the 1980s. Illinois was the first state in the union to acquire statewide Landsat data through EOSAT's Statewide Purchase Program. DNR's ***Geological Survey*** recently used two sets of Landsat data to prepare a multitemporal statewide **land-cover** classification and data layer to be used with GIS. It consists of 20 classifications delineating natural features and manufactured structures. A *Land Cover Atlas* and companion CD-ROM were completed in 1995.

Perhaps the greatest use of satellite data to date in Illinois was to respond to the Midwest **floods** of 1993. Illinois had relatively more damage and more use of GI/GIS and satellite data than any of the other affected states. A combination of various GIS software, satellite data, aerial photography, GPS, and other GI/GIS data and technology was used by various responders, including government agencies, utilities, insurance companies, and engineering and consulting firms.

Many state and Federal government agencies responded to this emergency, including DNR, the ***Illinois Emergency Management Agency,*** the ***Federal Emergency Management Agency (FEMA),*** the ***Department of Defense (DoD),*** and the ***U.S. Army Corps of Engineers (COE) Rock Island District Office.*** Much data were collected and analyzed at the COE's GIS and Remote Sensing Center at the Cold Regions Research Engineering Lab in Hanover, New Hampshire. COE compiled a bibliography of satellite data and aerial photography used during the floods. It is available on the Internet. DoD and FEMA also collected satellite data and processed them during the emergency. Satellite data of the impacted area were also used by such Federal agencies as the ***USDA Natural Resources Conservation Service (NRCS).***

Satellite data were used for several purposes during the Midwest floods, with GIS and image-processing software to evaluate conditions "before" and "after" the flood and to create situation maps of the entire region. They were also used to monitor the progression of flood levels and to assess damage to crops, roads, bridges, and other transportation facilities. The satellite data helped determine the water's impact on agricultural lands, showing that two-thirds of the river's volume had settled into the fields surrounding the floodplain. They helped estimate crop losses and encouraged communications between responders. Flood-related damage to landfills, water wells, and Superfund sites was also assessed with satellite data. The data were also used to update flood hazard maps, determine where to install future electric lines and sewers, predict potential dangers from rising water levels, and plan emergency recovery measures. By linking satellite data with other GIS data, the number of households affected was determined and "areas of need" were identified and prioritized. This work helped plan and



coordinate activities, prioritize response, plan for evacuations as needed, determine rebuilding efforts, and assess potential future damage. Several agencies used these data. For example, NRCS used the data to assess damage, determine the eligibility of farmers for Federal aid, and plan regional rebuilding efforts as farmers received aid funds. Satellite data were even used to trace the path of the damaging zebra mussel, which was previously only in the Great Lakes area but has now been identified as far south as New Orleans.

Satellite data have been applied to other projects in Illinois. For example, DNR's ***State Water Survey*** has used GIS and satellite data to help meet its responsibilities for the analysis of **water and atmospheric resources.** TM and SPOT data were used to provide updated land-use information for rapidly urbanizing areas in northeastern Illinois. This information has been used by the State Water Survey to conduct water quality assessment and modeling for planning and designing **storm drainage.** For example, a GIS interface was developed for the State Water Survey's urban runoff quality/quantity model, Q-ILLUDAS (Illinois Urban Drainage Area Simulator). It was modified to incorporate data, including Landsat and SPOT data for land-use information, as well as other data, such as USGS Digital Line Graph files, the U.S. Census Bureau's DIME files for population and street density, and attribute data determined to describe the geometric and hydraulic characteristics of the storm network and drainage area. Detailed storm sewer networks were added for each outfall point. By using this information to generate the required input for a watershed model, urban runoff was simulated on a regional and citywide basis, and the model is also used to evaluate best management practices. The results were verified by detailed aerial photographs.

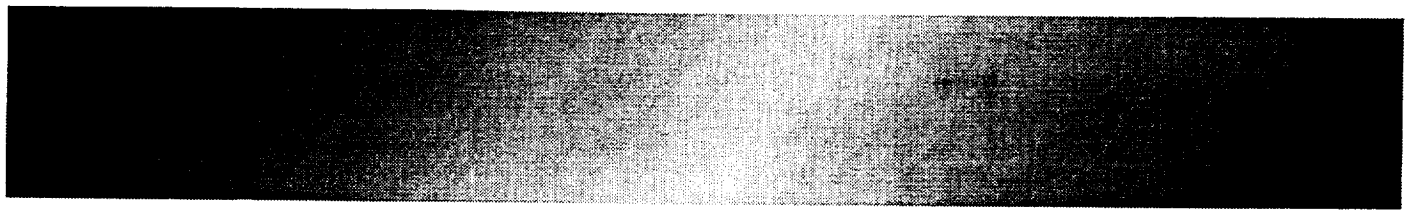
Landsat TM data have been used to help monitor **air quality.** A photochemical reactive grid model was implemented based on a comprehensive land-use/land-cover inventory that was derived from these satellite data for the Lake Michigan Ozone Study. This project was conducted with funding from the affected states and the ***U.S. Environmental Protection Agency.*** The U.S. Census Bureau's TIGER data were used to stratify the classification of urban versus rural areas, as opposed to the traditional principal components transformation approach to reduce the amount of waveband data. The paper describing this project won the second-place award from ERDAS Corporation in 1995 for best scientific paper in remote sensing.

Some **economic development siting** projects have also been aided by the use of satellite data. For example, DNR used such data to help prepare Illinois' bid for the Federal Superconducting Super Collider (SSC) and the Mitsubishi car manufacturing facility in the late 1980s. Land-use/land-cover classifications were derived for the proposed SSC site using Landsat data, image processing, and GIS.

DNR has been working with the University of Illinois and Northeastern Illinois University to **educate high school teachers** about GIS and satellite data. Initiated in 1996, the PLAN-IT Earth curriculum is centered on major Illinois ecosystems and is aligned with DNR's Critical Trends Assessment Project, which reports on environmental conditions in the state. The teachers learned how to implement a set of monitoring activities for forest and flowing water ecosystems to be used with their students during the 1996–1997 school year.

Gap Analysis Program Activities

The ***Illinois Natural History Survey*** at the DNR started the Illinois Gap Analysis Program (GAP) in November 1995. It received Landsat TM scenes for the state to conduct the Critical Trends Analysis Project (CTAP). The "first cut" vegetation map for Illinois was produced for CTAP using a Boolean mask and vector field (VF) segmentation.

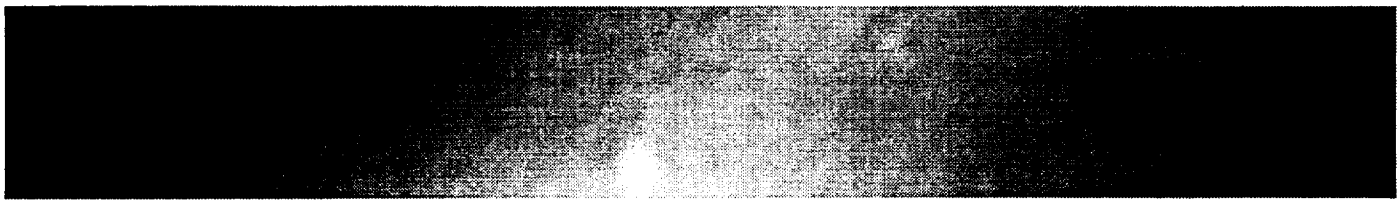


When using full TM scene data, experience has shown that clustering algorithms often fail to adequately discriminate landscape elements, which individually constitute small proportions of the entire scene. This is especially true where urban and built-up lands constitute a small overall percentage of the landscape. To ensure that the spectral signatures for the urban and built-up lands are properly characterized during the unsupervised training stage, these lands are extracted from each TM scene using a Boolean mask created from the block-level, rural-urban classification contained within the 1990 Census TIGER/Line and STF1B files. This Boolean mask was subsequently used to perform two separate classifications—one for the urban portion and a second for the predominantly rural portion of the TM scene. Luman and Ji (1993) determined that a similar approach is effective in improving classification accuracy.

Conventional approaches to unsupervised image classification use pixel classifiers that assign unknown pixels to a spectral class using no contextual information. Thus the spatial domain, expressed within the image as geometrically homogeneous areas (for example, agricultural lands), is ignored. Yet, such information is important to the conventional photo-interpretative process. Research has shown that the inclusion of spatial structure in the classification process can improve discrimination when used for some remote-sensing applications (Woodcock 1992, Nichol 1990). This approach used massively parallel deterministic relaxation optimization algorithms to partition an image into a set of regions that correspond to objects on the landscape, and this is generally referred to as image or VF segmentation. Research using VF segmentation extends back to the 1970s and was applied to large portions of the Illinois landscape in a cooperative study conducted by the Illinois Natural History Survey and the University of Illinois, Beckman Institute for Advanced Sciences (Kerfoot and Bresler 1993). It has been ascertained that VF segmentation is effective in discriminating homogeneous landscape elements within Landsat TM data. Extensive analysis using two TM full scenes subjected to VF segmentation strongly indicates that unsupervised clustering and subsequent classification based on image data is better compared to the same analyses using the original TM image data. In addition, it is anticipated that the application of VF segmentation will improve classification accuracy by minimizing the within-class variance.

The CTAP vegetation map identified 19 broad land-use classes in Illinois, covering urban areas, woodlands, grasslands, agricultural lands, and wetlands. Using the natural cover delineations from the CTAP classification, a Boolean mask will be used to further classify the broad natural CTAP classes into community/alliance classes where applicable. A total of 140 spectral signatures for each Boolean masked area within each VF-segmented TM scene will be extracted using an unsupervised isodata K-means clustering procedure (Duda and Hart 1973). Final unsupervised classification of each TM scene will be achieved from use of a maximum-likelihood classifier, which improves the classification accuracy over other classifiers (Gong and Howarth 1990). A pilot project has been completed on a portion of the ***Shawnee National Forest*** in southern Illinois using the methodology described above. An accuracy assessment will be conducted once spring leafout has occurred.

Boundaries for all federally and state-owned lands have been completed. Attributing is nearly complete, and management status codes are currently being input and verified. The Illinois Natural History Survey has extensive vertebrate distribution records, and wildlife habitat relationship models are being developed for several test species. Distribution maps and occurrence records are currently being linked to the Natural History Survey's home page on the World Wide Web.



Nonstate Government Activities

Several Federal agencies and others have used satellite data with state agencies, such as to help monitor and respond to the Midwest floods of 1993, as well as on other efforts.

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Indiana

State GI/GIS and Satellite Data Contacts

* Bill Ashton
Data Processing Oversight Commission
Indiana Government Center South
402 West Washington Street, Room W470
Indianapolis, IN 46204
(317) 232-0184
(317) 232-3530 (fax)
ashton@dpoclan.state.in.us

* Bill Holloway, GIS Manager
Graphic Engineering Division
Department of Transportation
100 North Senate Avenue, Room N801
Indianapolis, IN 46204
(317) 232-7275
(317) 233-4734 (fax)
holloway@gislcc.indot.state.in.us

* Shelley Liu, GIS Coordinator
Department of Natural Resources
Indiana Government Center South, Room 255C
402 West Washington Street, Room 255C
Indianapolis, IN 46204
(317) 232-0675
(317) 232-8036 (fax)
sliu@ideanet.doe.state.in.us

* Irvin A. Goldblatt, GIS Coordinator
Division of Management Information Systems
Department of Environmental Management
100 North Senate Avenue
P.O. Box 6015
Indianapolis, IN 46206-6015
(317) 233-3410
(317) 232-5539 (fax)
igold@opn.dem.state.in.us

Kathy McCarter, GIS Manager
POLIS Center
205 Cavanaugh Hall
425 University Boulevard
Indianapolis, IN 46202-5140
(317) 274-8400
(317) 278-1830 (fax)
kmccart@indyvax.iupui.edu

Gap Analysis Program Contact

Forest Clark
Bloomington Field Office
U.S. Fish and Wildlife Service
620 S. Walker Street
Bloomington, IN 47403
(812) 334-4261, ext. 206
(812) 334-4273 (fax)
forest_clark@mail.fws.gov

State Government Context

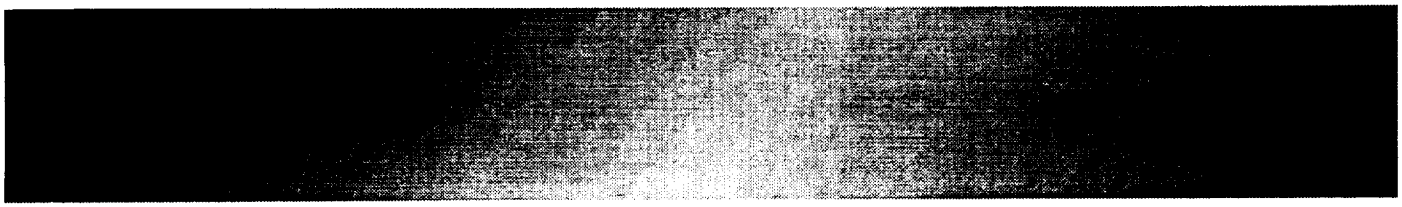
Indiana has an evolving statewide GI/GIS coordination effort. The ***Data Processing Oversight Commission (DPOC)*** has served as the GI/GIS coordination entity for state government during the 1990s. However, few staff resources have been available for this work, and no state agency provides GI/GIS services for other agencies. DPOC's director deputized the GIS manager of the Department of Transportation to serve as the state lead for GI/GIS coordination in 1996. He organized a new ***State GIS Technical Advisory Group*** composed of state and other agencies.

Four state agencies signed an agreement in 1993 to improve "coordination, research and development, access to, and technical assistance of geographically related environmental, health, and natural resource information within state government." The agreement formed the Indiana GIS Interagency Management Steering Committee and the Indiana GIS Interagency Technical Working Group. Members represented each of the four agencies signing the agreement. However, these groups have not met since 1995, and participants are now involved in the new group.

Satellite Data Use

Indiana's state government has had limited use of satellite data. In general, it also has had less GI/GIS activity than other states of its size and population.

The ***Department of Natural Resources (DNR)*** and the ***Department of Environmental Management (DEM)*** have most of the natural resources and environmental management responsibilities in state government. DNR began to use GIS in 1989, and DEM started to use it in the early 1990s. Both agencies have an agencywide GIS coordinator, and DNR is the larger user of GIS in state



government. DNR's ***Division of Fish and Wildlife*** has been working on the Gap Analysis Program (GAP) and its use of satellite data (see below).

The ***Department of Transportation*** also uses GI/GIS. It has used some Landsat TM data for highway mapping purposes.

Gap Analysis Program Activities

The ***U.S. Fish and Wildlife Service Bloomington Field Office*** is expected to be in the final year of the Indiana GAP. Past work focused on the challenging task of developing a meaningful map of actual vegetation from TM data and available ancillary data. Considerable time was expended to establish a remote-sensing methodology that will produce a defensible land-cover classification. A useful preliminary classification for much of the forested southern part of the state has been produced. Efforts are under way to produce a final vegetation map of Indiana, using concurrent aerial photography interpretation, in conjunction with the ***USDA Natural Resources Conservation Service*** and detailed ancillary data analysis.

Thanks to the support of the Indiana DNR's Division of Fish and Wildlife, significant progress has been made on the development of vertebrate models for the 539 vertebrate species in the state. A preliminary methodology has been established to incorporate these data into ARC/INFO for analysis. This work was completed in 1996. Agreements have been in place since the beginning of the project for DNR natural heritage data and managed areas data. The revision of these data for use in Gap Analysis began in 1995. Metadata protocols have been established and standardized across labs at Indiana University and Indiana State University.

Metaprojects have, as expected, manifested a variety of administrative and technical problems. The drive for client-oriented metaproject products indicated a weakness in the Indiana Gap Analysis methodology. Efforts have been under way to strengthen this methodology. These efforts have focused on improving coordination among the principal GAP partners. Early metaprojects have begun to yield results. For example, the copperbelly water snake metaproject delivered hard copy to the U.S. Fish and Wildlife Service. The landscape-scale wetland restoration project has produced preliminary products and reports and continues to generate interest among Indiana's conservation community. ***The Nature Conservancy*** metaproject at Blue River approaches completion. The Nature Conservancy project at Pigeon River will become part of a larger cooperative study with DNR and U.S. Fish and Wildlife Service—and funded in part by the U.S. Environmental Protection Agency. Other metaprojects, including population viability analysis, are ongoing. At least two new metaprojects seem to have funding and should go forward in 1997. Discussions with the Indianapolis Zoo and the Indianapolis Children's Museum to establish a biodiversity education metaproject seem promising, as does a proposal to evaluate the importance of agricultural landscapes to biodiversity.

An expert review is under way of land-cover maps and vertebrate models, and it is expected to lead toward a final product. A formal accuracy assessment of the land-cover map will also be designed. Finally, the Indiana GAP will continue to pursue metaprojects as funding becomes available and as metaprojects are feasible with respect to producing basic Gap Analysis products.

Nonstate Government Activities

Purdue University's Laboratory for Applications of Remote Sensing was one of the first remote-sensing facilities in the country; it was developed in the early 1970s (contact Chris Johansen at (317) 494-7054). ***Indiana State University***'s Remote Sensing Lab was established in 1974 and conducts remote-sensing and GIS work with various external organizations.

Iowa

State GI/GIS and Satellite Data Contacts

* Bernie Hoyer, Geographic Information Supervisor
Geological Survey Bureau
Energy and Geological Resources Division
Department of Natural Resources
123 N. Capitol Street
Iowa City, IA 52242
(319) 335-1571
(319) 335-2754 (fax)
bhoyer@gsbth-po.igsb.uiowa.edu

* Dave Miller
Mike Elliot
Division of Emergency Management
Department of Public Defense
Hoover Building
Des Moines, IA 50319
(515) 281-3231
(515) 281-7539 (fax)
melliot@max.state.ia.us

David J. Plazak
Center for Transportation Research and Education
Iowa State University
2625 N. Loop Drive, Suite 2100
Ames, IA 50010-8615
(515) 294-8103
(515) 294-0467 (fax)
plazak@ctre.iastate.edu

Kevin Kane, Manager
GIS Support and Research Facility
215 Durham Center
Iowa State University
Ames, IA 50010
(515) 294-0526
kk4631r@acad.drake.edu

Gap Analysis Program Contact

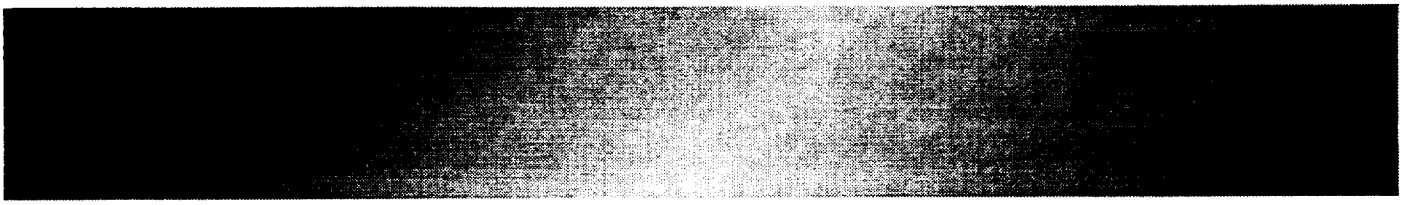
Dr. Erwin Klaas
Cooperative Fish and Wildlife Research Unit
Iowa State University
11 Science Hall II
Ames, IA 50011
(515) 294-3056

State Government Context

Iowa has been developing a statewide approach to GI/GIS for several years. The ***Department of Natural Resources (DNR)*** is responsible for virtually all natural resources and environmental programs in state government. DNR has had legislative authorization since 1987 to develop and maintain a state natural resource GIS and comprehensive water resource data system. Consequently, DNR has served as the lead for GI/GIS coordination in Iowa.

The ***Iowa Geographic Information Council (IGIC)*** is the state GI/GIS coordination group. While the council does not have official authorization, the governor wrote a letter of endorsement for it in 1995. Several agencies participate in the council, and its members signed a memorandum of understanding in 1996 that delineates the council's objectives and approach. Several GI/GIS coordination activities are conducted, such as an annual conference and a newsletter. DNR's GIS coordinator and others have helped staff the group.

Iowa also has an ***Intergovernmental Information Technology and Telecommunications Task Force (IITT).*** It has a ***GIS Work Group*** that analyzed state conditions regarding GI/GIS. The group recommended late in 1996 that IGIC should be formalized to oversee standards and



facilitate interorganizational cooperation. In addition, IITT recommended that an information technology department be developed in Iowa and that a GI/GIS coordinator position should be established within the new department.

Satellite Data Use

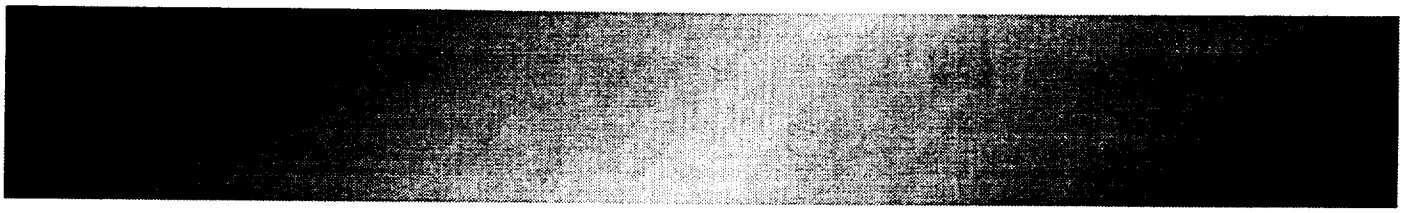
DNR is the omnibus natural resources and environmental agency in Iowa. Beginning GIS work in 1987 with legislative direction to use GIS for groundwater protection, all of DNR's divisions now use GI/GIS at varying levels. The department has had a GIS coordinator located in the ***Energy and Geological Resources Division,*** but this position has been vacant since early 1997.

DNR has used Landsat data to help meet some of its internal needs. One of its first satellite data efforts was when the state ***Geological Survey*** tested the usefulness of TM data with GIS to monitor soil conservation practices in the soil conservation district, including Johnson County, Iowa, in the late 1980s.

A larger project using satellite data was initiated in 1990 by DNR, the ***Department of Transportation (DOT),*** and the ***Iowa Utilities Board.*** These agencies received a $500,000 grant from the ***U.S. Department of Energy*** from its oil overcharge monies for a project titled "GIS Database for Energy Planning," which was funded to increase energy efficiency and expand energy development in Iowa. The project's goal was to increase interagency cooperation through the definition of complementary roles in developing compatible digital data sets, sharing digital geographic resource information, and applying data to applications that could be used in the energy-related programs of the individual agencies.

Half of the grant funding was used by DNR to acquire and analyze Landsat data to produce a land-cover map to identify potential energy sources, particularly biomass (the other half was used by DOT to increase energy efficiency and transportation planning). Three data bases have been under development, including the Landcover/Land use Statewide Database to identify forest cover available for use as an alternative energy supply, the Coal and Mineral Resources Database to improve coal resource evaluation and utilization, and the Energy Resources Database to provide energy data layers included in DNR's energy resources inventory atlas. Current efforts continue to develop these data; however, progress has been slow.

After this project began, Iowa was affected by the Midwest floods of 1993. This emergency became a driving force to increase the use and coordination of GI/GIS and satellite data among several agencies, including the ***Emergency Management Division (EMD)*** in the ***Department of Public Defense.*** While state government had not made much direct use of satellite data and GI/GIS in response to the 1993 floods, EMD's subsequently received a $325,000 grant from the ***Federal Emergency Management Agency*** in 1994 to help mitigate and respond to future floods. The grant was provided to develop 21 data layers for certain river corridors covering 350 1:24,000-scale quadrangles that can be used for floodplain management and emergency response. Satellite data was used to develop land-cover data. Other data were gathered, such as the National Wetlands Inventory, levees, schools, hospitals, soils, communications switching areas, water and sewer utility treatment plants and lines, powerplants and lines, flood gauge stations, bridges, barge facilities, land ownership, hydrology, river miles, dams, roads, railroads, pipelines, and historic sites. Much data development was contracted to the ***U.S. Army Corps of Engineers, Rock Island Office,*** and efforts have been conducted in coordination with DNR and other agencies. This work was similar, but more advanced, to the work that the Corps of Engineers had done for Illinois during the Midwest floods of 1993. The grant also included the



development and distribution of metadata with these data.

Gap Analysis Program Activities

The ***Cooperative Fish and Wildlife Research Unit*** at ***Iowa State University*** received initial funding in fiscal year 1997 to begin the Gap Analysis Program in Iowa. Efforts are under way in 1997 to develop plans and processes for this work.

Nonstate Government Activities

Iowa State University has a GIS Support and Research Facility, and the College of Social and Behavioral Sciences a the ***University of Northern Iowa*** has a Geographic Information Technology and Computer-Assisted Drafting and Design (GIT/CADD) Laboratory. Both universities offer several related courses, including remote sensing.

Kansas

State GI/GIS and Satellite Data Contacts

* Rick Miller, State GIS Coordinator
Kansas Water Office
109 S.W. 9th, Suite 300
Topeka, KS 66612
(913) 296-0877
(913) 296-0878 (fax)
rmiller@fog.kwo.state.ks.us

Stan Black
Division of Emergency Management
Adjutant General's Office
2800 S.W. Topeka Boulevard
Topeka, KS 66611-1287
(913) 274-1432
(913) 274-1426 (fax)

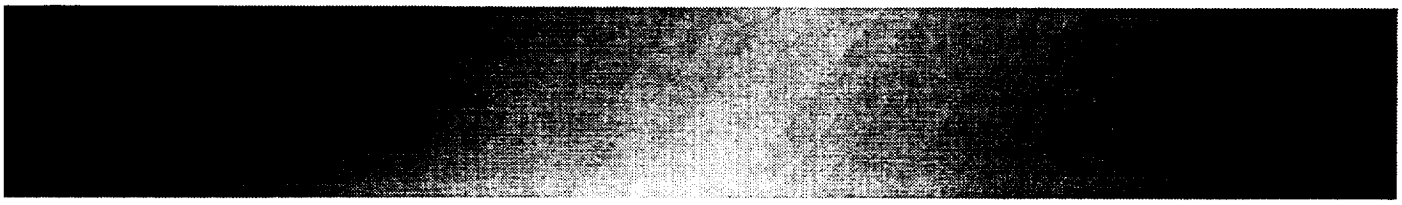
Lloyd Stullken
Division of Water Resources
State Board of Agriculture
901 S.W. Kansas Avenue
Topeka, KS 66612
(913) 296-6084

Thomas Mettille, Manager
Data Access and Support Center
Kansas Geological Survey
University of Kansas
1930 Constant Avenue, Campus West
Lawrence, Kansas 66047-3726
(913) 864-3965, ext. 347
(913) 864-5317 (fax)
dasc@monogogis.kgs.ukans.edu

James Parker
Division of Information Systems and Communications
Department of Administration
Landon State Office Building
900 S.W. Jackson, 7th Floor
Topeka, KS 66612
(913) 296-4394
(913) 296-1168 (fax)

Gap Analysis Program Contact

Dr. Jack Cully
Cooperative Fish and Wildlife Research Unit
Kansas State University
205 Leasure Hall
Manhattan, KS 66506-3501
(913) 532-6534
(913) 532-7159 (fax)
bcully@lter-konza.konza.ksu.edu



State Government Context

Kansas has had an official statewide approach to GI/GIS since 1989 when the governor established the state GIS initiative and a ***GIS Policy Board.*** It was reauthorized in 1995 by executive order. The board has been advised by the ***GIS Technical Advisory Committee,*** which was created by the board later in 1989. Kansas formerly was unique because it had a Commission on Applied Remote Sensing that was established by the legislature in 1984. However, the commission was eliminated by the legislature in 1993.

Kansas has a state GIS coordinator located in the ***Water Office.*** It is anticipated this position will move at some time to the Division of Information Systems and Communications in the Department of Administration. The ***Kansas Geological Survey (KGS),*** located at the University of Kansas, manages the ***Data Access and Support Center (DASC),*** which was authorized by the state GIS Policy Board and is administered under contract to KGS. The legislature appropriated funds for DASC beginning in 1991. DASC is archiving and redistributing core data bases to state agencies and others.

Satellite Data Use

The majority of the state's environmental and natural resources activities are located in the Water Office, the Department of Health and Environment, and the Board of Agriculture. Each of these agencies use GI/GIS and have made some use of satellite data through the ***Kansas Applied Remote Sensing (KARS) Program*** at the University of Kansas (see below). KARS completed the state's **land-cover** data layer during between 1990 and 1994. This data layer was derived from interpreted Landsat data and has many applications. For example, satellite data were used to assist in **water resources** planning and management, specifically for watersheds and reservoirs.

More recently, the state GI/GIS clearinghouse, DASC, is working with KARS and others at the university regarding satellite data, including on a recent project funded by NASA (see below).

Gap Analysis Program Activities

The Kansas Gap Analysis Program is in the early stages of map development. The primary cooperators involved are the ***Kansas Biological Survey (KBS)*** at the ***University of Kansas*** and the ***Geography Department*** at ***Kansas State University (KSU),*** with overall coordination by the ***Cooperative Fish and Wildlife Research Unit*** at KSU. The KARS Program of KBS began work on developing a prototype land-cover layer in late 1995. A multitemporal classification approach involving three TM scenes (late spring, early summer, and late summer) are being used to identify natural land-cover types in southwest Kansas. The goal is to map land cover to the alliance level using the modified TNC-UNESCO vegetation classification developed by KBS in cooperation with The Nature Conservancy's (TNC) Midwest Regional Office.

The Geography Department at KSU has begun work on tiling U.S. Geological Survey 1:24,000-scale quadrangle maps across the state. The purpose is to create mylar overlays on which protected land areas can be traced and then scanned into a GIS land management layer. Maps showing protected lands in Kansas are available from KBS, and the resulting GIS layer will serve to secure this data set in digital format. The quadrangle maps were originally used to develop a statewide soils map for the ***USDA Natural Resources Conservation Service.*** The soils map will provide a useful layer for the vertebrate distribution models and will facilitate the identification of natural vegetation types.

Nonstate Government Activities

The University of Kansas has had an active role in GI/GIS and satellite data in Kansas for more than 20 years. The KARS Program was established in 1972 at the University of Kansas' Space Technology Center. KARS has provided services, assistance, and training to various state and local government entities since then. It was authorized to serve in this role by the legislature in 1984 and is an affiliate of KBS. KARS provides technical assistance and training in the uses of remote sensing and GIS with natural resource data, land-use/land-cover interpretation, spatial analysis techniques, and research applications for remotely sensed data. KARS assists in identifying and tracking the remaining elements of Kansas natural heritage. It also applies GIS to the spatial analysis of land-use data as it relates to biological water quality, relational information on the occurrence of Kansas flora and fauna, habitat modeling, and water resources. KARS has conducted many projects using satellite data through several faculty, researchers, and students.

The Department of Geography teaches remote sensing and has the Geographic Research, Application and Information Laboratory providing onsite instruction in ARC/INFO, ERDAS, and so forth.

Kansas State University's Geography Department has used satellite data for both teaching and research. The department has developed a large "scanning lab," which is being used extensively to create the statewide soils data layer for use with GIS, in cooperation with the USDA Natural Resources Conservation Service.

NASA funded a project titled "Development of a Land Use Mapping and Monitoring Protocol for the Great Plains," with participants including the University of Kansas, Kansas State University, and DASC (contact Kevin Price at the University of Kansas)

Kentucky

State GI/GIS and Satellite Data Contacts

* Susan Carson Lambert, Executive Director
Office of Geographic Information
Finance and Administration Cabinet
1024 Capital Center Drive, Suite 305
Frankfort, KY 40601
(502) 573-1450
(502) 573-1458 (fax)
slambert.kirm@msmail.state.ky.us

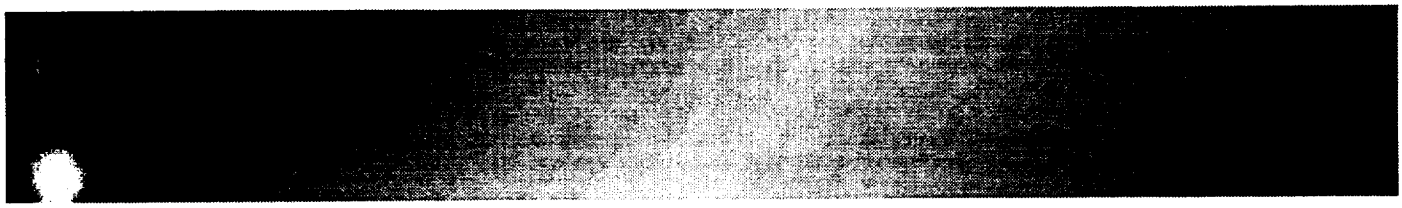
* Ken Bates, Manager
Tony Sturgill
Geographic Information Section
Division of Administrative Services
Natural Resources and Environmental Protection Cabinet
500 Mero Street, 14th Floor Capital Plaza Tower
Frankfort, KY 40601
(502) 564-5174
(502) 564-6736 (fax)

Gap Analysis Program Contact

Steve Czajkowski
Department of Fish and Wildlife
Natural Resources and Environmental Protection Cabinet
#1 Game Farm Road
Frankfort, KY 40601
(502) 564-4406

State Government Context

Kentucky has had a statewide approach to GI/GIS since the late 1980s. The legislature enacted legislation in



1994, which created the ***Geographic Information Advisory Council*** and the ***Office of Geographic Information,*** located in the ***Finance and Administration Cabinet.*** The office serves as the official statewide GI/GIS coordinator and has several efforts under way in this regard. Funding for GI/GIS development was delayed after the authorizing legislation, but efforts and support accelerated in 1996.

Beginning GI/GIS work more than a decade ago, the ***Kentucky Natural Resources and Environmental Protection Cabinet*** has had the earliest and currently the most extensive GI/GIS activities of any other cabinet in state government. This cabinet served as the unofficial GI/GIS coordinator for the state until the early 1990s—and again while the Office of Geographic Information was unstaffed during 1995.

Satellite Data Use

The Kentucky Natural Resources and Environmental Protection Cabinet has most of Kentucky's natural resources and environmental functions, and it is the leading state agency with satellite data activities. It initiated GIS efforts in the late 1970s with the Kentucky Natural Resources Information System (KNRIS), which was financially supported by the Federal ***Office of Surface Mining (OSM).*** KNRIS originated in what was the Department for Surface Mining, now known as the Department for Surface Mine Reclamation and Enforcement. Since 1987, KNRIS has been administratively managed in the ***Data Processing Branch,*** which has a Geographic Information Section. The cabinet's GIS manager and the rest of this section provide data management and GIS services to various departments within the cabinet.

In 1993, while GI/GIS activities continued and expanded to other areas in the cabinet, OSM funded the acquisition of Landsat and SPOT data to develop land-cover data to monitor coal fields and mine permits and to conduct **mining reclamation** work. The cabinet contracted with TRIFID Corporation to create a data base of 26 scenes covering eastern and western Kentucky. The satellite data are used to identify mines, subsidence zones, and other features and to take the measurements necessary for mine reclamation monitoring. Subsets of the data base were created, including high-resolution aerial photography to provide more detailed views of the features.

Since then, the ***U.S. Environmental Protection Agency (EPA)*** has been working with the cabinet (and other southeastern states in EPA'S Region 4) to use satellite data to develop **land-cover** data for the remainder of the state (and the entire region). These data are primarily being developed to help monitor change as needed for **wetlands protection** efforts, and they will complement the existing digital version of the National Wetlands Inventory for Kentucky. The cabinet is also using these data for other applications.

Gap Analysis Program Activities

The ***Department of Fish and Wildlife*** within the Natural Resources and Environmental Protection Cabinet received initial funding in fiscal year 1997 to begin the Gap Analysis Program for Kentucky. Efforts are under way in 1997 to develop plans and processes for this work.

Nonstate Government Activities

The ***Louisville/Jefferson County Information Consortium*** used SPOT data to help update its GIS data base. Satellite data from 1988 and 1991 were compared to identify areas of change.

Louisiana

State GI/GIS and Satellite Data Contacts

* Glen Daigre, Policy Planning Analyst
Office of Planning and Budget
Division of Administration
1051 North 3rd Street
P.O. Box 94095
Baton Rouge, LA 70804
(504) 342-7410
(504) 342-7220 (fax)
gdaigre@doa.state.la.us

Bo Blackmon, GIS Coordinator
Michael Schouest
Management and Finance Office
Department of Natural Resources
P.O. Box 94396
Baton Rouge, LA 70804
(504) 342-4500

Lynda Wayne, GIS Coordinator
Coastal Studies Institute
331 Howe Russell
Louisiana State University
Baton Rouge, LA 70803
(504) 388-8612

Gap Analysis Program Contact

Dr. James Johnston
Southern Science Center
USGS Biological Resource Division
F700 Cajundome Boulevard
Lafayette, LA 70506
(318) 266-8556
(318) 266-8616 (fax)
johnstonj@nwrc.gov

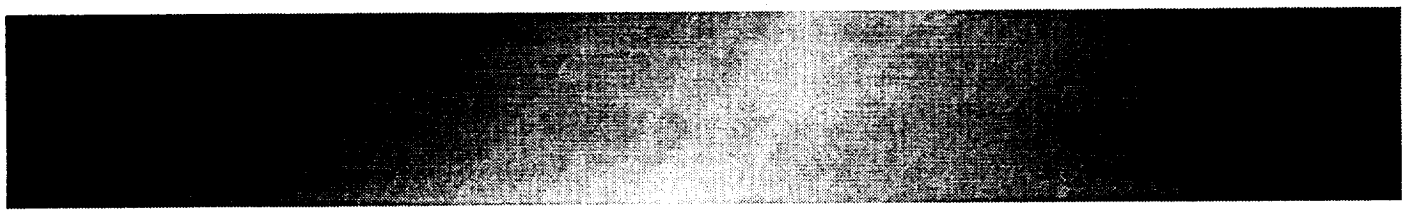
State Government Context

Louisiana has been developing a statewide approach to GI/GIS coordination since the late 1980s. Statewide GI/GIS activities are now coordinated by the ***Louisiana Geographic Information Systems Council.*** The council was established by the legislature in 1995 after the state GIS Task Force had facilitated GI/GIS coordination since 1989. The council is currently chaired and staffed by a representative of the ***Office of Planning and Budget.*** Several coordination activities are conducted. Louisiana also has an active chapter of the Urban and Regional Information Systems Association, which sponsors regular meetings and activities and publishes a newsletter about GI/GIS efforts in the state. No agency provides GI/GIS services for other state agencies.

Satellite Data Use

Environmental and natural resources responsibilities are shared by various agencies in Louisiana. GI/GIS and remote-sensing activities are primarily located in the ***Department of Natural Resources (DNR).*** While the agency formerly had several efforts under way, there has been a recent effort to coordinate internal GI/GIS activities. DNR appointed a departmentwide GIS coordinator in 1994 to facilitate this effort.

DNR's (and Louisiana's) first GIS use was initiated as a result of the passage of Louisiana's State and Local Coastal Resources Management Act of 1978. Louisiana's coastal wetlands include approximately 9 million acres and include the largest and most productive estuarine complex in North America. Louisiana has 40 percent of the Nation's wetlands within its boundaries and provides 30 percent of the Nation's commercial fish and shellfish harvest. The ***Coastal Restoration and Management Office*** is responsible for continuing GI/GIS work in this regard.



A Coastal Resources Analytical Mapping System was developed to provide managers, regulators, and researchers with geographically related data about coastal resources, particularly wetlands. Both SPOT and Landsat data were acquired for coastal areas, and some efforts have been under way to acquire statewide coverage. Additional data resources have included the U.S. Fish and Wildlife Service's Ecological Characterization and EcoAtlas maps; Natural Heritage Program rare, threatened, and endangered species and unique habitats; public and private wetland management plans; state and Federal wildlife management areas and refuges; political boundaries; small hydrologic units; and hydrologic basins and archaeological sites and analyses for the entire coastal area. The system provides information on wetland land-cover and land-use changes over time, with detailed vegetation cover and locations of environmentally and culturally sensitive features. Outputs include maps showing land-use or land-cover change, wetland loss and sensitivity, and statistical tables of wetland change. The system has also been used to identify problem areas in the coastal area and to monitor the results from restoration efforts.

The ***Louisiana Geological Survey*** began a program in 1989 with funding from the Geologic Division of the ***U.S. Geological Survey (USGS)*** to develop the Louisiana Coastal GIS Network (LCGISN) located at and in coordination with researchers at ***Louisiana State University (LSU)***. Louisiana is well known for its severe coastal erosion and wetland loss, and LCGISN was initiated to address the need for coastal resources information to assess the potential risk these changes pose to Louisiana's citizens. The initial purpose of the project was to assess and monitor coastal change, including barrier island erosion and wetland loss, and to help mitigate, monitor, and respond to potential risks such as oil spills. Furthermore, LCGISN's goal has been to take the variety of available coastal information and consolidate it into an easily retrievable form, despite the format, platform, software, and method of storage, to produce "one of the country's largest multidisciplinary and multifaceted wetlands data bases." The project has been considered by the USGS Geology Division as a prototype for other states and by state government as a pilot project for the sharing of GIS-related data. LCGISN has used some 1990 Landsat TM data that were acquired by DNR to provide an image of land cover, land/water interface, and environmental conditions in the state's coastal region and to help monitor change in this area.

Other state entities have made some use of satellite data. For example, the ***Department of Environmental Quality*** has experimented with SPOT data. The ***Oil Spill Coordinator's Office,*** located in the Governor's Office, used some GIS capabilities and Landsat TM data to develop maps to aid in preparing for and responding to oil spills. These maps have been used by other agencies as well.

Gap Analysis Program Activities

The Louisiana Gap Analysis Program (GAP) is currently in its fourth fiscal year at the ***Southern Science Center*** of the ***USGS Biological Resource Division.*** The entire state has been divided into a grid of 332 unclassified cluster panels of 900 by 900 pixels each. Strategies to ensure connectivity among classified TM panels and also between classified TM panels and National Wetlands Inventory data panels are being developed. Recently, members of the Louisiana GAP team completed an initial ground-truthing survey for postvisual classification of the vegetation map. Cognitive, or on-screen, classification of the land-cover map was completed in August 1995. The GAP team is currently compiling the ground-truth data into a data base. This data base, along with the National Wetlands Inventory data base, and the use of color infrared aerial photography will be used to refine the visual interpretation of the TM data. The color infrared photography is currently being indexed, scanned, and

stored on CD-ROM. Another auxiliary data set that is being compiled is a TM/SPOT merge. These two auxiliary data sets will provide a means of performing a classification accuracy assessment statement. Definitions to the land-cover classification terms are in progress.

Several GAP meetings have been held in recent years, involving cooperators and individuals interested in the GAP project. Attending were representatives from Louisiana Natural Heritage Program, The Nature Conservancy, the Louisiana DNR, the Louisiana Department of Wildlife and Fisheries, the Louisiana Department of Environmental Quality, the University of Southwestern Louisiana, LSU, the University of Northeastern Louisiana, the University of Northwestern Louisiana, Tulane University, Loyola University, the U.S. Army Corps of Engineers–New Orleans District, the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, the USDA Forest Service and Natural Resources Conservation Service, the National Marine Fisheries Service, and USGS.

Nonstate Government Activities

LSU has four laboratories using GI/GIS and remote sensing: the Computer Aided Design–GIS Laboratory, the Remote Sensing and Image Processing Laboratory, the Earth Scan Laboratory, and the Louisiana Agricultural Decision Support System and Knowledge-Based System Development Laboratory. Activities involve more than 10 academic departments, including work with LCGISN described above. Several projects have been conducted using satellite data.

LSU faculty are working with investigators at the ***University of Delaware,*** the ***National Oceanic and Atmospheric Administration,*** and the ***U.S. Environmental Protection Agency*** in a Coastal Change Analysis Project (C-CAP) concerning wetland condition and functional health over large wetland areas. Impaired and healthy pilot test sites in Louisiana marshes have been investigated. Field data are being correlated with Landsat TM data to assess biomass and stress indicators over large areas with the help of modified models and techniques developed during previous studies. Data derived from this work are crucial to C-CAP for the early detection of functional change in habitat.

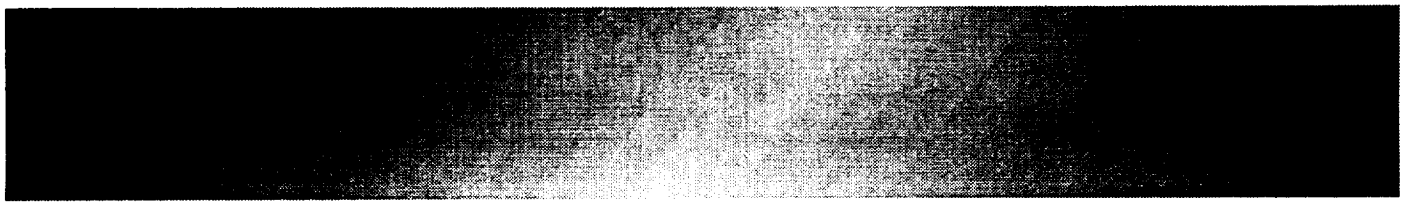
LSU's Veterinary School has had its own GI/GIS lab, the World Health Organization Collaborating Center for Reference and Training in Remote Sensing and GIS for Veterinary Public Health, since 1991. Its researchers have investigated ticks in Guadeloupe and vibrio and leprosy in Louisiana. Most recently, research has been conducted on Eastern Equine Encephalitis and mosquito breeding grounds in St. Tammany Parish to determine potential areas where the disease may occur.

The ***Mississippi Automated Resource Information System (MARIS),*** Mississippi's statewide GI/GIS center, conducted an inventory of land use in the Pearl River basin in Mississippi and Louisiana for LSU's Center for Wetland Resources. MARIS used Landsat data to help conduct this work (see under Mississippi).

Maine

State GI/GIS and Satellite Data Contacts

* Daniel Walters, Administrator
Bill Duffey
Maine Office of GIS
Bureau of Information Services
Department of Administration and Finance
71 Hospital Street
22 State House Station
Augusta, ME 04333



(207) 287-3897
(207) 287-7641 (fax)
isdwalt@state.me.us

Dave Struble
Maine Forest Service
Department of Conservation
22 State House Station
Augusta, ME 04333
(207) 287-2211
(207) 287-2400 (fax)

Gap Analysis Program Contact

Dr. William B. Krohn
Cooperative Fish and Wildlife Research Unit
5755 Nutting Hall, Room 240
University of Maine
Orono, ME 04469-5755
(207) 581-2870
(207) 581-2858 (fax)
krohnwb@wlm13 umenfa.maine.edu

State Government Context

Maine has a statewide ***Office of GIS*** located in the ***Bureau of Information Services*** of the ***Administration and Finance Department.*** While the office had previously existed, the legislature formally established its location, role, and responsibilities in legislation adopted in 1991—and again in 1995. The office is directed to create a data repository, maintain base map and other general-purpose data for use with GIS, and disseminate the data. It also manages GIS facilities and provides technical support for other agencies. While there is no mention of remote sensing in this legislation, the office works with satellite data on some projects. Maine formerly also had a separate statewide GIS coordinator to help agencies develop GI/GIS plans and facilitate interagency coordination. However, this position has been vacant since 1995, and its future status is uncertain.

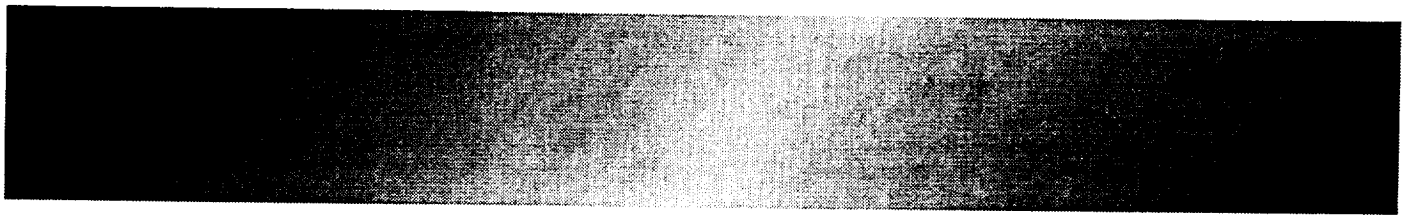
Maine has a ***GIS Steering Committee*** that was established by executive order in 1989. The state also has a ***GIS Users Group,*** created in 1995, that is composed of several GIS users in state government and other organizations. A remote-sensing interest group formerly existed in the state, but this topic is now addressed in the GIS Users Group.

Satellite Data Use

The ***Department of Conservation (DOC)*** is the primary natural resources agency in the state, and it is the primary user of satellite data. It also was the former location of the state GIS office. Other natural resources functions are conducted by the ***Department of Marine Resources*** and the ***Department of Inland Fisheries and Wildlife,*** and environmental regulation activities are conducted by the ***Department of Environmental Protection.*** Each of these agencies has GI/GIS activities.

DOC's ***Bureau of Forestry*** and the Office of GIS are the lead agencies working with satellite data. Maine participated in EOSAT's Statewide Purchase Program and acquired Landsat data in 1991 to help understand the state's **forestry resources.** Funding for this effort was provided through the Northern Forest Lands Study, which has also been one of the largest GIS efforts in the state. The study was authorized by Congress to study the resources of a 26-million-acre area in Maine, New Hampshire, New York, and Vermont.

Satellite data were used to develop forest cover and wetlands data in all four states, with early image-processing work conducted at the University of New Hampshire's remote-sensing facilities (see under New Hampshire). Various other offices and bureaus in DOC participated in



the project and contributed data. Several data sets were developed for the study, including zoning, land use, wetlands, parks and recreational sites, natural heritage land use, and land ownership. It was planned that satellite data, including both Landsat and SPOT, could be processed by researchers at the University of Maine to develop a land-cover data base for Maine. While efforts began in this regard, progress slowed because some problems were encountered. The Office of GIS became the lead for this effort, but the development of these data has not been a funded priority for the Office of GIS. However, various agencies have used the available satellite data and work for their individual needs.

The Bureau of Forestry has also used Landsat data in cooperation with the University of Maine and James W. Sewell Company to increase understanding of the location and trends regarding **pest management** in forests. For example, it was used to minimize Gypsy moth defoliation and to help localities determine where to conduct spraying. Plans are to use satellite data for other purposes, such as helping implement Maine's Forest Practices Act.

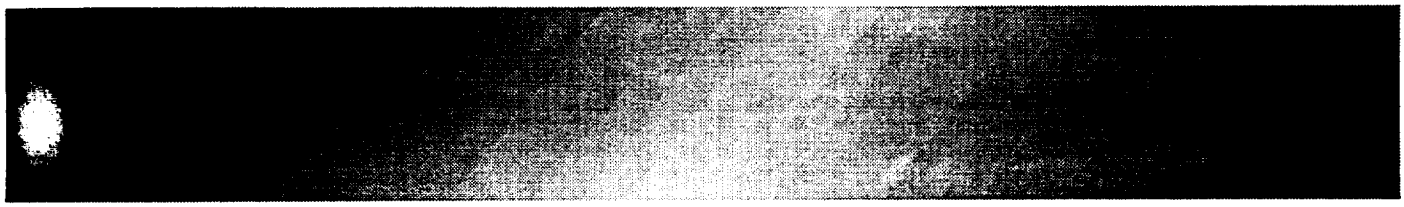
Gap Analysis Program Activities

The Maine ***Cooperative Fish and Wildlife Research Unit*** is the lead organization for the Gap Analysis Program. Phase I was recently completed after the completion of the final habitat map by the University of Massachusetts. Phase II is under way with the development of the habitat map using aerial videography and ancillary data bases as training information. In this phase, 1993 Landsat TM data will be used to identify habitat types. All TM images are being converted to the same format, coordinates, and grid size. A mosaic of images, including a 10-kilometer boundary around the state, are being developed from the 1993 satellite data. Clouds are being masked out, and a principal component analysis of the six TM bands is being used for data reduction. Supervised, unsupervised, and guided clustering algorithms are to be used to classify habitats within individual ecoregions. These ecoregions will be stitched together, and the resulting habitat map will be tested using aerial videography and ground-truthing.

Aerial videography, with the video frames positioned geographically using a GPS, will be used to identify satellite image signatures. Videography transects totaling 7,100 kilometers statewide were obtained in summer and fall of 1994. Maine was divided into eight regions, and six to eight examples of each habitat within each region were ground-truthed. Habitats on videography were printed out, and 120 sites along public roadways were visited to check the relationship between the videography and ground observations. A catalog of videography has been developed to use as reference in classifying satellite data and in testing the resulting map.

As part of Maine Gap Analysis and for use in other research, the acquisition of aerial videography has been contracted along 48 Breeding Bird Survey routes. These flights were completed in 1996, and the videography are being used to assess the accuracy of the predicted distributions of birds in Maine based on Gap Analysis.

Species synopses have been developed for each of the 278 terrestrial vertebrates that breed in Maine. The amphibian and reptile synopses are finalized, mammals have been reviewed and await final editing, and bird synopses are being reviewed. Synopses have been used to assist personnel of the Maine Forest Biodiversity Project and commercial forest industry personnel. After being finalized, the species synopses will be used in Randy Boone's doctoral research. The range maps will be used to research the effect of generalizing distributions to coarser political units (for example, counties). Ultimately, they will be reformatted to be more concise and published in two volumes.



Efforts to develop scores for how well species should be predicted by Gap Analysis have expanded. Predictability scores will be developed for the species of Maine and selected western states where Gap Analyses have been completed. Predictability as assigned, using ecological variables, will be compared to species lists from conservation areas to test agreement. Should correlations be high, others conducting Gap Analysis will be able to judge a priori which species should require more effort during modeling.

A digital data base of land ownership and an accompanying paper map were purchased from a local contractor. Coordination efforts are under way with the ***Maine State Planning Office*** to ensure that Maine conservation lands are accurately mapped and made current to 1993. Public lands will be classified as to the level of biodiversity conservation they provide. Species synopses that have been under development for Maine will be soon completed.

Nonstate Government Activities

The ***University of Maine*** at Orono is one of three sites of the National Center for Geographic Information and Analysis. The university has facilities and degree programs regarding GI/GIS.

A Coastal Change Analysis Project (C-CAP) has been conducted with the ***National Oceanic and Atmospheric Administration*** for the St. Croix River Estuary (the border of Maine and New Brunswick). Several entities have been involved in this effort, including the National Oceanic and Atmospheric Administration, the ***U.S. Environmental Protection Agency*** and the Gulf of Maine Program, the ***U.S. Fish and Wildlife Service,*** and ***Environment Canada.*** A change detection analysis has been performed using Landsat TM data from 1985 and 1992. This work has been conducted by the ***U.S. Department of Energy***'s Oak Ridge National Laboratory, with field verification by U.S. Fish and Wildlife Service personnel.

The ***Island Institute*** based in Rockland, Maine, published a book, *From Cape Cod to the Bay of Fundy: An Environmental Atlas of the Gulf of Maine*, which uses satellite data and GIS data to identify, interpret, and display environmental patterns and problems. Data from several sensors were applied to several different applications, including phytoplankton productivity, sea floor mapping, flood monitoring, seabird habitat identification, and acid rain impact on vegetation. In addition, it includes 11 remote-sensing projects prepared by K–12 students in the GAIA Crossroads program.

Maryland

State GI/GIS and Satellite Data Contacts

* Michel Lettre, Deputy Director
Maryland Office of Planning
301 W. Preston Street
Baltimore, MD 21201-2365
(410) 225-4455
(410) 225-4480 (fax)

* Sandy Johnson
Department of Natural Resources
Tawes State Office Building D-4
580 Taylor Avenue
Annapolis, MD 21401-2397
(410) 974-2640

* William Burgess, Director
Geographic Information Services Division
Chesapeake and Coastal Watershed Service
Administration

Department of Natural Resources
Tawes State Office Building, D-2
580 Taylor Avenue
Annapolis, MD 21401-2397
(410) 974-2721
(410) 974-2618 (fax)
wburgess@dnr.state.md.us

Gap Analysis Program Contact

Ann Rasberry
Fish, Heritage and Wildlife Administration
Department of Natural Resources
Tawes State Office Building, E-1
580 Taylor Avenue
Annapolis, MD 21401-2335
(410) 974-3195
(410) 974-3587 (fax)
arasberry@tawes.dnr.state.md.us

State Government Context

Maryland has a statewide GI/GIS coordination effort involving numerous participants, although there are no formal directives in this regard. The state does not have a statewide office that serves as the official GI/GIS coordination focal point or provides GIS services or products. However, the ***Office of Planning*** was one of the earliest state agencies in the country to use GIS software, beginning in 1974. That office and the ***Department of Natural Resources*** are the leading state agencies regarding GI/GIS. They and other state agencies have been developing digital data for use with GIS.

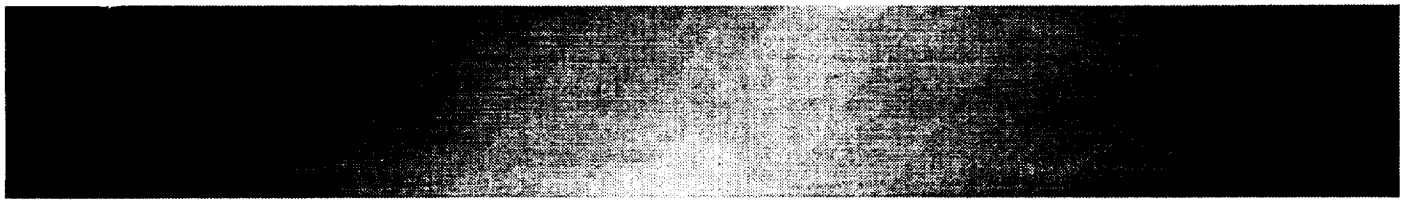
Many state agencies participate in the ***Maryland State Government Geographic Information Coordinating Committee,*** which was established in 1992 to coordinate statewide GI/GIS activities. It has been quite active, including the development of a GI/GIS statewide plan, resource guide, and other materials and activities. Maryland also has a ***Local Government GIS Committee,*** which primarily includes county representatives. An annual GI/GIS conference is held in Maryland with participants from all levels of government and other sectors.

Satellite Data Use

Maryland's state government has made extensive use of satellite data. Both Landsat and SPOT data have been used in various ways, and satellite data have been used as background for various map products. The state currently has four digital map systems, including two that use satellite data. These include statewide Landsat data and a parcel map data base that combines several files generated with SPOT data with property taxation data (see below). Maryland also has statewide digital 7.5-foot U.S. Geological Survey topographic quadrangle maps, as well as color infrared digital orthophoto quarter quadrangles, which will be completed statewide in 1997. The Department of Natural Resources, the Office of Planning, and the State Highway Administration are the leading users of satellite data in state government as described below.

The Office of Planning has been a user of GI/GIS since 1974, beginning with the Maryland Automated Geographic Information system. Through the mid-1980s, land-cover data were developed using aerial photography. Coverages stored in ERDAS include these and other data.

More recently, the Office of Planning used Landsat TM data to provide individual **land-use/cover** data sets for selected counties in the state in 1991. Statewide Landsat coverage was purchased through EOSAT's State Coverage Program in 1994. Efforts began in 1995 with Towson State University to prepare a land-use/cover update for each county and for statewide coverage using these new satellite data. These data are available for the entire state and are used for **planning** and other purposes.



The Office of Planning has developed another important data resource to assist in property taxation using satellite data in coordination with the ***State Highway Administration*** and the ***Department of Assessments and Taxation.*** Known as MDProperty View, this resource includes a parcel map data base for each county in the state in an ARCView format. It combines political, road, and stream files generated by the State Highway Administration with SPOT panchromatic data, binary rasters of the parcel maps, and point nodes for the parcels that are linked to the Department of Assessments and Taxation's property taxation data base. In addition to roads, addresses, and parcel centroids, the data base has other infrastructure information, including some data provided by Bell Atlantic of Maryland. These data are available on CD–ROM for individual counties or on a statewide basis.

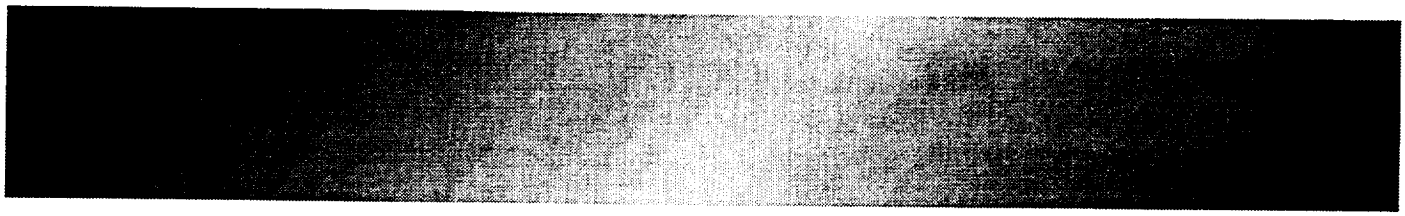
Maryland's natural resources and environmental responsibilities are primarily conducted by the ***Department of Natural Resources (DNR)*** and the ***Maryland Department of the Environment (MDE).*** A reorganization of program responsibilities between the two agencies occurred in 1995. For example, MDE's new ***Water Management Administration*** is responsible for floodplain management, while these roles were formerly within DNR. Multiple parts of both agencies use GI/GIS and satellite data.

Of the two agencies, DNR has the oldest and largest level of GI/GIS and satellite data activities. Its ***Geographic Information Services Division,*** formerly located in the Water Resources Administration, was reorganized into the new ***Chesapeake and Coastal Watershed Service Administration*** in 1995. The division serves as the departmentwide coordination office for DNR, and it has had several GI/GIS and satellite data projects for more than a decade. It created an on-line electronic atlas in 1996, with base maps ranging from Landsat data to large-scale digital orthophoto map products that are linked to various thematic data. The system is referred to as Maryland's Environmental Resources and Land Information Network (MERLIN), and public access is being planned for 1998.

Beginning in 1986, DNR's GI/GIS efforts have principally addressed the need for better wetlands map products, largely based on the state's Nontidal Wetlands Protection Act of 1989. The act was adopted in reaction to the perceived need of the state to increase its attention to activities in Chesapeake Bay. It allowed for DNR to become the wetlands permitting agency instead of the U.S. Army Corps of Engineers, as provided by Section 404 of the Federal Clean Water Act. A new series of wetlands maps was required to reflect wetlands of special state concerns, including those that have rare and endangered species or unique habitat types.

A project was initiated to meet the requirement of the act to provide guidance to property owners and permit investigators to help determine whether wetlands are present. While data have been primarily under development to help screen for wetlands permitting, they have also been used for various water resources applications, such as **watershed planning, water rights, and flood plain management,** as well as facilities siting. More than $3 million has been expended to complete this work for the entire state. This project has been conducted in coordination with other DNR units, the Office of Planning and MDE.

The first phase of the project merged SPOT 10-meter panchromatic image bases with National Wetlands Inventory data on wetland locations and commercially digitized roads, hydraulic features, and place names from 1:24,000-scale U.S. Geological Survey quadrangle maps. The Nontidal Wetlands Protection Act provided more than $380,000 for satellite data purchased under the project. The wetlands processing work was conducted



under contract with ***Salisbury State University's Image Processing and Remote Sensing Center.*** These maps are printed on-demand using electrostatic printers at the 1:24,000 scale.

The second phase of the project developed new digital orthophoto quarter quad maps at a scale of 1:12,000. Additional funding for this phase II was provided from the ***U.S. Environmental Protection Agency (EPA),*** the Coastal Zone Management Program of the ***National Oceanic and Atmospheric Administration (NOAA),*** and several counties. These maps are annotated with newly interpreted wetlands locations, critical areas, and 100-year floodplain boundaries. This phase of work has been conducted by Photo Science, Inc. Final maps are produced at a scale of 1:7,200. The initial work was conducted in Worcester and Carroll Counties. This project is nearing completion, with plans to update data on a 5-year cycle.

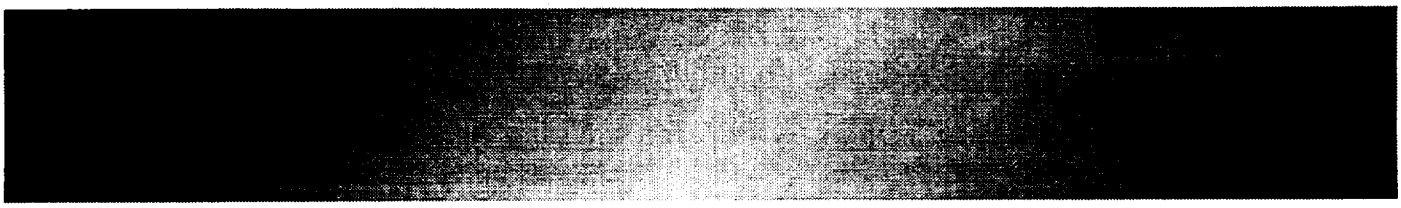
In addition to these watershed activities, DNR is also responsible for management of the forest, wildlife, natural heritage, and freshwater fishery resources of the state. Satellite data have been used in some of these efforts, such as forestry inventory efforts. In addition, DNR is conducting the GAP project for Maryland (see below).

Satellite data have also been used in other state activities. For example, efforts began in 1983 by the Governor's Office, MDE, the Office of Planning, DNR, and the Department of Agriculture to improve the quality of the coastal resource conditions of Chesapeake Bay. The Chesapeake Bay Program was initiated by EPA and the States of Maryland, Pennsylvania, and Virginia and the District of Columbia in 1983. The Clean Water Act specifically mentions the Chesapeake Bay project, which served as the Nation's first estuarine restoration effort of its size and has been a model for other estuarine projects. Various water quality models in the Chesapeake Bay and its drainage area, particularly the watershed model, are intensive users of GI/GIS. The Office of Planning's land-use/cover and other data were used to assist in these efforts and for additional purposes.

Gap Analysis Program Activities

The ***Fish, Heritage and Wildlife Administration*** of DNR is responsible for the Mid-Atlantic Gap Analysis Program (MidA-GAP), currently under way for the States of Maryland, Delaware, and New Jersey. Cooperative agreements were finalized with three museums to obtain data for vertebrate species modeling in 1995. Mammal data were also acquired from the University of Delaware's mammal collection. A memorandum of agreement was completed with the ***Delaware Natural Heritage Program,*** and a complete copy of their Biological and Conservation Database was obtained. As a result of this latest memorandum of agreement, the MidA-GAP now has Biological and Conservation Database data for its entire project area. A cooperative agreement was also entered into with the ***Birds of Delaware Publication Committee,*** and a complete digital copy of the *Breeding Bird Atlas* data has been acquired. Some butterfly data have been obtained, including Opler's county-based data (Stanford and Opler 1993) and data from the ***University of Delaware,*** and other data sets have been identified.

Several GIS coverages have been developed or acquired, including a coverage of Delaware Natural Heritage Program element occurrence locations, as well as a previously developed element occurrence coverage for New Jersey. The Biodiversity Research Consortium (hexagon) project is under way in Maryland and Delaware, with several draft range maps completed (see Master and Jennings 1993). Preliminary GIS data base structures have been designed for all vertebrate distribution coverages.



The University of Delaware has been actively involved. A graduate student is conducting a pilot project involving random sampling of vertebrates, including live trapping, in a variety of habitats within a small watershed in Delaware. A handheld GPS receiver is being used to record precise geographic positions of occurrences and attribute data about habitat features. Preliminary field work has yielded some bird and amphibian data, some of which have been converted to GIS coverages. Another University of Delaware student, working as an intern, will be conducting small mammal live trapping in another watershed. The data from these projects will be used in accuracy assessment. Volunteers from the University of Delaware's Wildlife Program spent 60 hours in the field using standard field data forms to collect data on vertebrate breeding and associated habitat.

In Maryland, a partnership project is developing protocols for "censusing" reptiles and amphibians in different physiographic provinces of the region. The data collected during the study will be used for accuracy assessment. Breeding Bird Survey route stops are being digitized for Maryland to make use of the survey data.

Expert reviewers have been found for the bird, herptile, butterfly, and bat models and distribution maps. Literature syntheses of habitat requirements have been completed, in a standardized format, for approximately 25 percent of all species to be modeled, and most of the remaining work will be completed this winter. MidA-GAP investigators in Delaware are involved in the development of a state desktop mapping, data base, and decision management system, which will eventually include GAP data sets.

The air video project began in late fall after working through unexpected hardware problems. The West Virginia GAP is conducting flights for MidA-GAP, and a second flight is planned for the spring of 1996 after leafout. Video will be instrumental in developing the vegetation maps using protocols as set forth by Slaymaker (in press) and others.

Landsat TM scenes needed to be re-registered after the registration accompanying the files was found to be off by more than 250 meters. All hyperclustered data received were registered, and work is under way to use them with the video. Preliminary land-cover maps were completed in 1996. MidA-GAP is working to collaborate on other projects in the region, such as the joint ***National Park Service–The Nature Conservancy*** effort to map vegetation for national parks. Opportunities to do more of these projects are expected as the vegetation mapping process proceeds.

Nonstate Government Activities

The ***University of Maryland at College Park*** worked with DNR, the Chesapeake Bay Foundation, the Eastern Shore Land Conservancy, and others on a cooperative project funded by NASA titled "Monitoring and Modeling the Dynamics of Coastal Marshes: A Regional Approach Using Landsat Data" (contact John Townshend). The ***University of Maryland at Baltimore County*** has also been active in remote sensing, including the development of a national curriculum for remote sensing, with funding from NASA (contact Tim Foresman).

The ***Virginia Institute of Marine Sciences*** participated in a Coastal Change Analysis Project (C-CAP) for the Chesapeake Bay Region with NOAA and the ***Oak Ridge National Laboratory.*** A land-cover classification was completed for a four-scene area using Landsat MSS data. Change detection work was conducted, also using some TM data, to develop data bases that are now available to the public. The institute has conducted photographic mapping of submersed vegetation for the entire Chesapeake Bay since 1978—and annually since 1984. The institute's methodology was used as a base for the C-CAP protocol.

The Image Processing and Remote Sensing Center at ***Salisbury State University*** has remote-sensing and GIS facilities and has worked with DNR regarding wetlands identification and forestry. While several of their efforts were for mapping production, during 1995 they changed their focus to educational and consulting services.

Towson State University and ***Frostburg State University*** have also been actively involved in using GIS and satellite data with state agencies. For example, Towson has worked with the Office of Planning to develop MDProperty view and hosts the annual Maryland GI/GIS conference (see above; contact Jay Morgan).

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Massachusetts

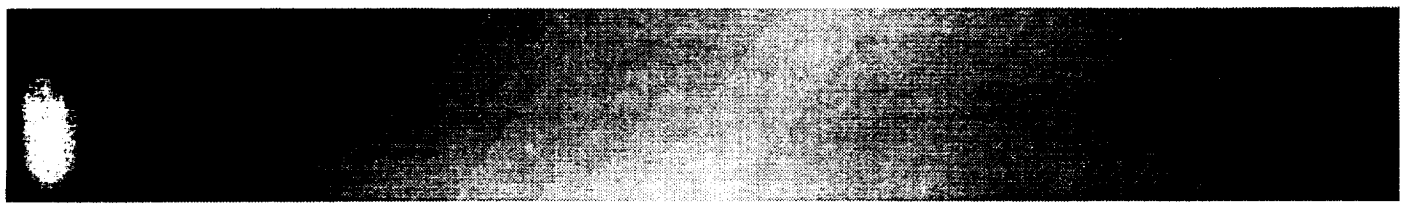
State GI/GIS and Satellite Data Contacts

* Christian Jacqz, GIS Manager
MassGIS
EOEA Data Center
Executive Office of Environmental Affairs
20 Sommerset Street, 3rd Floor
Boston, MA 02108
(617) 727-5227, ext. 309
(617) 227-7045 (fax)
cjacqz@state.ma.us

* Joseph Pelazarski
Coastal Zone Management Office
EOEA Liaison for Emergency Management
Executive Office of Environmental Affairs
100 Cambridge Street
Boston, MA 02202
(617) 727-9530, ext. 456

William DiLibero, GIS Program Administrator
Department of Environmental Protection
One Winter Street
Boston, MA 02202
(617) 556-1049

Elaine Socha
Strategic Planning Bureau
Information Technology Division
Executive Office for Administration and Finance
One Ashburton Place, Room 1601
Boston, MA 02108
(617) 973-0865
(617) 973-0761 (fax)
esocha@state.ma.us



Gap Analysis Program Contact

Dr. Curtice Griffin
Department of Forestry and Wildlife Management
University of Massachusetts
Amherst, MA 01003
(413) 545-2640
(413) 545-4358 (fax)
cgriffin@forwild.umass.edu

State Government Context

Massachusetts has had GI/GIS activities under way for more than a decade, and several state agencies now use GI/GIS. The state has an informal statewide GI/GIS coordination effort, and it does not have a office providing statewide GI/GIS coordination or services. However, most of the state's GIS activities are located at the ***Executive Office of Environmental Affairs (EOEA),*** and it has a central GI/GIS center, known as "MassGIS." This office is considered the unofficial GI/GIS coordination focal point within the executive branch of state government.

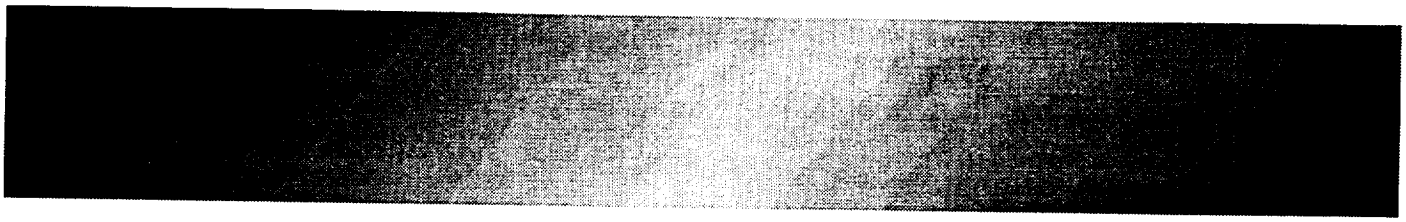
The ***Massachusetts Geographic Information Council (MGIC)*** is the leading GI/GIS coordination group in the state. It is an informal organization of representatives of several sectors in the state. EOEA has recently taken a leadership role to reinvigorate MGIC after a dormant period in 1996. Some executive orders and legislation have been proposed over the years to formalize coordination in the state, but no such directives have been adopted to date. Some efforts are under way again in 1997 to advocate legislation.

Satellite Data Use

Satellite data have had limited use in Massachusetts state government, although activities are under way at the University of Massachusetts (see below). However, EOEA is a comprehensive cabinetwide office including virtually all of the state's environmental and natural resources agencies, and it has made extensive use of GIS for more than a decade. It includes the Department of Environmental Management, the Department of Environmental Protection, the Department of Food and Agriculture, the Water Resources Authority, and the Coastal Zone Management Office, among others. EOEA's ***Research and Data Systems Office*** is responsible for maintaining information technology, and it includes EOEA's ***Data Center.*** "MassGIS" has been located at the Data Center since 1989, and it is used by its agencies and other users, such as regional planning commissions. Without a statewide GI/GIS focal point, MassGIS serves in this role on an informal basis (see above).

MassGIS maintains a core data base, provides cartographic production and analytic services to the Secretary's Office, distributes data to others, and provides training, project evaluation, and technical assistance to agency users. While satellite data has not been used by MassGIS, some EOEA agencies have shown an interest or requirement for additional software that will allow the inclusion of satellite data and advanced three-dimensional modeling capabilities that, for example, would assist in pollution dispersal modeling. A National Aerial Photography Program (NAPP) project was initiated, and a 1991 land-use data layer is under development by the ***University of Massachusetts*** at Amherst under a $400,000 contract with EOEA. The university is also a lead organization for the Gap Analysis Program (see below).

MassGIS and EOEA's agencies have developed various applications of GIS. Virtually all agencies of EOEA make use of GI/GIS. Many applications concentrate on water quality, supply, and management, including wetlands and coastal management. In addition, GIS has been used to monitor hazardous materials, depositories, and treatment.



EOEA's Office of Coastal Zone Management is working closely with the ***National Oceanic and Atmospheric Administration (NOAA),*** the ***U.S. Environmental Protection Agency,*** and various neighboring states, provinces, and other Federal agencies. Many of these efforts are intended to improve conditions in the Gulf of Maine. The Office of Coastal Zone Management has chaired the Gulf of Maine Data and Information Management Committee and is working with the ***Department of Environmental Protection,*** NOAA, and the NMFS Beaufort Laboratory on a Coastal Change Analysis Project (C-CAP) for the border of Maine and New Brunswick.

Gap Analysis Program Activities

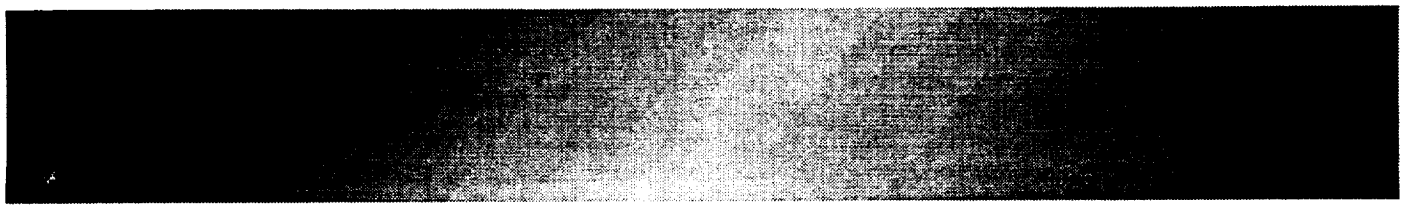
The University of Massachusetts and the ***Massachusetts Cooperative Fish and Wildlife Research Unit*** are cooperating with the Vermont and Maine Cooperative Fish and Wildlife Research Units in the New England Gap Analysis Program (GAP). New England GAP work is expected to be completed in 1997. A primary focus of the Gap Analysis activities in Massachusetts has been the development of a systematic approach for mapping deciduous forests. The New England landscape is 50 to 95 percent forested, with a wide variety of forest types occurring in relatively small stands interspersed throughout the region. These regional vegetation characteristics pose new challenges for developing an efficient and reliable methodology for developing base vegetation maps in New England and for much of the eastern deciduous forested region of the United States.

The approach has been to use hyperclustered, multitemporal Landsat TM data in combination with aerial videography. The Multi-Resolution Land Characteristics Program provided staff with 12-band hyperclustered TM images that combined spring and summer coverages. Ground reference of vegetation cover was obtained from a grid of large-scale GPS-logged videography flown over the region. Video data were collected along a 20-kilometer grid pattern using two Super 8 video recorders mounted on a Cessna 172. One video camera was set at wide angle, the other at 12x zoom, providing a swath of 30-meter-wide large-scale satellite data down the middle of a 0.4-kilometer wide-angle coverage when flying at 600 meters above ground level. The GPS time code was recorded onto the video images and the audio track.

After developing a visual key of forest types obtained from video prints and field visits to training sites, the flight line was displayed over the hyperclustered image. The corresponding video images were used to label the vegetation at nearly 18,000 sample points from approximately 2,300 locations. Thirty natural community alliances were identified. Through an iterative process, inference rules were developed, and the image was classified. Accuracy was determined by an error matrix using a stratified subsample of video points that had been set aside during the video interpretation phase. The overall accuracy for all classes was nearly 90 percent.

The hyperclustered TM image seems to represent a considerable improvement in the discrimination of spectral classes, especially in forested regions. Furthermore, GPS-logged aerial videography provides a time- and cost-efficient method for obtaining sufficient samples of ground-truthed data to label the spectral classes in the TM scene. A measure of this methodology's usefulness is its applicability to other Gap Analysis projects. Training workshops have been conducted, interpretation systems have been set up, or aerial videography has been flown for GAP projects in nine states. Regional workshops in the Northeast are ongoing to standardize video interpretation criteria, vegetation classification, and species habitat models.

The Massachusetts GAP team also continues to be involved with international initiatives in biodiversity inventory, cooperating with projects in Romania,



Madagascar, Portugal, the Ukraine, and Mexico. Efforts are centering on providing technical tools and training to small groups of foreign scientists and the development of GIS-based products that contribute to their conservation planning needs. Goals focus on the rapid development of in-country GIS capabilities, making critical data available for resource management decisions and strengthening institutions within these host countries.

Nonstate Government Activities

The University of Massachusetts at Amherst is working with the state to develop a land-cover data base and on the GAP project (see above). Additional satellite data activities are also under way.

The ***University of New Hampshire*** processed Landsat data and prepared land-cover data for the part of Massachusetts that is in the Merrimack River Basin. These data are compatible with data under development by the university for the State of New Hampshire (see under New Hampshire).

Michigan

State GI/GIS and Satellite Data Contacts

* Michael N. Beaulac, Manager
Michigan Resource Information System (MIRIS)
Real Estate Division
Department of Natural Resources
530 West Allegan
P.O. Box 30028
Lansing, MI 48909
(517) 335-3445
(517) 335-3131 (fax)
beaulacm@dnr.state.mi.us

* Frank Sapio
Forest Management Division
Department of Natural Resources
P.O. Box 30028
Lansing, MI 48909
(517) 335-3347

* Mike Donovan
Wildlife Division
Department of Natural Resources
P.O. Box 30028
Lansing, MI 48909
(517) 373-7027

* Maynard Dyer
Survey and Remonumentation Commission
Department of Consumer and Industry Services
6546 Mercantile Way
P.O. Box 30222
Lansing, MI 48909
(517) 334-7369
(517) 334-7813 (fax)

* Eric Swanson, Director
Michigan Information Center
Department of Management and Budget
320 S. Walnut
P.O. Box 30026
Lansing, MI 48909
(517) 373-7910

Gap Analysis Program Contact

Frank D'Erchia
Environmental Management Technical Center
USGS Biological Resource Division
575 Lester Avenue
Onalaska, WI 54650
(608) 783-7550, ext. 11

(608) 783-8058 (fax)
frank_derchia@nbs.gov

State Government Context

Michigan has an informal statewide GI/GIS coordination effort because it does not have a state office providing statewide GI/GIS services. The majority of GI/GIS activities, and the informal lead for GIS in Michigan's state government, has been located in the ***Department of Natural Resources (DNR)*** for over a decade. Other agencies also have GI/GIS activities.

The ***IMAGIN (Improving Michigan Access to Geographic Information Network) Consortium*** is the state's GI/GIS coordination group, although it not have an official status within state government. IMAGIN includes voluntary participation of representatives of several state and other agencies. IMAGIN has several projects under way, including development of an online library of digital data for Michigan.

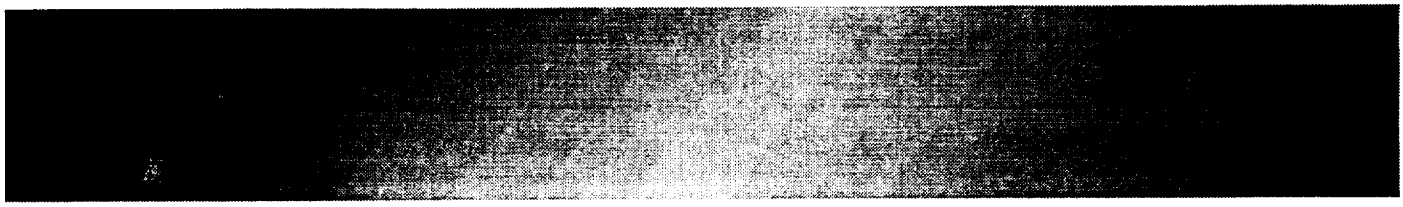
Michigan also has the ***Survey and Remonumentation Commission,*** which was created and funded by the Legislature in 1990 to develop a statewide land surveying information base. It provides grants to counties to conduct remonumentation of the original public land survey corners that serve as the basis for all public and private property locations in Michigan. In addition, the ***Michigan Information Center*** in the ***Department of Management and Budget*** is providing access to and management of socioeconomic data including TIGER for use by state entities.

Satellite Data Use

The majority of GI/GIS and satellite data activities have been located in DNR. This agency was a comprehensive agency, including almost all of Michigan's natural resources and environmental protection programs until 1996. At that time, the environmental and regulatory part of DNR was moved to the new ***Department of Environmental Quality.*** Several internal changes were also made within DNR. The Michigan Resource Information System (MIRIS), the focal point of DNR's GI/GIS activity, was moved into DNR's ***Real Estate Division*** in 1996. MIRIS serves as a data clearinghouse and provides assistance to others, particularly counties. MIRIS has an annual budget of more than $1 million.

MIRIS includes the Michigan Resource Information Program, which was established in 1979 by the 1979 Michigan Resource Inventory Act. The focus of the act and program has been to provide counties with useful information for their internal needs. MIRIS also includes the Great Lakes Information System (GLIS), the Statewide Groundwater Data Base (SGDB), and the Statewide Aerial Photography Program. The primary mission of MIRIS, as stated in the legislation, is the development and maintenance of a statewide inventory of land and water resources, including a land-cover/use data base. GLIS has served as a clearinghouse and source of information about the Great Lakes since 1985, sharing facilities and personnel with MIRIS and having partial funding from the Coastal Zone Management Act administered by the ***National Oceanic and Atmospheric Administration (NOAA).***

MIRIS's digital land-cover/use data was initially developed from 1978–79 1:24,000-scale leaf-on color infrared photography for the entire state and is available on a county basis. A 60-part classification system, consistent with the classification scheme of the U.S. Geological Survey (USGS), was used to identify land-cover/use activities. A statewide aerial photography mission was conducted to update these data beginning in 1986. MIRIS staff have developed some land-cover/use updates by comparing aerial photographs with available satellite



data. Some county governments are developing digital data from newer photography, using MIRIS's methodology, and are providing these updates to MIRIS. Three county governments have provided satellite data to MIRIS (see below for Alpine Township).

MIRIS jointly developed C-MAP, a microcomputer-based software program, with Michigan State University's Center for Remote Sensing. MIRIS uses C-MAP for spatial and nonspatial data entry, display, update, and analysis at the microcomputer level. MIRIS, in fulfilling its mission to assist local governments, began installing C-MAP hardware/software systems in localities in 1986. C-MAP allows local users to load MIRIS data layers, such as land cover, land use, and soils, for the processing, display, and building of their own data layers in low-cost microcomputer environments. The program enables localities to enhance and update data files.

DNR's ***Forest Management Division*** and ***Wildlife Division*** recently acquired and processed Landsat data to develop **land-cover** data for the Upper Peninsula of Michigan (about half the state). The satellite data were initially used to assist in **forest** inventory and related efforts and to monitor **wildlife** and their habitat, particularly deer. After some work was completed for some of the Upper Peninsula, it was decided to expand efforts for other habitat analysis and additional forestry applications. These data have also been used to assist in DNR's **pest management** efforts. Some efforts have been made to compare these data with the MIRIS land-cover data derived from aerial photography as described above. Additional work is under way to process satellite data with similar objectives for other parts of the state.

Gap Analysis Program Activities

The Upper Midwest Gap Analysis Program (UM-GAP) has been under way at the ***Environmental Management Technical Center (EMTC)*** of the ***USGS Biological Resource Division.*** This work is for Michigan, Minnesota, and Wisconsin and has been some of the most extensive and well-funded of the Nation's GAP efforts. Landsat TM scenes necessary for classification of actual vegetation of the three states were reviewed at EMTC for quality control and were converted to an ERDAS Imagine format before being distributed to state partners. The ***Minnesota and Wisconsin Departments of Natural Resources*** are in the process of classifying scenes for their states. Michigan is soliciting contractual support to classify the northern half of the Lower Peninsula. EMTC will retain responsibility for classifying the Upper Peninsula of Michigan and has recently begun that effort. UM-GAP coordination efforts now also include Illinois, and EMTC is working with Indiana and Iowa to encourage regionally compatible vegetation classifications. A series of meetings to promote that effort was held this past winter.

The ***USDA Forest Service*** has contributed to the UM-GAP vegetation mapping effort by assisting in the acquisition of additional TM data for the Lower Peninsula of Michigan. The Forest Service's Great Lakes Assessment will benefit from the use of UM-GAP-developed GIS coverages of current vegetation and predicted species distribution. In addition, the North Central Forest Experiment Station has signed a memorandum of understanding with EMTC to share TM data and Forest Inventory and Analysis (FIA) plot data. The Forest Service will use the satellite data to georeference the FIA plots, and UM-GAP will use FIA plot information for accuracy assessment.

In an effort to develop a uniform, current vegetation map for the Upper Great Lakes Region of the United States, UM-GAP has developed a common image-processing protocol and a common classification scheme for Michigan, Minnesota, and Wisconsin. The classification

scheme was developed in accordance with national GAP standards, following The Nature Conservancy/UNESCO design. The protocol was developed at the ***Environmental Remote Sensing Center, University of Wisconsin–Madison,*** in cooperation with the ***GEO Services Division*** of the Wisconsin Department of Natural Resources. Technical approaches of the protocol include (1) use of multidate TM scenes, (2) use of GIS-assisted preclassification stratification into urban/nonurban and upland/lowland categories, (3) use of an extendible classification scheme that can be cross-walked to other classification systems, (4) preclassification stratification of scenes into spectrally consistent geographic subscenes based on ecoregion boundaries, (5) use of guided clustering techniques for the classification of nonurban uplands, and (6) use of geographically stratified, systematic, nonaligned sampling for the collection of training and accuracy assessment data. UM-GAP also will be testing the aerial videography system acquired by the national GAP office for the acquisition of training site and accuracy assessment data.

The protocol, in a compressed Postscript format, can be downloaded from EMTC's anonymous FTP site *(ftp.emtc.nbs.gov/pub/misc/umgap/protocol.zip)*. In an effort to coordinate TM scene classification among UM-GAP's three state partners, EMTC has also established an e-mail technical discussion list *(umgap-tech@emtc.nbs.gov)*. By using the list to discuss TM scene-processing issues, state partners are sharing experiences in solving problems with corner coordinates, file headers, and software and are saving much time, frustration, and duplication of effort.

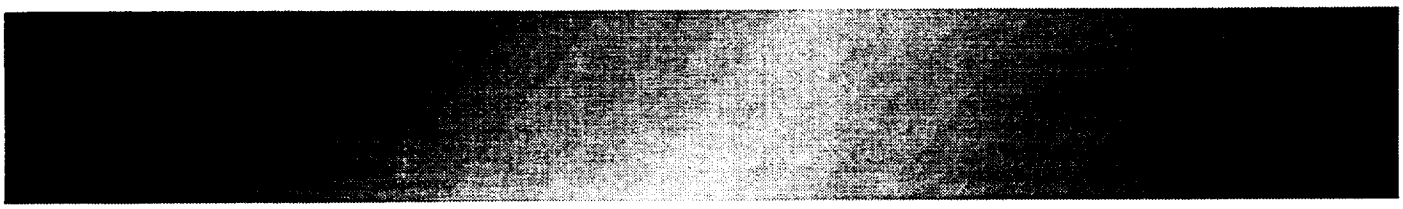
UM-GAP has also established a home page on the World Wide Web *(http://www.emtc.nbs.gov/umgaphome.html)* The image-processing protocol can also be retrieved directly from that page. A false color infrared composite of the Landsat TM satellite data covering the Chippewa Plains Ecoregion Subsection in Minnesota is also available through the UM-GAP home page. The coverage is available as single-band ERDAS Imagine files, clipped to 1:100,000-scale USGS quadrangles. The files can be used as image backdrops in GIS programs, including ARC/INFO. These files have been used to assist in the delineation of land-type associations, the ecoregion unit below the subsection level.

A unified regional effort to develop species-habitat associations and predicted vertebrate distributions is being coordinated by EMTC with the University of Wisconsin–Madison, providing technical assistance and oversight. A committee has been formed to oversee this effort, with membership including representatives of the USDA Forest Service, the USGS Biological Resource Division, and the Michigan, Minnesota, and Wisconsin Departments of Natural Resources. In addition, UM-GAP is working with Illinois, Indiana, and Iowa in exploring the potential for a larger regional effort to map predicted species distributions.

Nonstate Government Activities

The Center for Remote Sensing at ***Michigan State University*** has worked closely with DNR. For example, it maintains and sells licenses for the C-MAP software that was jointly developed by both organizations (see above). Work has also begun with the ***Environmental Research Institute of Michigan,*** a nonprofit corporation in Michigan that works with satellite data.

The ***Consumers Power Company*** owns and operates six dams in the Au Sable River Basin in Michigan that provide hydroelectric power for electric utility. It used Landsat TM data and GIS to enhance the accuracy of factors used to estimate flooding and to calculate the probable maximum flood within a river basin. Several other studies estimated floods requiring dam upgrades with a cost of up to $10 million, so the company initiated this study to more accurately determine whether the



upgrades were needed. The company hired Mead and Hunt, Inc., which had developed a method to use satellite data and GIS to determine estimated floods. Probable maximum flood is calculated by determining probable maximum precipitation for the basin, simulating the interaction of rainfall with ground cover and underlying soils, and then running a rainfall-runoff model to determine the spatial and temporal effects of the resulting flood. Probable maximum precipitation is determined by using data about peak rainfall collected by the National Weather Service. While several methods can be used to model the interaction of rainfall with a basin's ground cover and soils, the project used a method developed by the Soil Conservation Service that uses a runoff curve number to define the runoff of a thoroughly wetted soil. Landsat TM data were used to determine cover and some indication of soil type. Meteorological data were correlated with dates of satellite data. ERDAS software was used. This method removed much uncertainty in determining the runoff curve number, and it estimated a probable maximum flood value of less than half of other methods, resulting in less need for the expensive upgrades.

Researchers at the Water Resources Institute at ***Grand Valley State University*** in Allendale helped the ***Alpine Township*** in Michigan use Landsat data with GIS to help make **land-use planning** decisions. A system was developed to encourage local decision makers to consider appropriate watersheds in these decisions. An analysis for the area including ***Kent County*** was conducted with funds provided by the U.S. Environmental Protection Agency through Section 319 of the Clean Water Act and administered by the Michigan DNR. A primary goal of this funding is the control of nonpoint source pollution. DNR's MIRIS data and Landsat data were used with stormwater runoff models. The system allows township officials to make queries about specific properties and their potential to generate runoff to make improved decisions regarding land use and zoning.

References

Fry, Ed, and Denning, Rod, "Michigan Township Uses Watershed-Based Decision-Support System," *Geo Info Systems* (September 1995): 55–57.

Mettel, Carson, "GIS and Satellite Images Provide Precise Calculations of Probable Maximum Flood," *Geo Info Systems* (June 1992): 43–48.

Minnesota

State GI/GIS and Satellite Data Contacts

* David Arbeit, Director
* Chris Cialek, Data Management and Operations Supervisor
Land Management Information Center
MN Planning
330 Centennial Building
658 Cedar Street
St. Paul, MN 55155
(612) 297-1211
(612) 296-1212 (fax)
chrisc@lmic.state.mn.us

* Les Maki
GIS and Data Manager
Management Information Services Bureau
Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55155
(612) 297-7877

* David Heinzen
Resource Assessment Unit
Division of Forestry
Department of Natural Resources

2002 Airport Road
Grand Rapids, MN 55744
(218) 327-4449

* Tim Wahl
Geological Survey
2642 University Avenue
St. Paul, MN 55114
(612) 627-4787

Gap Analysis Program Contact

For Minnesota and Wisconsin, see under Michigan.

State Government Context

Minnesota has a longer history and level of GI/GIS activity than most states. It also has perhaps the most extensive data resources for use with GIS compared to any other state, with more than $10 million spent to date on these data. As compared to other states, much data development is uniquely funded by a legislative committee, the Legislative Commission on Minnesota Resources. Much of this work has been conducted by the ***Land Management Information Center (LMIC),*** which has existed since 1977 and serves as the official statewide GI/GIS center according to an executive order signed in 1991.

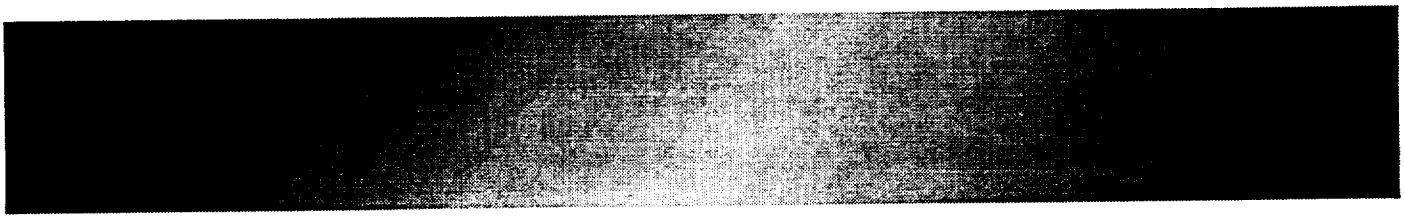
Minnesota also has two active GI/GIS coordination groups. It has a ***Governor's Council on Geographic Information,*** which was established by the same executive order. Composed of members from various sectors whom have been approved by the Governor's Office, the council provides policy direction for the state regarding GI/GIS activities. The state also has a ***GIS/LIS Consortium,*** which complements the council's coordination efforts. The consortium includes many users of GI/GIS from various sectors in the state. It prepares a state GI/GIS newsletter and sponsors an annual GI/GIS conference.

Satellite Data Use

While Minnesota has extensive GI/GIS activities in several agencies, satellite data work is primarily conducted for natural resources management. LMIC serves as the official statewide GI/GIS center. With more than a $1.5 million annual budget and 20 staff members, LMIC is one of the largest GI/GIS organizations among the states. It is currently located in the ***State Planning Agency*** and has provided GIS and related services for public agencies since 1977. With other agencies, LMIC has developed, managed, and provided access to much data and has developed many GIS applications used by various agencies.

LMIC has not used satellite data for internal purposes, but consideration is being given to acquire some satellite data and use them as a base for land-cover delineation for the state's northern lands. Minnesota has been evaluating similar work conducted in Manitoba and may initiate a similar process. Minnesota is in the process of developing statewide digital orthophoto quads and statewide coverage at the 1:24,000 scale for digital elevation model data. With funding provided by the state, the ***USDA Forest Service,*** the ***USDA Natural Resources Conservation Service,*** and the ***U.S. Geological Survey,*** these data are expected to be completed in 1997.

The ***Department of Natural Resources (DNR)*** is Minnesota's primary natural resources management agency and has been the state's primary user of satellite data. DNR includes the Divisions of Water, Minerals, Forestry, Parks and Recreation, and Fish and Wildlife, among others. DNR is also responsible for managing most state-owned lands in Minnesota, which form the third largest holdings of state land of any state in the country. DNR has a departmentwide GI/GIS coordination effort and has had several GI/GIS efforts under way since the late 1960s. Similar to LMIC, much data development has



been funded by the Legislative Commission on Minnesota Resources. Most early and current GIS applications have been related to forestry and wildlife.

The primary use of remote sensing has been for forestry applications in the ***Division of Forestry.*** This division, as with all state forestry entities in states, conducts a forest inventory in coordination with the USDA Forest Service. However, Minnesota has uniquely used satellite data to assist in this effort. Participants in this work have included the Forest Service and the ***Department of Forest Resources*** of the ***University of Minnesota,*** among others. Change detection has been possible by comparing the satellite data with aerial photography used in past forest inventory efforts. In one example, Landsat TM data were used to classify and estimate the acreage of forest cover types in northeastern Minnesota, covering about five counties. Classification accuracies of up to 75 percent were achieved, with most misclassification between similar or related satellites. Resulting area estimates for total forest land was within 3 percent of the estimate made independently by the Forest Service. With these benefits, project results have been the basis for implementing an annual system of forest inventory that uses Landsat TM data to detect changes in forest cover.

The ***Geological Survey*** is one of the many agencies that has contracted with LMIC for services and received funding for specific projects from the Legislative Commission on Minnesota Resources. For example, a county geological mapping effort was initiated in 1992. A aeromagnetic survey was previously initiated as a $3 million dollar project to conduct an inventory of subsurface geophysical conditions conducted by remote-sensing methods to determine magnetic and gravity anomaly.

Gap Analysis Program Activities

For Minnesota and Wisconsin, see under Michigan.

Nonstate Government Activities

The ***University of Minnesota at St. Paul*** has been conducting some remote-sensing work for forestry applications with DNR (see above). The ***University of Minnesota at Duluth*** has a Center for Water and the Environment in its Natural Resource Research Institute. Remote sensing and GIS are used at the institute to research a variety of natural resource topics, including **wildlife biological and ecological monitoring** to encourage diversity. For example, in a project with DNR, land-cover and vegetation mapping of the forested region of the state was used and analyzed with field and historic data to relate bird populations to changes in forest types and their extent over the landscape. Protocols for monitoring birds and techniques for predicting large-scale change in forests and bird populations were developed. The center has also conducted related work in forested areas of Wisconsin.

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Mississippi

State GI/GIS and Satellite Data Contacts

* Paul Davis, Director
Mississippi Automated Resource Information System (MARIS)
Institutions of Higher Learning
3825 Ridgewood Road
Jackson, MS 39211
(601) 982-6354
(601) 987-5587 (fax)
Paul@supernova.ihl.state.ms.us

Claud Johnson
Strategic Services Director
Department of Information Technology Services
301 North Lamar Street
Jackson, MS 39201
(601) 359-1395
(601) 354-6016 (fax)

James E. Maher, Director
Emergency Management Agency
P.O. Box 4501
Fondren Station
Jackson, MS 39296-4501
(601) 352-9100
(601) 352-8314 (fax)

Gap Analysis Program Contact

Dr. Francisco Vilella
Rich Minnis
Cooperative Fish and Wildlife Research Unit
Mississippi State University
Dorman Hall
P.O. Drawer BX
Mississippi State, MS 39762-5604
(601) 325-0784

State Government Context

Mississippi has had an official statewide approach to GI/GIS and remote sensing since the early 1980s. The ***Mississippi Automated Resource Information System (MARIS),*** located in the Mississippi Institutions of Higher Learning, serves as a statewide service center for GI/GIS, including satellite data, and also staffs statewide GI/GIS coordination efforts. MARIS was formally established in 1983 and authorized by the legislature in 1986. It provides data management and access for use with GIS, and GI/GIS services are conducted for several state and other agencies.

GI/GIS coordination in the state is accomplished by two groups, the ***MARIS Policy Committee*** and the ***MARIS Task Force,*** and both groups direct and operate MARIS. These groups were also established by the legislation adopted in 1986. While the statute does not identify types of geographic information, the membership of the task force specifically includes the Remote Sensing Center at Mississippi State University.

Satellite Data Use

Mississippi has a long history of using satellite data compared to other states. MARIS provides GI/GIS coordination and GI/GIS services for various natural resources and environmental projects. Over the years, several of these projects have used satellite data. MARIS also manages and disseminates data. It formed and maintains a library of satellite data collected through the use of satellite data for projects, as well as statewide land-cover data derived from satellite data.

MARIS recently updated land-cover data for the state at 5-acre resolution using Landsat TM data. MARIS purchased statewide coverage through EOSAT's State Coverage Program in 1993 to conduct this work. Mississippi received a grant from the ***U.S. Environmental Protection Agency*** (as have other southeastern states in EPA's Region 4) to fund the processing of these data to monitor change as needed for wetlands protection efforts for the state (and the entire region). This work was completed in 1995.

MARIS has had a variety of projects under way over the years that have used satellite data and GIS, many with state and Federal agencies. Involved state agencies include the ***Department of Environmental Quality,*** the ***Mississippi Forestry Commission,*** the ***Department of Wildlife, Fisheries and Parks,*** and the ***Department of Transportation.***

Several GI/GIS, remote-sensing, and image-processing projects have been conducted with the ***USDA Natural Resources Conservation Service (NRCS)*** since 1978. Most of these projects are conducted for NRCS's River Basin staff to update land use and produce crop and soil inventories and for GIS modeling for different soil types. For example, Landsat images from the growing season and the winter were analyzed using ERDAS software to produce a map of general land use and crop types for the drainage area of Moon Lake in Coahoma and Tunica Counties. Similar projects are under way or planned in the Big Creek, Upper Leaf River, and Tangipahoa River watersheds. In the first two project areas, the analysis was limited to the floodplain areas of the streams and their tributaries. The Tangipahoa River project encompasses the entire watershed and serves as the basis of a cooperative project with NRCS and DEQ.

MARIS has also been conducting work with satellite data with local governments. For example, it has helped the ***Tax Assessor's Office of Pike County, Mississippi,*** develop a sophisticated GIS to maintain property records and related data needed to perform regular tax appraisals of property in the county. Forest cover is an important factor in determining the value of rural property. The Tax Assessor's Office used a system of sketching forest cover from aerial photography and digitizing into its GIS. In an effort to streamline this process, the office contacted MARIS about the potential of using Landsat TM digital data for this purpose. TM imagery contains seven spectral bands of data with a spatial resolution of 30 meters.

As shown in Figure B4, MARIS classified the imagery into four categories: forest, brushland (cut area), nonforest, and water. Paper maps and digital data were provided to Pike County for review. Staff from the Tax Assessor's Office intensively reviewed the data in the field and found them highly accurate. In fact, the only inconsistencies found were two adjacent recently harvested soybean fields that had been classified as forest.

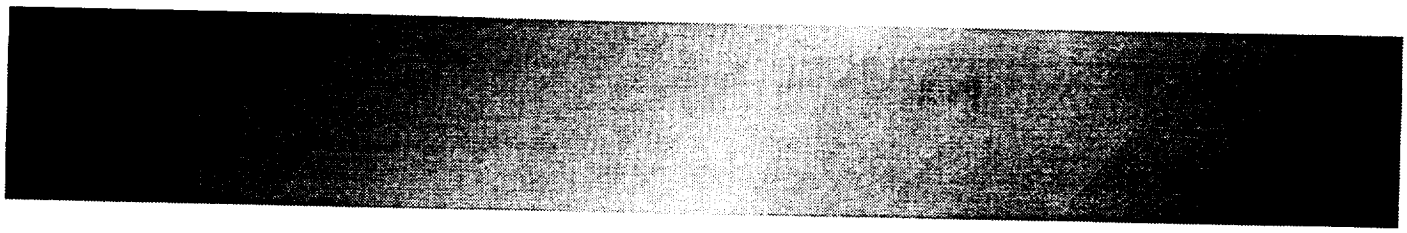
This Landsat-based forest cover is now used for all rural tax appraisals in Pike County. As more people became aware of this data source, the Tax Assessor's Office has received requests for paper copies of the map. One unique use for the data was by the county game warden. He uses the forest cover map to locate clearings that cannot be seen from the road to help apprehend persons hunting illegally. Commercial foresters have used the maps to assist them in locating land for purchase, and the county civil defense office has obtained copies to assist in fire prevention and search-and-rescue responsibilities.

Forest Cover of Pike County, Mississippi



Figure B4

This map of forest cover in Pike County, Mississippi, was developed from Landsat TM. It was initially used by the Tax Assessor's Office for property appraisals and has been requested by the county game warden, commercial foresters, and the civil defense office. (courtesy of Walter Belokon, Mississippi Automted Resource Information System, (601) 982-6353)



The ***Mississippi Emergency Management Agency (MEMA)*** has contracted with MARIS since the mid-1980s for various GI/GIS and remote-sensing activities. For example, MEMA used GI/GIS to help assist in and plan evacuations and other operations near **nuclear powerplants** in preparation for potential disasters, with initial funding from a utility. During the 1980s, MEMA contracted with MARIS to produce maps of land-use patterns using remote sensing to assist in preparing for nuclear plant disasters. This work was conducted for areas within a 50-mile radius of the Grand Gulf Nuclear Power Station in Mississippi and the River Bend Nuclear Power Station in Louisiana for emergency preparedness programs. MEMA has considered developing more internal GIS and remote-sensing capability and direct access to MARIS data for various projects, such as to address potential earthquakes.

Significant GI/GIS and remote-sensing assistance has been provided to the Mississippi Forestry Commission for several **forestry** applications, including **wildfire** response, planning, and management, as well as forest inventory, analysis, and management uses.

The Pearl River Advanced Identification Wetlands Assessment Project was conducted by the Vicksburg office of the ***U.S. Army Corps of Engineers*** and EPA, in cooperation with MARIS, to identify **wetlands** in the Pearl River Basin near Jackson, Mississippi, to assess areas suitable or not suitable for development. Previously, MARIS conducted an inventory of land use in the Pearl River Basin in Mississippi and Louisiana for the ***Center for Wetland Resources at Louisiana State University.*** Landsat data were used to produce maps of the area.

MARIS has also conducted satellite data work in collaboration with the Space Remote Sensing Center (SRSC) at ***NASA's Stennis Space Center*** and the Remote Sensing Center at ***Mississippi State University*** (see below).

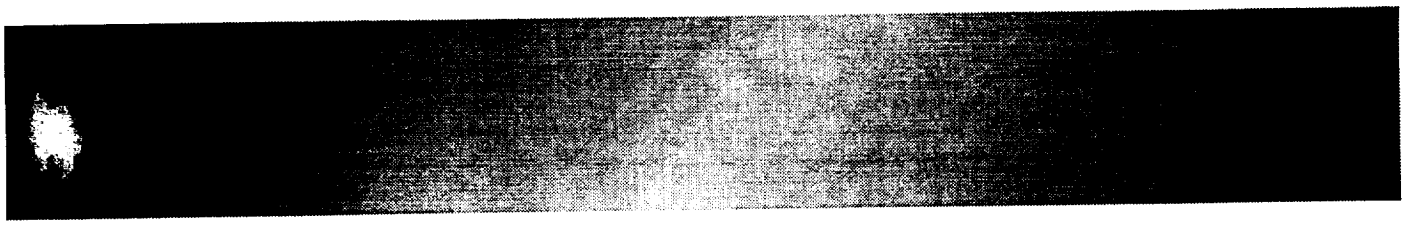
Gap Analysis Program Activities

The ***Cooperative Fish and Wildlife Research Unit*** at Mississippi State University received initial funding in fiscal year 1997 to begin the Gap Analysis Program (GAP) for the state. Efforts are under way with NASA's Stennis Space Center in this regard.

Nonstate Government Activities

Stennis Space Center's SRSC has conducted a variety of remote-sensing work on a contract basis for state and other agencies, as well as the private sector. For example, it has had grant funding from NRCS to test the use of satellite data for wetlands mapping. The benefit of this approach is to reduce the time spent and improve the accuracy of locating wetlands as compared to aerial photography. It also has conducted some work for localities on **transportation** siting projects.

SRSC received national attention in 1993 because it produced satellite images to show the progression of the **Midwest floods of 1993** between May and August. Images from SPOT and the European Radar Satellite were merged to illustrate underlying terrain. The radar data, collected by penetrating cloud cover, were centered around the confluence of the Mississippi, Illinois, and Missouri Rivers. Conventional satellites had been hampered by the persistent cloud cover over the Midwest. The radar images were used by the U.S. Army Corps of Engineers, the ***National Oceanic and Atmospheric Administration,*** and the Illinois Department of Energy and Natural Resources (now ***Illinois Department of Natural Resources***). Other SRSC work includes use of Advanced Very High Resolution Radiometer (AVHRR) data to assess the flood's impact on agriculture. County-level estimates of crop damage were generated for use in crop insurance and commodity programs.



Mississippi State University has a Remote Sensing Center that has conducted satellite data work for various applications, including forestry and environmental assessment. The university was recently designated as the lead for the GAP work in Mississippi (see above).

Missouri

State GI/GIS and Satellite Data Contacts

* Ryan Burson, State Demographer
Division of Budget and Planning
Office of Administration
Capitol Building, Room 124
P.O. Box 809
Jefferson City, MO 65102
(573) 751-9318
(573) 526-4811 (fax)
rburson@mail.state.mo.us

* Jack Stewart
GIS and Database Administrator
Department of Natural Resources
205 Jefferson
P.O. Box 176
Jefferson City, MO 65102-0176
(573) 751-1850
(573) 751-7749 (fax)
jstewart@mail.state.mo.us

* Tim Haithcoat, Director
Spatial Data Information Service
University of Missouri
18 Stewart Hall
Columbia, MO 65211
(314) 882-2324
(314) 884-4239 (fax)
grctlh@mizzou1.missouri.edu

* Dr. David Diamond, Director
Missouri Resource Assessment Partnership
Environmental Technology Center
University of Missouri
4200 New Haven Road
Columbia, MO 65201
(573) 876-1862
(573) 876-1896 (fax)
david_diamond@nbs.gov

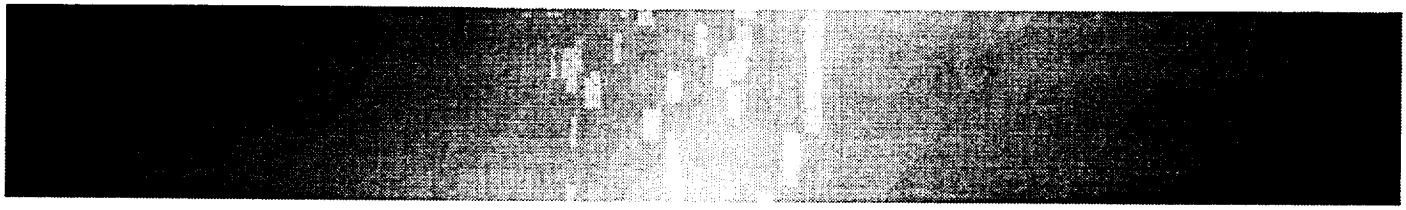
Gap Analysis Program Contact

* Dr. David Diamond, Director
Missouri Resource Assessment Partnership
Environmental Technology Center
4200 New Haven Road
Columbia, MO 65201
(573) 876-1862
(573) 876-1896 (fax)
david_diamond@nbs.gov

State Government Context

Missouri has been actively developing a statewide GI/GIS coordination effort in recent years. A central agency had not had a leading role regarding GI/GIS until 1996, after a new Office of Information Technology (OIT) was established in 1995. A new ***GIS Advisory Group*** and a ***GIS Technical Advisory Committee*** were organized in 1996. The GIS Advisory Group reports to the new Information Technology Planning Board that was created at the same time as OIT. It is chaired by the state demographer, located in the Division of Budget and Planning of the ***Office of Administration.***

The ***Missouri Spatial Data Information Service (MSDIS)*** was recently established at the Geographic Resource Center of the ***University of Missouri.*** The legislature authorized and funded MSDIS in 1995 to serve



as a clearinghouse for data to be used with GIS and to provide GI/GIS services to state and other agencies. It acquired several Federal data sources and is acquiring and providing access to data resources from others, such as state agencies. MSDIS staff are working with the new committees and developed a GI/GIS plan for the state.

The ***Missouri Resource Assessment Partnership (MORAP),*** with staff also located at the University of Missouri, is an interagency initiative among state, Federal, and other entities to coordinate resource management activities. This group also uses GI/GIS and remote sensing.

Satellite Data Use

Missouri state agencies have had limited use of satellite data to date. MSDIS is recently under development and has not made satellite data a focused part of its work (see above). However, the state also has MORAP, which is using satellite data with GI/GIS. MORAP is an interagency initiative including state and Federal agencies and other entities. It was formed to bring together the expertise and resources of multiple entities to develop and provide the information and technical assistance needed for comprehensive state-level resource assessment, scientific planning programs, and biodiversity protection. MORAP is coordinating several resource management activities; it used Landsat TM data to help develop land cover and other information for the state.

The ***Department of Conservation (DOC)*** and the ***Highways and Transportation Department*** are leading participants in MORAP from state government. Others involved in MORAP include field offices of several agencies in the ***U.S. Departments of the Interior and Agriculture.*** Support for these efforts is provided through staff located at the University of Missouri's Environmental Technology Center. The MORAP office also serves as the lead agency for the Gap Analysis Program (GAP) for Missouri.

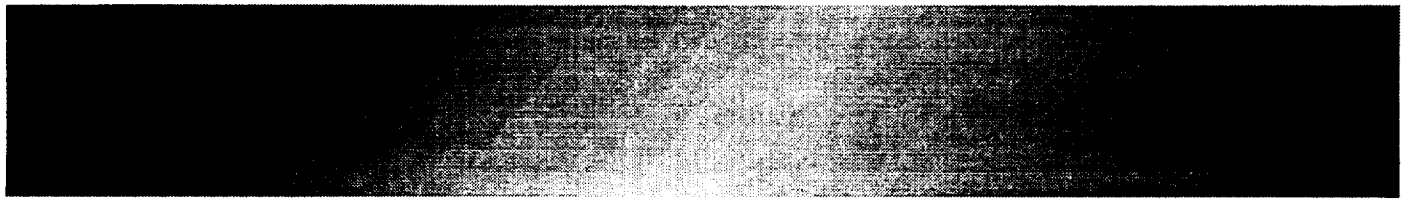
In addition to DOC, the ***Department of Natural Resources (DNR)*** and the ***Department of Health*** are the leading environmental and natural resources agencies in Missouri. All three agencies use GI/GIS, and both DNR and DOC have a designated staff member who serves as their department's GIS coordinator. However, satellite data have only been used on a limited basis within these agencies. DNR has conducted some investigation of the potential use of data, such as Landsat TM to help identify wetlands sites and features.

Gap Analysis Program Activities

Missouri's GAP has been integrated into and is being conducted with MORAP and managed at the University of Missouri. All of the TM data for the state were received in 1995, and PCI image-processing software was purchased and resides on both workstation and personal computer platforms. The first iteration of the public lands data base and vertebrate distribution mapping was completed in 1996 and sent out for review. Processes are under way to create a mechanism for the continual update of the public lands data base with cooperators. The socioeconomic data base development is nearing completion for the state and will aid in the assessment of priorities for biodiversity mapping.

Nonstate Government Activities

The University of Missouri in Columbia has two important GI/GIS activities that are important to the state. The ***Geographic Resources Center*** houses MSDIS, which was established and funded by the legislature to serve as a clearinghouse of data about Missouri that can be used with GIS. While it has not made significant use of satellite data to date, the ***Environmental Technology Center,***



also located at the University of Missouri, is using satellite data as part of MORAP (see above).

Southwest Missouri State University has had projects involving the merging of satellite, aerial photography, and ground information into GIS for localities, such as Greene County, Missouri. Planning services are offered through the Center for Resource Planning and Management, especially targeting small municipalities. ***Lincoln University*** has also conducted some projects using remote sensing.

Montana

State GI/GIS and Satellite Data Contacts

* Allan Cox, Director
Fred Gifford, GIS Coordinator
Natural Resource Information System
Montana State Library
1515 E. 6th Avenue
Helena, MT 59620-1800
(406) 444-5355
(406) 444-0581 (fax)
acox@nris.mt.gov
Dan Hawkins
Information Services Division
Department of Administration
Sam W. Mitchell Building, Room 21
125 N. Roberts
Helena, MT 59620
(406) 444-2758
(406) 444-2701 (fax)

Gap Analysis Program Contact

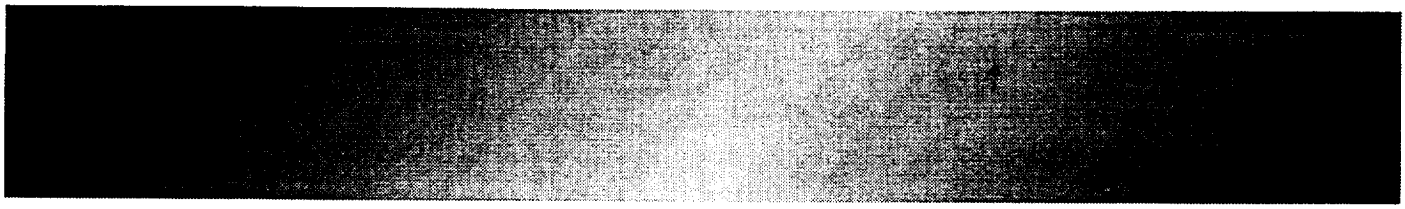
Dr. Roland L. Redmond
Cooperative Fish and Wildlife Research Unit
University of Montana
Missoula, MT 59812
(406) 243-4906
(406) 243-6064
red@selway.umt.edu

State Government Context

Montana has had a statewide approach to GI/GIS since the mid-1980s. The state has a ***Natural Resource Information System (NRIS)*** located at the ***Montana State Library,*** which includes Montana's state GI/GIS coordination entity and service center. NRIS was created and directed in 1985 by legislation to design and implement a comprehensive system for the acquisition, indexing, and retrieval of natural resource information statewide. NRIS includes four programs: the GIS Program, the Natural Resources Indexing System, the Water Information System, and the Montana Natural Heritage Program, which is a joint venture between the state and ***The Nature Conservancy.***

NRIS provides data clearinghouse services, including online access to its GIS; application-specific spatial analyses, maps, and data base services; and project design, technical assistance, and development support to state agencies that have GIS needs. It also develops standards for GI/GIS and supports statewide GI/GIS coordination groups and efforts. Montana is unique; it is the only state with its GI/GIS center located in the State Library, and The Nature Conservancy's Natural Heritage data are also in this office.

Four GI/GIS coordination groups exist in Montana, including the ***GIS Management Steering Committee*** and its ***GIS Technical Working Group,*** which are composed of representatives from Federal and state agencies. In addition, a ***GIS Users Group*** and the ***Local Government GIS Coalition*** work with these groups to facilitate coordina-



tion efforts. NRIS staffs all but the last of these groups and provides a coordinated link among their activities. Several activities are undertaken by the groups.

Satellite Data Use

Montana agencies have conducted some, but limited, work with satellite data as part of specific projects. Environment and natural resources programs are primarily located in the Department of Natural Resources and Conservation, the Department of Environmental Quality, the Department of Fish, Wildlife and Parks, and the Department of State Lands. These agencies and NRIS have used remote sensing on a project-by-project basis. NRIS has maintained an archive of SPOT data as encouraged by the ***USDA Forest Service.*** The GIS Technical Working Group, staffed by NRIS, has an agreement with SPOT, forming the archive and allowing agencies to obtain SPOT data at reduced cost. Data from the Gap Analysis Program (GAP) will be available through NRIS (see below).

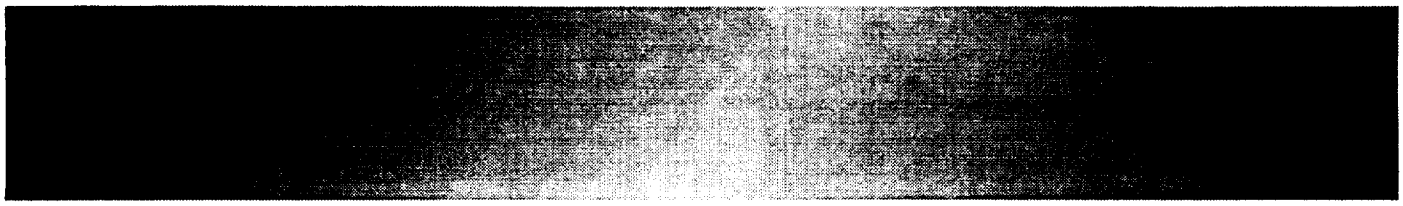
Various projects have used satellite data in Montana, including some at the ***University of Montana*** in coordination with NRIS and others. NRIS will be the distributor of data from these and other projects (see below). Within state government, the ***Reserve Water Rights Compact Commission*** has used some satellite data and GIS to quantify reserve water rights for the Indian reservations, including irrigation feasibility analyses. The ***Department of State Lands*** has also investigated the use of satellite data on a project basis, particularly for forestry applications in its ***Division of Forestry,*** as described below in coordination with the university. These applications include evaluating resource management alternatives, forest productivity, forest growth, and potential tax revenue from forest harvesting.

Gap Analysis Program Activities

The ***Wildlife Spatial Analysis Lab*** at the University of Montana began work on the Montana GAP project in 1991. State cooperators include the ***Department of Fish, Wildlife, and Parks,*** the Department of State Lands, NRIS, and other parts of the University of Montana. Cooperating Federal land management agencies include the USDA Forest Service, the ***U.S. Fish and Wildlife Service,*** the ***Bureau of Land Management,*** and the ***Natural Resource Conservation Service.*** Because of the size of the state relative to the amount of available data, the Montana GAP effort has been extensive. Sufficient funding was provided for fiscal year 1997 to complete this work in 1997.

The first set of vegetation mapping and a land-cover map of western Montana were completed in 1996. Work began at that time on eastern Montana. A two-step digital process was developed for classifying existing vegetation. The first step is discerning the pattern of spectral polygons and delimiting their boundaries. A classification algorithm accomplishes this by mimicking a TM false color composite. The resulting unsupervised classification is then aggregated to a user-defined minimum mapping unit (MMU) using an object and rule-based merging algorithm. The second step entails a supervised classification to label the polygons. These methods have been used to map existing vegetation in western Montana at 2-hectare MMU according to cover type, size class, and canopy closure. Forest Service field crews provided most of the ground-truth data used to train the supervised classification. The main product is a set of GIS data bases that characterize existing vegetation and land cover across 64.8 million acres in northern Idaho and western Montana. A separate GIS layer was created to map riparian cover types in each TM scene.

To fully utilize detailed vegetation data, plans are to develop correspondingly detailed habitat models and



species distribution maps and, in the process, build a wildlife habitat relationships data base specifically for Montana. Limited comparisons of habitat at 2 hectares and 100 hectares suggest that much could be gained by investing additional time and money in the construction of a wildlife habitat relationships data base executed at 2-hectare MMU. The mapping of species distribution information is expected to be completed in 1997.

The Bureau of Land Management finished a digital statewide land ownership layer, which will be recoded to reflect management status as of the end of 1996. GAP data are being distributed to state users by NRIS.

Nonstate Government Activities

The University of Montana has several projects under way using satellite data in addition to conducting the GAP work for the state. The ***School of Forestry*** used vegetation and land-cover data that were developed from digital classification of Landsat TM data for Montana's GAP project to conduct several investigations regarding forestry with the state's Division of Forestry (see above; contact Ken Wall at (406) 243-2449).

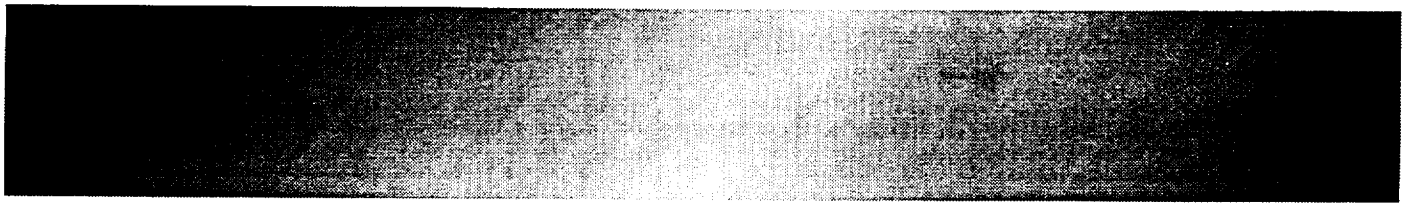
More recently, researchers at the School of Forestry are investigating the use of remote sensing to monitor and evaluate the **atmospheric impact of fire.** Biomass burning includes wildland fires, land clearing for shifting cultivation, deforestation, and fuel wood consumption, and it is an important source of many trace gases and aerosols. This burning has a potential impact on atmospheric chemistry, global climate change, biogeochemical cycles, and regional air quality. Previous remote-sensing approaches have concentrated on single-platform data, such as AVHRR for fire detection, burn scar assessment, and pre- and postfire vegetation conditions. The school has a fire modeling project, including the university's Remote Sensing Program, the Numerical Terradynamic Simulation Group, and the USDA Forest Service Intermountain Fire Science Laboratory in Missoula. The project goal is to develop methodologies using currently available satellites and aircraft sensors to prepare for the 1988 launch of *NASA*'s EOS AM-1 platform. Existing data will be used to simulate forthcoming EOS sensors. Preliminary studies will focus on historic data for methodological development of fire detection, burn scar assessments, and various vegetation product algorithms in the Pacific Northwest and Montana. Expected results are new fire danger indices, a new drought index, and composite images of fire occurrence. NRIS will be an important partner in the project and will distribute the resulting data to users in the state (contact Lloyd Queen at the School of Forestry).

Montana State University also has faculty and students working with satellite data. Its Geographic Information and Analysis Center has various remote-sensing and GIS projects under way. The center also staffs the Local Government GIS Coalition, one of Montana's GI/GIS coordination groups, and conducts work with local governments (contact John Wilson or Jackie Magnant at (406) 994-6921).

Nebraska

State GI/GIS and Satellite Data Contacts

* Larry Zink, Intergovernmental and Geographic Information Coordinator
Division of Intergovernmental Data Services
Department of Administrative Services
Executive Office Building
521 S. 14th Street, Suite 101
Lincoln, NE 68508
(402) 471-3206
(402) 471-3339 (fax)
lzink@doc.state.ne.us



Terry Kubicek
Nebraska Natural Resources Commission
NSOB—4th Floor
Lincoln, NE 68509
(402) 471-2081
(402) 471-3132 (fax)
tkubicek@nrcdec.nrc.state.ne.us

Pat Hammond
Department of Environmental Quality
1200 N Street, Suite 400
PO Box 98922
Lincoln, NE 68509
(402) 471-2234

Dr. Kevin Church
Wildlife Research Section
Game and Parks Commission
PO Box 30370
Lincoln, NE 68503-0370
(402) 471-5435
(402) 471-5528 (fax)

Dr. James W. Merchant, Associate Director
Center for Advanced Land Management Information Technologies (CALMIT)
Conservation and Survey Division
University of Nebraska–Lincoln
113 Nebraska Hall
Lincoln, NE 68588-0517
(402) 472-7531 or 2567
(402) 472-2410 (fax)
jm1000@tan.unl.edu

Gap Analysis Program Contacts

Dr. James W. Merchant, Associate Director
Center for Advanced Land Management Information Technologies (CALMIT)
Conservation and Survey Division
Dr. Dennis E. Jelinski
Department of Forestry, Fisheries and Wildlife
University of Nebraska–Lincoln
113 Nebraska Hall
Lincoln, NE 68588-0517
(402) 472-7531 or 2567
(402) 472-2410 (fax)
jm1000@tan.unl.edu

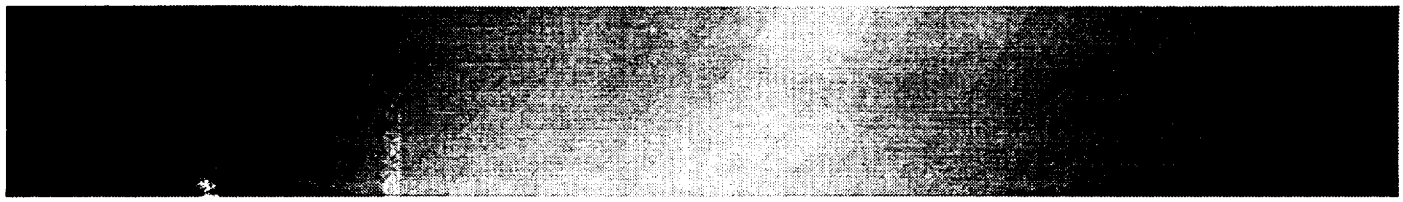
State Government Context

Nebraska has had an official statewide GI/GIS coordination effort since 1991 when the legislature created the ***GIS Steering Committee.*** The committee is staffed by the state GIS coordinator, administratively located in the ***Division of Intergovernmental Data Services*** of the ***Department of Administrative Services.*** While the state does not have a statewide GI/GIS service center for GI/GIS, several agencies have activities (see below).

The GIS Committee, the coordinator, and others have several activities under way to coordinate GI/GIS, particularly data and data clearinghouse development. The committee has not directly addressed satellite data, but it has endorsed the efforts of ***University of Nebraska at Lincoln*** researchers to produce a statewide land-cover data base using satellite data as part of the statewide GAP project (see below).

Satellite Data Use

Various entities are responsible for natural resources and environmental functions in Nebraska's government, and they are the primary locations of remote-sensing and GIS activities in the state. These agencies include the ***Department of Health,*** which monitors and regulates the drinking water program and collects information about groundwater and surface water quality, the ***Department of***



Environmental Control (DEC), which is responsible for protecting the environment and improving water quality for human consumption and other uses, the *Department of Water Resources,* which is responsible for water quantity, and the *Natural Resources Commission (NRC),* which was created to improve coordination among related state agencies. Many of their and others' remote-sensing and GIS efforts are conducted in coordination with researchers at the University of Nebraska.

In addition, the University of Nebraska at Lincoln includes two functions that are more frequently located within the structure of state government. These include the State Geologist's Office and the State Forest Service, both of which have used GI/GIS and remote sensing. The *Conservation and Survey Division,* in the Institute of Agriculture and Natural Resources, historically has the largest concentration of GI/GIS and satellite data activities of any entity in state government. The division includes the *State Geologist's Office,* with a Water Branch and the GIS Branch, and also has the *Center for Advanced Land Management Information Technologies (CALMIT),* formed in 1986. CALMIT has served as a coordinator of GI/GIS and remote-sensing activities at the university, including organizing committees and projects across disciplines. The *State Forest Service* is located in the Department of Forestry, Fisheries and Wildlife, which is in the same institute. This office has also used some satellite data and GI/GIS for state forestry applications.

Remote-sensing and GI/GIS activities are conducted for research and technical support services in groundwater, geology, soils, and mineral resources, with both the Conservation and Survey Division and CALMIT having internal capabilities in this regard. CALMIT also provides services in image processing and automated cartography and has a complete field remote-sensing capability. Numerous projects are conducted by CALMIT associates with others at several universities, companies, and Federal, state, and local agencies. Spatial modeling work is focused on **land-use/land-cover** change, **renewable resources management,** and **environmental hazard assessment.** CALMIT is creating and making various digital data bases available for the state and elsewhere.

CALMIT and the Department of Forestry, Fisheries and Wildlife have been the lead agencies for the Gap Analysis Program (GAP) in Nebraska since 1995. They are developing a vegetation and land-cover data base for the state as part of this work (see below).

CALMIT and the *California Institute of Technology's Jet Propulsion Laboratory* received a grant from NASA in 1995 to organize, enhance, and disseminate NASA and other space data and analytical tools to educators and their students, as well as to prove technical services and training to ensure the successful use of those data and tools. The Consortium for the Application of Space Data to Education was created to conduct this work in cooperation with *Johns Hopkins University* and *NASA's Goddard Space Flight Center.* The consortium (through CALMIT) is collecting satellite images of Nebraska in a real-time mode and making them available for rapid dissemination via both Internet and CD-ROM. For example, CALMIT installed a ground station capable of receiving real-time Advanced Very High Resolution Radiometer (AVHRR) images in 1996. These data are available on the Internet so that state agencies, educators, students, and others can access them.

Other projects have included a statewide assessment of groundwater pollution hazards using the DRASTIC model with Nebraska's DEC and the U.S. Environmental Protection Agency (see below), statewide vegetation monitoring, the preparation of a GIS for the state arboretum, an analysis of historical channel changes in the Platte River, and GIS production for the Central Platte

Power and Irrigation District. CALMIT researchers have also conducted spatial analysis of landslides in Nebraska, developed expert systems for updating land-use/land-cover maps, conducted a prototype study for a statewide feedlot inventory, modeled land-use change on the Great Plains, investigated GIS as a tool to assist in siting landfills, and prepared a GPS-based GIS for the Arapahoe Prairie Field Station. Efforts are also under way with the ***U.S. Geological Survey's (USGS) EROS Data Center*** in South Dakota to develop strategies for characterizing land cover and land use of the continental United States using remote-sensing data.

Nebraska's NRC is responsible for the long-range management and planning of land and water resources in Nebraska. NRC manages the Nebraska Natural Resources Data Bank and has used and promoted GI/GIS and remote sensing since the 1980s. It uses GIS and image-processing software in a network that is shared with the Department of Water Resources and other agencies in its building. Various digital data are used for planning and managing land and water resources, and NRC is the lead agency in the state's efforts to develop digital orthophoto quads.

Nebraska's DEC is responsible for protecting the environment and the quality of water for human consumption. DEC began working with GIS and remote sensing to help evaluate **groundwater** conditions and the impact of different **agricultural** practices.

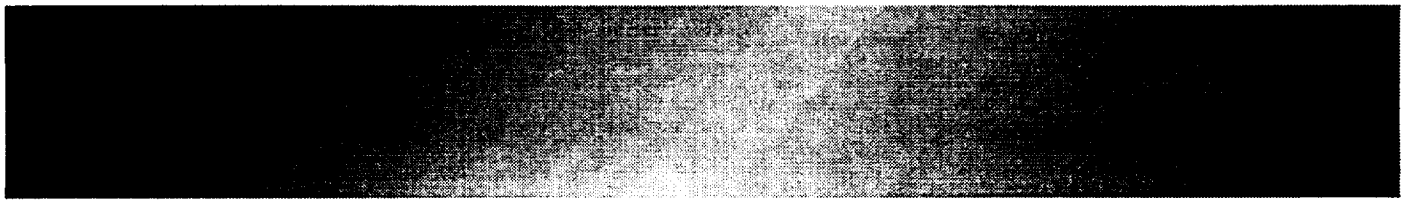
A project has been conducted with the ***U.S. Environmental Protection Agency*** and CALMIT to implement the DRASTIC model statewide to forecast **groundwater pollution** hazards. Landsat images were used to prepare land-use/land-cover data. The project was initially conducted using ERDAS software in 1986, and efforts have been made to enhance the model using Landsat TM data of eastern Nebraska to map crop types. Crop maps have been used to estimate the types and probable quantities of farm chemicals used on particular sites. Information on conservation practices, irrigation, and well density are also being incorporated in the model, and techniques are being tested in western Nebraska to verify performance statewide.

Another project in cooperation with CALMIT defined, identified, and classified Nebraska's livestock feedlots using satellite data to determine environmental impacts. Important aspects of this work were the placement of selected feedlot operations into their proper spatial/environmental contexts, the consideration of each feedlot in terms of both proximity to municipal water supplies and hydrologic parameters, and the development of a model, within a GIS framework, for quantifying the **environmental impacts of feedlot activities.**

The ***Game and Parks Commission*** is using satellite data, aerial photography, and GI/GIS to help understand **wildlife distribution and habitat suitability** of the whooping crane in the Rainwater Basin and Central Platte River of Nebraska. This project was funded by the National Biological Survey (now the ***USGS Biological Resource Division***) in 1995. Efforts include analyzing regional changes in habitat, land cover, and climate, as well as documenting known whopping crane sighting records for the 1960s to the 1990s.

Gap Analysis Program Activities

The Nebraska GAP was initiated in October 1995 and is led by CALMIT, in the Conservation and Survey Division at the University of Nebraska in Lincoln, and by the university's Department of Forestry, Fisheries and Wildlife. Several state agencies and others are also involved. An article on the Nebraska GAP project was published in the magazine *Resource Notes*, a publication of the Conservation and Survey Division.



Progress has been made in several areas, with the project expected to be completed in 1998. A statewide mosaic of Landsat TM data based on Landsat TM data from 1992 and 1993 was completed in 1996. Aerial photography and other data have been used in this effort. The mosaic and ancillary data sets have been co-registered in the preparation for land-cover analysis. The mosaic will also be used to prepare a poster to be printed by the Conservation and Survey Division.

Efforts are under way with other entities for remaining work. A cooperative agreement has been established with the ***State Museum of Natural History*** to automate faunal collection records, and data entry has begun for these data. Nebraska GAP staff are working with the Nebraska Game and Parks Commission to acquire and augment digital data on land ownership and land management. A cooperative agreement has also been developed with the ***USDA Natural Resources Conservation Service (NRCS)*** to cooperate on the development of ancillary data sets. A formal request was made to gain access to primary sampling unit data acquired for NRCS's Natural Resource Inventory to facilitate GAP.

Nonstate Government Activities

See above for the University of Nebraska.

Nevada

State GI/GIS and Satellite Data Contacts

* Ronald H. Hess, GIS Supervisor
Bureau of Mines and Geology
University of Nevada, Reno
SEM—Room 301
MS 178
Reno, NV 89557-0088
(702) 784-6691
(702) 784-1709 (fax)
rhess@nbmg.unr.edu

David Cowperthwaite
Environmental Commission
Department of Conservation and Natural Resources
333 West Nye Lane
Carson City, NV 89710
(702) 687-4670

* Beau Pankiw
Department of Information Services
505 East King Street, Room 403
Carson City, NV 89710
(702) 687-5965
(702) 687-3846 (fax)
bpankiw@govmail.state.nv.us

Paul Tueller
Environmental and Resource Sciences
University of Nevada, Reno
MS 186
Reno, NV 89557
(702) 784-4053

Gap Analysis Program Contact

Dr. Tom Edwards
Utah Cooperative Fish and Wildlife Research Unit
Utah State University
Logan, UT 84322-5210
(801) 797-2529
(801) 797-3798 (fax)
tce@nr.usu.edu

State Government Context

Nevada has a coordinated approach to GI/GIS, although state agencies have had limited use of GIS as compared to other states. To date, no state agency provides GI/GIS

services for other agencies. State GI/GIS efforts have been primarily coordinated through the ***State Mapping Advisory Committee (SMAC)*** and its GIS Subcommittee. SMAC has been chaired for many years by the state geologist, also known as the director of the Nevada ***Bureau of Mines and Geology***, which is located at the ***University of Nevada at Reno.*** The bureau's GIS supervisor has staffed SMAC and the GIS Subcommittee ever since the state geologist has chaired SMAC, and this individual has served as the state's leading GI/GIS contact for the state.

In 1995, the Governor's Office established a ***Temporary GIS Task Force*** to develop recommendations for how GI/GIS coordination can be enhanced in Nevada. The ***Department of Information Services*** is staffing the group. A final report of the group's findings is anticipated shortly, and plans are to establish a GIS Advisory Board in 1997.

Satellite Data Use

Nevada has had very limited use of satellite data and less GI/GIS use than several other states, with the exception of work conducted at the University of Nevada (see below). Environmental and natural resources responsibilities are distributed among various agencies in Nevada. Some efforts have been under way with Federal agencies. For example, the ***Division of Water Resources*** in the ***Department of Conservation and Natural Resources*** has been developing a divisionwide approach to GI/GIS for surface water resources in coordination with the Water Resources Division of the ***U.S. Geological Survey*** since 1990.

The Nevada Bureau of Mines and Geology has used GI/GIS longer than most other state agencies. Beginning in 1989, one of its first GIS projects was the Las Vegas Subsidence Study, which was conducted with ***Clark County*** to analyze areas in high risk of subsidence. The bureau has also used GI/GIS to monitor radon occurrences in homes, conducted in cooperation with the ***U.S. Environmental Protection Agency*** and the state ***Department of Health.***

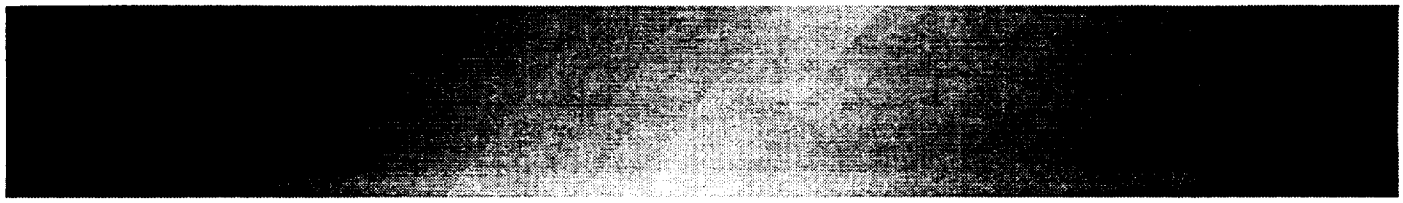
Gap Analysis Program Activities

The ***Utah Cooperative Fish and Wildlife Research Unit*** at ***Utah State University*** in Logan conducted the Gap Analysis Program for Nevada. Recently completed, this work was performed through coordination with researchers at the University of Nevada at Reno. Initial mapping of Nevada vegetation for Gap Analysis was completed at the pixel level. There are 65 mapped covertype classes statewide that were identified and verified.

Nonstate Government Activities

The University of Nevada has been the site of various projects using remote sensing. The university has worked with satellite data for more than a decade, with early NASA funding to serve as the Technology Application Center for the state. More recently, the ***Desert Research Institute*** has received funding from NASA, although most of its work has been conducted with limited involvement of state government entities. The University of Nevada at Reno's Geological Sciences, Agriculture, and Minerals Departments have conducted some remote-sensing work with GIS, and the university is where the informal GI/GIS coordination office for the state is located (see above). The Agriculture Department has conducted some projects using satellite data with state agencies. The ***University of Nevada at Las Vegas*** also has GIS activities.

The ***U.S. Department of Energy*** has directed some of the largest efforts in Nevada to use GI/GIS and satellite data, particularly the work to evaluate the use of Yucca Mountain as a potential geologic repository site for high-level



nuclear waste. Various state and county agencies and the University of Nevada at Las Vegas have been involved in this effort.

New Hampshire

State GI/GIS and Satellite Data Contacts

* James F. McLaughlin, Senior Planner
Office of State Planning
2 1/2 Beacon Street
Concord, NH 03301
(603) 271-2155
(603) 271-1728 (fax)
j_mclaug@tec.nh.us

J.B. Cullen, Chief
Forest Information and Planning
Division of Forests and Lands
Department of Resources and Economic Development
172 Pembrooke Road
Concord NH 03301
(603) 271-3457

Chris Simmers
Department of Environmental Services
6 Hazen Drive
Concord NH 03301
(603) 271-2961

* Fay Rubin, GIS Coordinator
Complex Systems Research Center
University of New Hampshire
Morse Hall
Durham NH 03824
(603) 862-1792
(603) 862-0188 (fax)
fay.rubin@unh.edu

Gap Analysis Program Contact

For New Hampshire, see under Vermont.

State Government Context

New Hampshire has had a coordinated approach to the use of GI/GIS, including satellite data, since the early 1980s. The ***Office of State Planning (OSP)*** began a cooperative project with the ***University of New Hampshire (UNH)*** in 1984 to apply computer mapping to land-use planning and resource management. OSP has served as the lead agency in state government regarding GI/GIS coordination since then. It also uses GI/GIS for internal purposes and staffs and funds various state GI/GIS coordination efforts and activities. New Hampshire has a ***Council on Resources and Development*** with a ***GIS Advisory Committee*** that are staffed by OSP. These groups have members from several agencies and encourage and set direction for GI/GIS coordination in the state.

OSP contracts with the ***Complex Systems Research Center (CSRC)*** at UNH's ***Institute for the Study of Earth, Oceans and Space*** to accomplish several efforts. Through their annual agreement, CSRC conducts data base development, maintenance, and dissemination for the state's GIS, known as GRANIT (Geographically Referenced Analysis and Information Transfer). CSRC also conducts applications development and other projects using satellite data and GI/GIS for OSP and others (see below).

New Hampshire is one of the few states to have a statutory reference to satellite data. The 1993 legislature directed OSP, in coordination with the Department of Resources and Economic Development's Division of Forests and Lands, to contract with CSRC to "conduct a satellite survey of clearcut areas" (see below).

Satellite Data Use

Several state agencies use satellite data and GI/GIS in New Hampshire including OSP, which is responsible for monitoring growth and development in the state. It is also charged with assisting state and local government in planning for and managing growth, particularly in land-use planning. Environmental and natural resources agencies, including the Department of Resource Protection and Development, the Department of Environmental Services, and the Department of Fish and Game, also use GI/GIS.

OSP has a variety of internal GI/GIS projects and funds data development and clearinghouse work conducted by UNH's CSRC. OSP also provides GI/GIS assistance to the state's nine Regional Planning Agencies (RPAs) as directed by the legislature in 1988, and the RPAs in turn help local governments. OSP, CSRC, and state agencies have used satellite data in various projects.

Efforts are under way with the ***Department of Transportation (DOT)*** to use satellite data to conduct an **environmental impact assessment for a highway corridor study.** The study uses innovative approaches to assess the interdependence between land-use and transportation issues. Both Landsat TM and SPOT images are being used to generate corridor-wide data sets. These generalized data sets are being enhanced by larger scale aerial photography for more detailed urban land-use mapping. As a result of this effort, DOT is investigating the utility of satellite data for the initial phases of other corridor evaluation activities.

The New Hampshire clearcut inventory project was authorized and funded by the legislature in 1993. The act required OSP, in coordination with the ***Division of Forests and Lands*** in the ***Department of Resources and Economic Development,*** to contract with CSRC to "conduct a satellite survey of clearcut areas." Staff of the White Mountain National Forest of the ***USDA Forest Service*** also participated in the study. The project identified and mapped all clearings in the state that are a minimum of 3 acres in size that have been cleared over the last 10 to 15 years and that have been cleared for silvicultural purposes (see Figure B5). The development of the statewide clearcut inventory involved the use, processing, interpretation, and integration of both Landsat TM (primarily eight TM images acquired during the period 1986–1990) and SPOT data, as well as GIS analysis, GPS, and standard field work.

New Hampshire Timber Clearcut Inventory

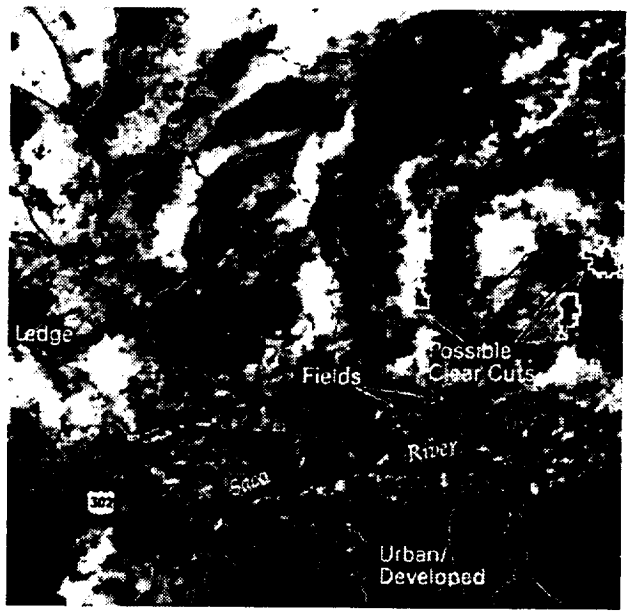
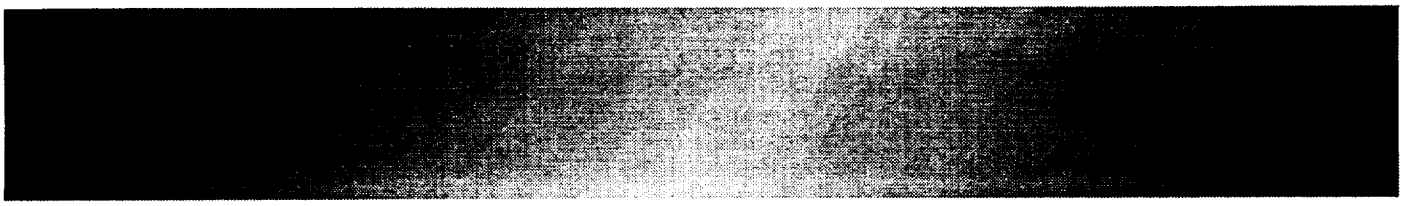


Figure B5

This Landsat TM imagery (September 8, 1980) shows a section of the Bartlett, New Hampshire, quandrangle in the northern part of the state, displayed with an overlay of U.S. Geological Survey base data. Features identified as possible clearcuts are outlined in white; other spectrally similar land-cover types are also identified. (courtesy of Fay Rubin, GIS Manager, Complex Systems Research Center, University of New Hampshire, (603) 862-1792, *fay.rubin@unh.edu*)



The project was accomplished in three phases: (1) a pilot phase to evaluate alternative approaches and methodologies for the mapping of clearcuts; (2) the application of a selected methodology to generate a statewide inventory; and (3) an accuracy assessment of the statewide inventory. Image-processing tools were applied to the TM imagery to enable the classification and delineation of the clearcuts. GIS tools provided reference data, aided in the feature delineation process, supported the accuracy assessment efforts, and enabled the production of final tables and map products. Data from GPS units were used to navigate to field sites. Finally, standard field techniques were used in the assessment of potential clearcut sites and in the accuracy assessment efforts.

The project resulted in an accurate and georeferenced determination of clearcuts in the state and has been beneficial for other efforts, such as habitat studies. This digital, spatially referenced, statewide inventory of clearcuts met the following criteria: (1) minimum size of 3 acres; (2) residual basal area per acre of less than 20 square feet; and (3) harvested within the last 10 to 15 years. The digital inventory has been archived as a data layer in New Hampshire's statewide GIS, GRANIT. As with all GRANIT data sets, it is available to the public in digital or hardcopy format.

Previously, OSP, CSRC, the ***Department of Environmental Services (DES)***, DOT, and the ***U.S. Environmental Protection Agency (EPA)*** funded the development of a statewide **land-cover** data base using Landsat data in 1993. The satellite data were also used to delineate **wetlands** in the state. This effort was preceded by a pilot project supported by EPA to classify Landsat TM data as a means of identifying wetland areas within the Merrimack River Basin. The project included a comparison of wetlands acreage estimates from Landsat, National Wetlands Inventory data from the ***U.S. Fish and Wildlife Service***, and soils data from the ***USDA Natural Resources Conservation Service (NRCS)***. Various other projects using satellite data and GIS were conducted after this pilot to expand the uplands classification resulting from the wetlands inventory.

Another project built on this wetlands delineation project extended the study area to include the remaining Merrimack River Basin, which is located in ***Massachusetts***. In Task I of the project, CSRC used the appropriate Landsat TM image on a loan basis from the EPA EMAP program, carried out TM image classification, and then supervised the field verification to produce a seamless land-cover data set for the entire basin. Task II refined the urban/developed land-cover class resulting from the TM classification in a pilot test area by using SPOT panchromatic data and U.S. Census Bureau TIGER data. Various entities use the results of this work, including the ***Massachusetts Department of Fisheries, Wildlife and Environmental Law Enforcement*** to support its wildlife habitat studies.

CSRC and others used satellite data in another important project crossing New Hampshire's boundaries. The Northern Forest Lands Study was authorized and funded by Congress to assess the **forest resources** of a 26-million-acre area called "the Northern Forest" in Maine, New Hampshire, New York, and Vermont. This effort was conducted in coordination with the USDA Forest Service. Landsat data were used to assess forest cover and resources in all four states. New Hampshire was used as the study's pilot project because its use of satellite data is the most advanced of the four states. This work was conducted at CSRC, with participation by the Department of Resources and Economic Development's Division of Forests and Lands. Various data were developed and used, including timber, fish and wildlife, lakes and rivers, recreation, historical land ownership patterns and projected future land ownership, management, and use, the likely impacts of changes in land and resource owner-

ship, management, and use patterns, and alternative strategies to protect the long-term integrity and traditional uses of land. Part of the study effort identified land with important resources, including eight criteria, such as wildlife habitat, scenic areas, river corridors, recreation opportunities, productive forest land, natural areas, lake shore, and large contiguous blocks of forested land. These criteria were developed after researching natural resources identification schemes used in each of the four states and public input.

Gap Analysis Program Activities

For New Hampshire, see under Vermont.

Nonstate Government Activities

Researchers at the Institute for the Study of Earth, Oceans and Space at the University of New Hampshire have conducted many remote-sensing projects, including those discussed above and others. Much of this work has been funded by **NASA** and other Federal agencies.

Other entities in New Hampshire are also using satellite data. For example, the ***Appalachian Mountain Club*** used satellite data to determine changes in conditions along the Appalachian Trail. It used this information to help participate in the development of the state resource plan. In addition, the club is using satellite data, GPS, and GIS to determine the future location of trails.

Reference

Rubin, Fay, and Justice, David, *Final Report: New Hampshire Timber Clear Cut Inventory* (Durham, NH: University of New Hampshire, 1995).

New Jersey

State GI/GIS and Satellite Data Contacts

* Henry L. Garie, Assistant Director
Pat Cummens, GIS Manager
Office of Information Resources Management
Bruce Ruppel
Division of Science and Research
Department of Environmental Protection
401 E State Street, CN 428
Trenton, NJ 08625-6070
(609) 984-6639
(609) 292-7900 (fax)
hgarie@dep.state.nj.us

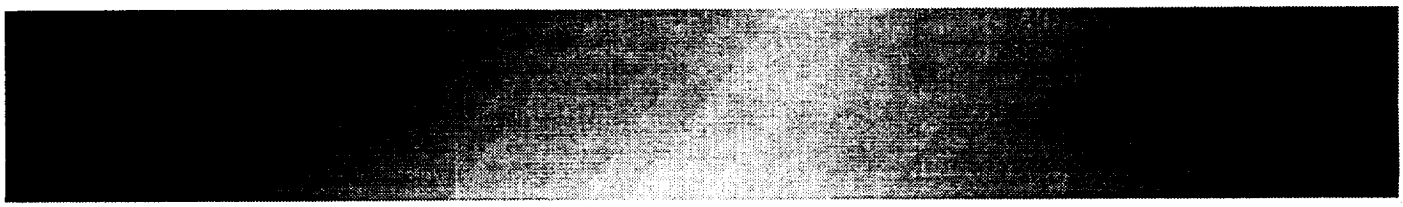
Gap Analysis Program Contact

For New Jersey and Delaware, see under Maryland.

State Government Context

New Jersey has used GI/GIS for several purposes for more than a decade. The majority of GIS activities in New Jersey's state government address environmental protection and management needs, and these activities are conducted by the ***Department of Environmental Protection (DEP).*** DEP also serves as the lead agency regarding statewide GI/GIS activities and provides statewide data management and dissemination to various state and other agencies. No other agency provides statewide data management or dissemination.

New Jersey's GI/GIS coordination group is the ***State Mapping Advisory Committee (SMAC).*** SMAC has been traditionally chaired and staffed by DEP. The group has multiple participants and conducts a variety of GI/GIS coordination activities. For example, SMAC



produces a *GIS Resource Guide* with much information for GI/GIS users and interested parties in the state.

Satellite Data Use

New Jersey has made limited use of satellite data to date. DEP is the comprehensive natural resources and environmental agency in New Jersey's state government, and it has the majority of the state's GI/GIS activity. DEP's ***Bureau of Geographic Information and Analysis (BGIA)*** has served as a coordinator of DEP's GI/GIS activities since 1986, including systems and data base administration, training and technical support, and applications development. BGIA uses various GIS and image-processing software and has provided GI/GIS services for all of DEP's divisions. Some divisions also have their own facilities. BGIA has also worked with various parts of DEP and other agencies to develop GI/GIS applications related to environmental protection. The state's county health departments and several nonprofit organizations are active participants in DEP's efforts. Extensive data exchange efforts exist between DEP and these departments and organizations.

Much of DEP's efforts have concentrated on data development, but there has been little use of satellite data except for experimental purposes. There are no short- or long-term plans to make more extensive use of satellite data at this time. DEP and others have funded participation in the National Aerial Photography Program (NAPP), and the state now has statewide digital orthophoto coverage. DEP is currently developing four new statewide data layers for use with GIS in the state's new environmental plan. These layers include land use, flood prone areas, soils, and geology.

Some DEP projects have evaluated the potential for satellite data use with GIS. For example, Landsat TM data were used in classifying land-use/land-cover data for **Ocean County.** Another project evaluated the effectiveness of Landsat TM data to provide an overview of water quality in Barnegat Bay in 1995. After comparing satellite data with field samples in the bay, it was determined that the satellite data might help supplement and reduce the work required of traditional water quality monitoring efforts.

Gap Analysis Program Activities

For New Jersey and Delaware, see under Maryland.

Nonstate Government Activities

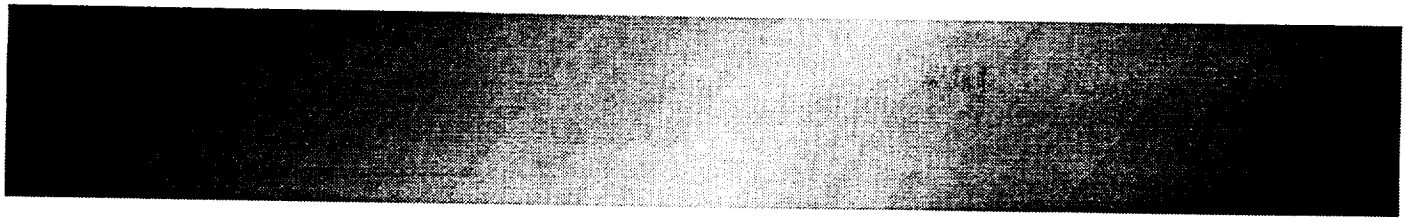
Cook College of ***Rutgers University*** has conducted some projects using satellite data. It recently received funding from **NASA** to provide Internet data access to satellite data about New Jersey, so DEP and others will have more opportunities to use satellite data.

New Mexico

State GI/GIS and Satellite Data Contacts

* William S. Baillargeon, GIS Manager
Information Systems Division
General Services Department
715 Alta Vista
P.O. Drawer 26110
Santa Fe, NM 87502-0110
(505) 827-2047
(505) 827-2325 (fax)
billb@gsd.state.nm.us

Garry Nielson
Information Systems Division
State Engineer Office
P.O. Box 25102



Santa Fe, NM 87504-5102
(505) 827-6192

Greg Fitch
Forestry and Resources Conservation Division
Energy, Mineral and Natural Resources Department
P.O. Box 1948
Santa Fe, NM 87504-1948
(505) 827-7864

* Mike Inglis
Amelia M. Budge
RGIS Clearinghouse
Earth Data Analysis Center
University of New Mexico
2500 Yale SE, Suite 100
Albuquerque, NM 87131
(505) 277-3622
(505) 277-3614 (fax)
abudge@spock.unm.edu

Gap Analysis Program Contact

Dr. Bruce Thompson
Cooperative Fish and Wildlife Research Unit
New Mexico State University
P.O. Box 30003, Dept. 4901
Las Cruces, NM 88003-0003
(505) 646-6093
(505) 646-1281 (fax)
bthompso@nmsu.edu

State Government Context

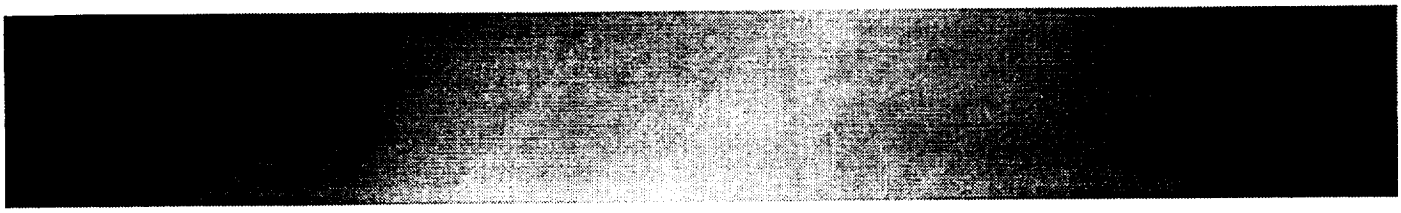
New Mexico has had a statewide GI/GIS coordination approach for more than a decade. Multiple offices and groups are involved in GI/GIS direction, coordination, and implementation. Within the executive branch of state government, the ***Information Systems Division*** of the General Services Department has a ***GIS Section,*** which provides GIS assistance and support to state agencies. The manager of the section serves as New Mexico's statewide GI/GIS coordinator. The GIS Section specifically addresses GIS, while related efforts in the state have other GI/GIS activities, such as the ***Earth Data Analysis Center (EDAC)*** at the ***University of New Mexico,*** which provides GI/GIS, remote-sensing, and GPS services to state agencies and others (see below).

New Mexico has two statewide GI/GIS coordinating groups. The ***New Mexico Geographic Information Council*** was authorized by an executive order signed in 1987 and includes members from various levels of government, academia, and the private sector. The ***GIS Advisory Committee*** of the Information Systems Council is composed of state agency representatives. These groups have both independent and collaborative activities. For example, the groups have a joint standards subcommittee.

Satellite Data Use

New Mexico has a variety of agencies responsible for environmental and natural resources agencies. These agencies have had limited use of satellite data in house. However, some state agencies have benefited from using the remote-sensing services at the University of New Mexico's EDAC. Formerly known as a NASA Technology Application Center, EDAC has been actively providing GI/GIS, remote-sensing, and GPS services to state agencies and others since 1968 (see below). EDAC is also the USGS Earth Science Information System Center affiliate for New Mexico; it manages an archive for aerial photography and satellite data for the state, including the Gap Analysis Program (GAP) data (see below).

In addition, EDAC and other parts of the university are responsible for the Resource GIS (RGIS) Clearinghouse. RGIS was authorized and received funding from the



legislature beginning in 1988. RGIS provides data development, management, and dissemination services to state agencies and others through a memorandum of understanding with the state. This memorandum of understanding is maintained by the GIS Section of the Information Systems Division.

The ***Forestry and Resources Conservation Division*** of the ***Energy, Minerals and Natural Resources Department*** developed its first GI/GIS pilot project with EDAC's assistance. This project developed a methodology to analyze **forest fire hazard** areas in New Mexico. The pilot project used digital elevation model data, vegetation cover maps, road network data, and other data to determine these areas and how to access the areas if fires occur. More recent efforts have used satellite data to conduct **timber inventories.** The ***Mining and Minerals Division*** has also used EDAC's remote-sensing services to help monitor **mining activities.**

The ***State Engineer Office*** is responsible for administering **water resources** in the state. This role includes all the surface waters in New Mexico, as well as the groundwater within declared basins, which currently comprise approximately 71 percent of the state. The office has used GI/GIS since 1990, including work with EDAC to help monitor legal and illegal irrigated agriculture use with SPOT and Landsat TM data.

Gap Analysis Program Activities

The ***Cooperative Fish and Wildlife Research Unit*** of ***New Mexico State University*** has been responsible for the New Mexico GAP. This work has been carried out in coordination with the state ***Department of Game and Fish.*** New Mexico's GAP work was recently completed.

The state land-cover map consists of 42 categories of vegetated and nonvegetated cover. It includes 33 categories mapped at the GAP standard of 100-hectare MMU. Two vegetation communities were mapped at 2 hectares and seven at 16 hectares to ensure that their general distribution was not lost during aggregation to a larger MMU. This mapping effort resulted in a statewide map with approximately 26,000 mapped land-cover polygons. A stratified random sample representative of the mapped categories was subsequently drawn. Standardized polygon evaluation instructions, a data form, and location maps (with polygons numbered but unlabeled) were distributed to 43 assessment coordinators representing more than 100 assessment cooperators statewide. The final analysis and accuracy statements regarding the land-cover map were subsequently completed.

The distribution of 602 vertebrate species were predicted based on associations with mapped land cover, watersheds, soils, elevation, precipitation, hydrology, and slope. The basic approach was to develop a "hypercoverage" consisting of the intersection of all polygons in the previously listed themes. Each vertebrate species was then assigned a presence or absence value for each hypercoverage polygon based on an algorithm of theme associations in a data base system. Preliminary distributions were predicted, graphed, and submitted to expert cooperators representing bird, mammal, and herpetozoan expertise statewide. Wildlife models were altered based on expert comment, and the hypercoverage was updated to represent the corrections needed in the individual themes.

Specific management descriptions and tract boundaries were received from a wide array of public resource management agencies and private interests statewide. These data were integrated with the previously obtained "Public Land Survey System and Ownership" data files compiled jointly by the Federal ***Bureau of Land Management,*** the ***New Mexico Land Office,*** and EDAC. The resultant land-tract boundaries and descriptors were then converted to management status categories. A dichotomous key was developed to provide a repeatable method for assigning status categories.

A final analysis followed the format described in the recent standard final report outline. In addition, New Mexico's GAP effort explored the variation in avian richness between processes, including and excluding wintering distribution. EDAC serves as the state repository and distributor for GAP digital files and metadata.

Nonstate Government Activities

The University of New Mexico has been an active participant in New Mexico's GI/GIS development and coordination efforts since the beginning of the state's efforts in this regard. In addition, the university has an official role as a data repository and dissemination agency for geographic data (see above). Various projects have been conducted since 1968. Examples of applications include **economic development, facility siting, soil loss estimation, habitat and grazing analyses, public land assessments, crop identification, geology, transportation, land-use planning,** and **various border assessments with Mexico,** in addition to the applications discussed above. For example, a long-term effort has been the Long Term Ecological Research Sites project sponsored by the ***National Science Foundation.*** This project has studied climate change based on vegetation boundary changes. Additional vegetation work has been conducted for the ***USDA Forest Service*** and the Bureau of Land Management.

The Albuquerque Area office of the ***Bureau of Indian Affairs*** uses GI/GIS, remote sensing, and GPS for **forest fire planning and management** in New Mexico and southern Colorado. These technologies are used to develop integrated fire management plans and to assess the relative risk of fire, potential damage, and response time of firefighting crews. Satellite data and GPS are used together to identify and classify vegetation and fuel types and produce composite maps of resource value-at-risk.

Reference

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New York

State GI/GIS and Satellite Data Contacts

* Bruce Oswald
Governor's Task Force on Information Resources Management
Executive Chambers
State Capitol
Albany, NY 12224
(518) 473-5622
(518) 473-3389 (fax)
oswaldb@emi.com

* Larry Alber, GIS Coordinator
Department of Environmental Conservation
50 Wolf Road
Albany, NY 12233
(518) 457-1148
(518) 457-1088 (fax)

Jerry Rasmussen
Division of Fish and Wildlife
Department of Environmental Conservation
50 Wolf Road
Albany, NY 12233
(518) 783-5733
(518) 457-1088 (fax)

John Banta
Ray Curran
Adirondack Park Agency

State Route 86
Ray Brook, NY 12977
(518) 891-4050

* Marty Goldblatt, GIS Manager
Office of Real Property Services
Executive Department
16 Sheridan Avenue
Albany, NY 12210-2714
(518) 474-3453
(518) 486-7237 (fax)
mgold@emi.com

Gap Analysis Program Contact

Dr. Charles Smith
Cooperative Fish and Wildlife Research Unit
Department of Natural Resources
Fernow Hall
Cornell University
Ithaca, NY 14853-3001
(607) 255-3219
(607) 255-1895 (fax)
crs6@cornell.edu

State Government Context

New York State has a long history of GI/GIS use in several agencies. However, until recently, it has not had an entity leading or supporting statewide GI/GIS coordination. A Governor's Task Force on Information Resources Management was formed in 1995 to coordinate all information and related technology activities in New York. This group established a ***GIS Committee*** and associated advisory and work groups in September 1996. The committee is staffed by one of the staff of the Task Force's office, who serves as New York's part-time GI/GIS coordinator. The formation and focus of this committee follow the completion of a report on statewide GIS conditions and recommendations by the New York State Temporary GIS Council, which had been created by the 1994 legislature. The state ***Division of the Budget*** was the lead agency that organized and completed this study, and it is represented on the new committee.

New York has other statewide GI/GIS coordination activities. A GIS conference has been held each year since 1984, and a GI/GIS clearinghouse was developed by the ***Center for Technology in Government*** at the ***State University of New York (SUNY) at Albany*** in 1995. This data clearinghouse role is being transferred to the State Library. While no central agency provides GI/GIS services for state or other agencies, the ***Office of Real Property Services (ORPS)*** has a GI/GIS service bureau that provides GI/GIS services and data to external entities.

Satellite Data Use

Several state agencies use GI/GIS, but the use of satellite data has been limited to a few projects. The three agencies with the largest use of GI/GIS include ORPS, which has a GI/GIS service bureau providing GI/GIS services and data to external entities, the ***Department of Environmental Conservation (DEC),*** which is the state's primary environmental and natural resources agency, and the ***Department of Transportation.*** Each of these agencies has a department-level GIS coordinator and various divisions with GIS activities. Additional agencies have natural resources responsibilities and use GI/GIS, such as the ***Adirondack Park Agency (APA)*** and the ***Office of Parks, Recreation and Historic Preservation.***

State agencies have cooperated on various data development and dissemination activities. For example, some agencies jointly funded the acquisition of Landsat TM data in 1992 through EOSAT's Statewide Purchase Program. Data derived from these satellite data have been used for a statewide vegetation data base for the New York Gap Analysis Program (GAP) being conducted at

Cornell University (see below) and to determine **forest resources** in the northern part of the state as needed for the Northern Forest Lands Study. Authorized by Congress, this work was conducted by SUNY's College of Environmental Science and Forestry (in Syracuse) for New York State, while similar work was conducted for the other parts of the study area in Maine, New Hampshire, and Vermont (see under New Hampshire).

In addition, DEC has investigated and used satellite data for various applications. For example, satellite data and GIS were used in the Lake Champlain Special Designation Project, which was a 5-year project authorized by Congress in 1990 and located in and involving both New York and Vermont. Imagery interpretation for the project was conducted by Vermont for both states in coordination with DEC.

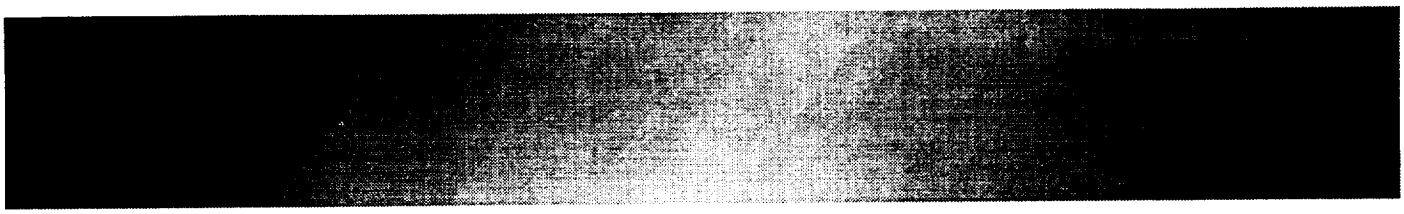
The ***Division of Fish and Wildlife*** has been DEC's largest user of satellite data and GIS. The data have been used for **wildlife applications,** including work with researchers at Cornell University on the GAP project (see below). DEC's ***Division of Lands and Forests*** had a leading role in working with the APA, the Tug Hill Commission, and SUNY's College of Environmental Science and Forestry to implement the Northern Forest Lands Study, including the use of satellite data as discussed above. The ***Division of Marine Resources*** has also used some satellite data to assist in **coastal resources,** including mapping and analyzing title wetlands.

APA is a state agency created in 1971 to promote land management and planning for the Adirondack Park, which includes an area of 9,600 square miles, 38 percent of which is state owned. The park is the largest area of designated wilderness east of the Mississippi River. Beginning in the late 1970s, APA was one of the first state agencies to use some satellite data, and it was the first state natural resources agency in New York to make a commitment to GIS. With one of the first sites of ERDAS software, APA initiated a system to **monitor vegetative change** and create a 1-acre scale baseline of geographic information for the park. A master plan for the park was created using this software beginning in the early 1980s. Work conducted through the 1980s included efforts with ***SUNY at Plattsburgh***'s remote-sensing laboratory. APA's data base contains several parkwide digital map layers used for environmental assessment, economic development programs, and grant applications, including land-cover data from Landsat. Imagery and GIS have been used for monitoring change in vegetation and wetlands, preliminary habitat characterization work, and other **planning** efforts.

ORPS contracted with SUNY's College of Environmental Science and Forestry to assist in determining whether satellite data can help the agency conduct **property tax assessment** and support functions. ORPS has aerial photos of all state-owned and some other lands, and it considered the use of satellite data as a method to provide updated information to ensure that forested lands are assessed in an equitable manner. The study evaluated whether available satellite data can help ORPS delineate, inventory, and classify forest lands for individual parcels and timber stands. Completed in 1995, the study concluded that it was not cost-effective to use current satellite data for this purpose because of limitations in ORPS's other data and the difficulties inherent in differentiating forest classifications in New York.

Gap Analysis Program Activities

The ***Cooperative Fish and Wildlife Research Unit*** at ***Cornell University*** is the lead organization for the New York GAP. Additional cooperators include the ***Institute for Resource Information Systems*** (also at Cornell University), DEC, the state ***Natural Heritage Program,*** and the ***USDA Forest Service.*** Strong cooperation has existed in developing the GAP data base.



New York has all the GIS coverages required for a state-level Gap Analysis of species either in hand or promised for delivery by reliable cooperators. A major component of the GAP effort is the production of a statewide vegetation map using Landsat TM data. A provisional, first-cut vegetation classification derived from these satellite data was completed using a single-scene clustering algorithm based on 100 clusters. The delivery of additional multi-temporal, processed TM data from the EROS Data Center under the Multi-Resolution Land Characterization Consortium agreement, along with associated 240-cluster spectral data, was completed in 1995. However, several problems need to be solved before the EROS data can be used to the fullest extent. Obtaining and installing Spectrum/Khoros software have been difficult, and some of the EROS-processed scenes were not accurately georeferenced.

Representatives from the Pennsylvania, New York, and New England GAP projects have met since 1995 to discuss a land-cover classification that would be appropriate for the Northeast. Elements of the modified vegetation classification schemes from The Nature Conservancy and UNESCO were incorporated into an expanded northeastern classification. The provisional vegetation classification scheme, which expands on both the modified UNESCO and The Nature Conservancy Heritage Program schemes, is currently being reviewed, taking into account the extensive land-use/land-cover patterns that result largely from the activities of humans on the northeastern landscape of the United States. Additional focus has been on vegetation classification, vertebrate range delineation, and edge-matching.

Additional coverages used in GAP efforts include breeding birds, mammals, reptiles, amphibians, butterflies, threatened/endangered/sensitive species, and public lands (state and Federal, including large Department of Defense holdings). The mammals data base has been made available through cooperation with the New York ***State Museum*** and the ***U.S. Fish and Wildlife Service***'s Region 5 office. The reptile and amphibian data are the most recent available from New York State, based on an atlas being produced by DEC, updated through 1996. Birds and butterflies are complete and linked to the GIS. A digital elevation model was compiled for New York State, as well as a model of growing degree days, digital soils information, and a compendium of published information about edaphic factors relating to vegetation types. These data assisted in developing and refining vegetation classifications. The wildlife modeling phase of the project is expected to be completed in 1997.

Nonstate Government Activities

SUNY includes campuses throughout the state. Some of them have remote-sensing and GIS educational programs and projects. ***SUNY at Buffalo*** is one of three sites of the National Center for Geographic Information and Analysis, which has had funding support provided by the National Science Foundation. SUNY's College of Environmental Science and Forestry has GIS and image-processing facilities; it has worked on the Northern Forest Lands Study and the ORPS studies described above. SUNY at Plattsburgh has worked with APA on its early use of satellite data. Cornell University is conducting the GAP work for the state in coordination with DEC. SUNY at Albany has conducted some work with the ***National Oceanic and Atmospheric Administration*** regarding wetlands change.

Cayuga County previously used Landsat data for some land-cover work and is recently beginning a new project to evaluate and use satellite data for various planning and other applications. This project is being conducted in coordination with **NASA.**

North Carolina

State GI/GIS and Satellite Data Contacts

* Karen C. Siderelis, Director
Center for Geographic Information and Analysis
Office of State Planning
115 Hillsborough Street
Raleigh, NC 27602
(919) 733-2090
(919) 715-0725 (fax)
karen@cgia.state.nc.us

Carol Hanchette
ESGIS/SCHES
Department of Environment, Health and Natural Resources
P.O. Box 29538
Raleigh, NC 27626
(919) 733-7051
(919) 733-0680 (fax)

Kris Matson
DEM-Groundwater Section
Department of Environment, Health and Natural Resources
P.O. Box 29535
Raleigh, NC 27626
(919) 733-3221
(919) 715-0588 (fax)

Ed Shuller, Director
GIS Branch
Department of Transportation
P.O. Box 25201
Raleigh, NC 27611
(919) 250-4187
(919) 250-4176 (fax)

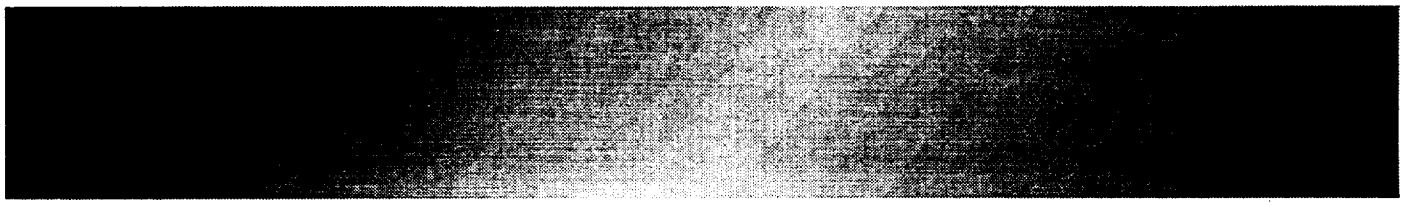
Gap Analysis Program Contact

Dr. Jaime Collazo
Department of Zoology
North Carolina State University
Box 7617
Raleigh, NC 27695
(919) 515-8837
(fax) 515-5327
jaime_collazo@ncsu.edu

State Government Context

North Carolina has a long history of using and coordinating GI/GIS. While other agencies have GI/GIS capabilities, the majority of these activities have been located in the state's ***Center for Geographic Information and Analysis (CGIA)***. CGIA was authorized in 1991 by executive order to officially serve in a statewide GI/GIS coordination role and to also provide GI/GIS services as a service bureau. It had informally served in these roles for more than a decade before they became official in 1991. CGIA is one of the largest state GI/GIS service bureaus among the states, with more than 30 employees. The executive order also authorized CGIA's move to the Governor's ***Office of State Planning*** from the ***Department of Environment, Health, and Natural Resources (DEHNR)***.

North Carolina has a ***Geographic Information Coordinating Council,*** which was created by the aforementioned executive order and provides state direction regarding GI/GIS. The council has various groups that address specific issues, including a GIS user group that facilitates coordination among GI/GIS users. CGIA provides staff support to the council. Several GI/GIS coordination activities are conducted by the council, its groups, and CGIA, including a conference and other meetings.



Satellite Data Use

CGIA provides GI/GIS services for and with numerous agencies. Some of its projects have used satellite data and image processing as well as GIS. An important CGIA role is developing, managing, and providing access to several data sets for use with GIS. CGIA has been assembling a corporate data base of statewide digital geographic information.

A recent effort has been the development of both a **statewide land-use/cover** layer and a **wetlands** data layer. Landsat TM data were acquired in 1994 under EOSAT's Statewide Purchase Program. Earth Satellite Corporation (EarthSat) was hired to develop a comprehensive statewide land-cover database composed of more than 20 thematic classes that can be integrated with the state's other data. This data base was designed following extensive participation and review by several entities in the state. A thorough document was prepared to describe applicable classifications, titled "Standard Classification System for the Mapping of Land Use and Land Cover for the State of North Carolina" (January 1994). In addition, a statewide Landcover Forum was jointly sponsored by the Geographic Information Coordinating Council and the Federal Geographic Data Committee in 1996. The land-cover data base is being built on the work that CGIA performed for the Albemarle-Pamlico Estuarine Study for the eastern part of the state and the Southern Appalachian Man and the Biosphere (SAMAB) program, which mapped the SAMAB region in western North Carolina. This information is being incorporated into the statewide land-cover data base under development by EarthSat and expected to be completed in 1997. The satellite data were acquired to meet several needs.

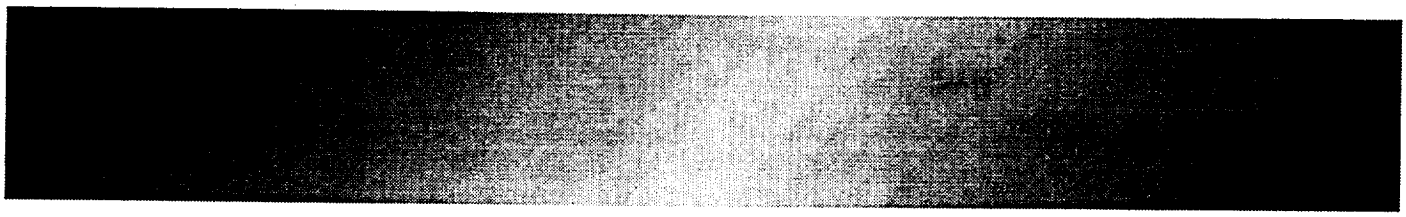
Much of the land-cover work has been conducted with funding provided by the ***Department of Transportation*** under agreement with CGIA. These data will be used by DOT to assist in selecting the best locations for **highway corridors.** For example, by using these data, DOT will be able to avoid wetlands and prime farmland as part of environmental impact assessment work, as well as facilitate economic development. Some satellite data have been used in the past for this purpose to test their utility. DOT has funded some of CGIA's other data development work as well, such as soils and archeological and historic sites data that have also been used in the planning and environmental review of highway projects.

The satellite data are also being used by CGIA to develop a wetlands data layer. This work has been funded by Region 4 of the ***U.S. Environmental Protection Agency (EPA)*** as part of its effort to have full wetlands coverage for the entire southeastern region of the United States. This layer is being prepared by CGIA staff by combining the satellite data with soils and National Wetlands Inventory data from the ***U.S. Fish and Wildlife Service.*** It is expected to be completed in late 1997.

It is anticipated that new satellite data products will also be used for additional resource management, planning, and emergency management applications, particularly to help regional councils of governments and local governments develop land-use plans. In addition, CGIA has used satellite data in a variety of ways in the past in coordination with others.

DEHNR is the state's comprehensive natural resources and environmental protection agency. It was the agency in which CGIA was located until 1991. It has worked with CGIA in various projects using satellite data.

The Albemarle-Pamlico Estuarine Study has been a $10 million program jointly funded by the EPA and the state. The study has been one of the leading state projects to use satellite data. The estuary is the second largest in the Nation and the first to be designated as an estuary of national concern under the National Estuarine Program of the 1987 Clean Water Act. The goal of the study was



to generate and consolidate the scientific knowledge necessary to develop a viable, long-term **coastal resources management** strategy and plan for the estuary. Work was primarily conducted by state agencies and universities in the late 1980s, with CGIA serving as the designated information management center for the study. Various data have been developed using satellite data and have helped assess trends in **water quality** and the **impact of land-use decisions** on water quality and the productivity of the estuary. This work was used as a basis for the statewide land-cover work now under way.

The Water Quality Section DEHNR's ***Division of Environmental Management*** has worked with CGIA to use satellite data to conduct **watershed planning** for the state's water basins. Funding has been provided by the state and EPA. An ongoing program in DEHNR is the Nutrient Sensitive Watershed program, which was initiated to identify selected watersheds where water quality is severely affected by nutrients and to implement procedures to reduce the nutrient-inducing nonpoint source pollution.

Efforts are continuing at CGIA to coordinate various efforts under way in the state that are using satellite data. These efforts include those described above and those at the university level.

Gap Analysis Program Activities

The Gap Analysis Program (GAP) is being conducted by the ***Department of Zoology*** at ***North Carolina State University.*** Initial work concentrated on land-cover mapping in coordination with the statewide land-cover mapping effort under way by CGIA and the Coastal Change Analysis Program (C-CAP) being conducted at the North Carolina State University's ***Computer Graphics Center.*** GAP work is being conducted in coordination with both centers to refine the vegetation classification to meet the national GAP standards.

Analyses will be stratified based on three general physiographic provinces (coastal plain, piedmont, and mountains) and subunits within those. Coastal vegetation classification was refined, and available ground-truth data were compiled for the piedmont and mountains in 1996. Work is being coordinated with the Multi-Resolution Land Characterization Consortium to integrate the North Carolina vegetation mapping methodologies with those of neighboring states.

Nonstate Government Activities

North Carolina State University is the site where both the GAP and C-CAP are being conducted for the state (see above). The university's Computer Graphics Center has been the lead for work conducted with the ***National Oceanic and Atmospheric Administration*** on C-CAP. It had previously conducted a land-cover classification project for a four-scene area contiguous to a four-scene area analyzed by ***Oak Ridge National Laboratory*** in the Chesapeake Bay Project (see under Maryland). University faculty worked with laboratory staff to investigate the potential to merge portions of these independently conducted classifications based on Landsat TM data. This research was a test of the C-CAP concept of regional compatibility among neighboring data bases developed by different organizations. Additional work included accuracy assessments of classifications and change detection over time.

An effort has been under way by the ***Tennessee Wildlife Agency*** and the ***University of Tennessee*** to understand changes in the Appalachian Mountains in eastern Tennessee and western North Carolina. Various satellite data have been acquired to reveal changes over time. The project includes efforts to monitor forest-cutting practices, road development, recreation, and other influences to determine their effects on the black bear population (see under Tennessee).

North Dakota

State GI/GIS and Satellite Data Contacts

* Allen Veit
Associate Director for Security
Information Services Division
Office of Management and Budget
600 E. Boulevard Avenue
Bismarck, ND 58505-0100
(701) 328-3173
(701) 328-3000 (fax)
veit@pioneer.state.nd.us

Mark Luther
North Dakota Geological Survey
600 E. Boulevard Avenue
Bismarck, ND 58505-0840
(701) 328-9700
(701) 328-9898 (fax)
mark@eagle.ndgs.state.nd.us

Bill Miller
Water Commission
900 E. Boulevard Avenue
Bismarck, ND 58501
(701) 224-2754

Gap Analysis Program Contact

None reported.

State Government Context

North Dakota has had a relatively limited amount of GI/GIS activity and little satellite data use compared to other states. The state does not have an office or full-time position dedicated to GI/GIS coordination or services. However, the ***Information Services Division*** of the ***Office of Management and Budget*** serves as the lead agency for GI/GIS as implied in an executive order signed in 1995.

The state GI/GIS coordination effort has become stronger and more formal with the executive order. It authorized the North Dakota ***GIS Technical Committee*** to provide direction, communication, and coordination of GI/GIS activities, although the group had existed before 1995. The committee is chaired and staffed by the Information Services Division. The order also states that the committee shall act as a clearinghouse of GIS activities. State agencies have been requested to report their holdings of digital spatial data to the committee, and plans are under way to have these data maintained by the ***North Dakota Geological Survey.***

Satellite Data Use

North Dakota has limited GI/GIS usage to date, with most work concentrated on soils and transportation. Satellite data have not been used by state government in recent years.

However, a satellite downlink is used by one state agency. Natural resources and environmental programs are conducted by various agencies in North Dakota. The ***State Water Commission*** is responsible for water management activities. Its ***Atmospheric Resource Board*** collects and archives lightning information, predicts lightning, and identifies the location of severe weather for emergency management purposes. It has operated with funding from the ***National Oceanic and Atmospheric Administration*** and uses data from a satellite downlink from the State University of New York at Albany.

Gap Analysis Program Activities

None reported.

Ohio

State GI/GIS and Satellite Data Contacts

* Gary Schaal
Bruce Motsch
Remote Sensing Unit
Department of Natural Resources
1952 Belcher Drive, Building C-4
Columbus, OH 43224-1387
(614) 265-6769
(614) 267-2981 (fax)

* David Crecelius, GIS Manager
Office of Computer and Information Services
Department of Natural Resources
1930 Belcher Drive, Building D-1
Columbus, OH 43224-1387
(614) 265-6776
(614) 265-7223 (fax)
Dave.Crecelius@dnr.ohio.gov

Barb Wooldridge
Division of Surface Water
Ohio Environmental Protection Agency
Watermark Drive
P.O. Box 1049
Columbus, OH 43216-1049
(614) 644-2150
FAX 644-2329
bwooldri@chagrin.epa.ohio.gov

* Stu Davis, Executive Director
Ohio Geographically Referenced Information Program
2151 Carmack Road
Columbus, OH 43221-3595
(614) 466-4747
(614) 752-1359 (fax)
ogrip_field@ohio.gov

Ann Bardwell
GIS Support Center
Division of Computer and Information Systems Services
Department of Administrative Services
2151 Carmack Road
Columbus, OH 43221-3595
(614) 752-8391
(614) 728-5297 (fax)
gis_bardwell@ohio.gov

John Bossler, Director
Center for Mapping
Ohio State University
1216 Kinnear Road
Columbus, OH 43212
(614) 292-1600
(614) 292-8062
bossler@cfm.ohio-state.edu

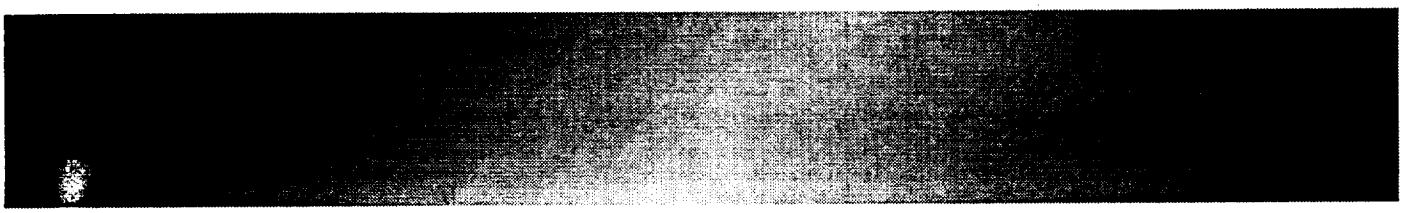
Gap Analysis Program Contact

None reported.

State Government Context

Ohio has had an active statewide GI/GIS coordination effort under way since 1988, known as the ***Ohio Geographically Referenced Information Program (OGRIP).*** According to an executive order in 1993, OGRIP is directed by the ***OGRIP Council,*** composed of selected members from various sectors in the state. Additional GI/GIS coordination is conducted through the ***OGRIP Forum,*** which is composed of many GI/GIS users in Ohio. OGRIP has a small staff dedicated to conducting coordination activities, and several efforts are under way.

Ohio also has a statewide ***GIS Support Center,*** located in the ***Division of Computer and Information Systems Services*** of the ***Department of Administrative Services.***



Created in 1990, the center provides GI/GIS services to state agencies on a fee-for-service basis. It also provides data dissemination services for several data bases that can be used with GIS. The center is physically located at the same office with OGRIP staff.

In addition, Ohio State University has a Center for Mapping, which has several GI/GIS activities both at the state and national levels, including several projects concerning advanced uses of GPS. The center has developed a statewide digital data base at the 1:24,000 scale with funding from four state agencies. A Federal match to these funds was provided by the U.S. Geological Survey, and additional Federal assistance is provided through NASA funding support (see below). The center is also represented on the OGRIP Council.

Satellite Data Use

Ohio has a long history of using GI/GIS and remote sensing, both in state government and academia. The ***Department of Natural Resources (DNR)*** and the ***Ohio Environmental Protection Agency (OEPA)*** carry out most of the state's natural resources and environmental programs, and they have had various GI/GIS activities under way for more than 20 years. More recently, the state established the GIS Support Center in 1990 to provide data dissemination and GI/GIS services for multiple entities. For example, it is providing access to data developed by various state entities, including the 1:24,000-scale scanned data developed by Ohio State University's Center for Mapping (see below).

DNR began using geoprocessing in 1973. It was one of the first users—and the most extensive—of satellite data and GIS in Ohio's state government. It has a departmentwide GIS coordinator located in its ***Office of Computer and Information Services.*** The Resource Analysis Section in the Real Estate and Land Management Division includes the ***Remote Sensing Unit*** and the ***Ohio Capability Analysis Program (OCAP).*** OCAP was authorized by the legislature in 1984 to provide natural resources information for county planning agencies and others for local land-use and resource management planning and decision making, including land capability and suitability analysis, as well as agricultural tax assessment information for county auditors. OCAP's digital data have been under development for individual counties since 1973. OCAP data are from various sources, including land-use data collected from aerial photography flown and interpreted by DNR's Remote Sensing Unit. Current efforts include data development, maintenance, and management for various DNR needs.

Ohio's DNR is unique compared to other states because of its dedicated Remote Sensing Unit. Few states have such a unit and staff. It has used satellite data with ERDAS software to help develop statewide land-cover/use coverage and analysis, as well as other data and applications. The largest project, a joint effort with OEPA and funded by NASA, is titled "Updating Ohio's Land-Use/Land-Cover Data Base." The land-use/land-cover project was developed to support coastal and watershed management efforts as needed based on water quality conditions. This work has implications for other states sharing the Great Lakes shorelines. The priority focus of the project was to provide data to support the Lake Erie GIS project and the Ohio Coastal Management Program.

The project updated and compared land-cover work done in the past in cooperation with the ***U.S. Geological Survey (USGS);*** it included the development of a current land-cover data base for the entire state using 1992–1993 Landsat TM data to identify Level 1 land cover. The Lake Erie watershed in the northern part of the state was the first area completed in accordance with the overall project goals. Agricultural impacts on the lake were determined using existing OEPA water quality data and Level 2 land-

cover classification data in the watersheds. In addition, the sediment concentrations of rivers flowing into the lake were also determined, including coupling a USGS sampling effort to future Landsat data. Groundwater discharge to Lake Erie was also estimated using thermal measurements from satellite data and field measurements of groundwater and temperatures near shorelines. Areas identified where groundwater is moving into the lake basin are targeted as "Lake-Drainage protection zones," similar to wellhead protection zones where monitoring and remediation can occur.

Satellite data have also been used in other efforts at DNR, including to support its **wetlands inventory, abandoned mine lands management and reclamation, and conservation tillage-making.** DNR cooperates with other state and Federal agencies, as well as Ohio State University's Center for Mapping, in these efforts. DNR's primary use of satellite data to date has been to develop a comprehensive wetlands data layer for the state, known as the Ohio Wetlands Inventory from Landsat data. The Remote Sensing Unit worked with DNR's ***Division of Wildlife,*** the ***USDA Natural Resources Conservation Service,*** and others on the Ohio Wetlands Inventory, which is used for **wildlife resource management, planning, and regulation.**

One example of a DNR effort is a land-cover classification conducted for eastern and southeast Ohio using June 1988 Landsat TM data as part of an abandoned mine lands inventory. The ***Resource Analysis Section*** conducted the digital image processing for the DNR ***Division of Reclamation***'s Abandoned Mine Lands Program (see Figure B6). The processing was performed using PC ERDAS version 7.5 and VAX ERDAS version 7.4. The classification was achieved using TM data converted to principal components. Land-cover spectral signatures were collected using both the supervised and unsupervised methods. Field information from the Division of Reclamation was used to guide the spectral signatures

Land Cover of Ohio Coal Mining Counties

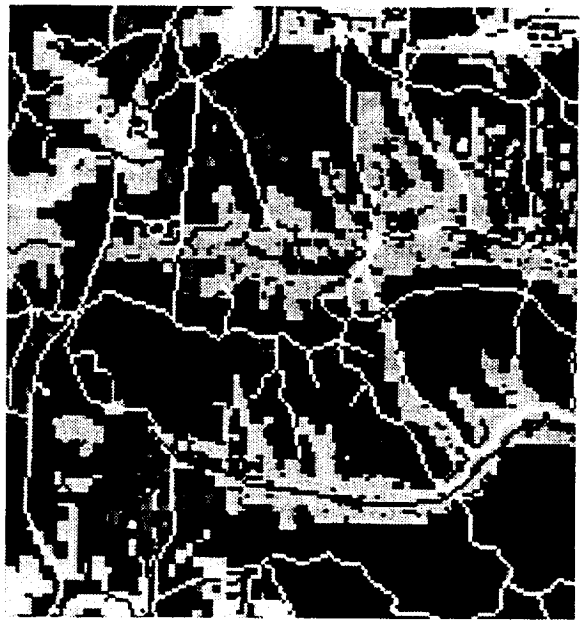


Figure B6

This map is part of a change detection study using abandoned mine data collected in the early 1980s. The change detection will help Ohio's Division of Reclamation review past reclamation projects and provide guidance in allocating resources for future projects. (courtesy of Gary Schaal and Bruce Motsch, Remote Sensing Unit, Department of Natural Resources, (614) 265-6769)

associated with abandoned mine lands: coal wastes, mine spoil, bare soil, and vegetation. The Division of Reclamation is conducting a classification review and an accuracy assessment. This classification will be used in a change detection study using abandoned mine data collected in the early 1980s. The change detection will help the Division of Reclamation review past reclamation projects and provide guidance in allocating resources for future projects.

OEPA has perhaps the longest history of GIS use compared to environmental protection agencies in other states. It is also using satellite data as a cooperator in the

NASA project described above. OEPA received funding from the ***U.S. Environmental Protection Agency (EPA)*** for various GI/GIS projects, including the use of GPS to locate sites and the application of GIS and land-cover data to evaluate biologic information as environmental indicators of changes and improvements in environmental quality. EPA also supported the compilation of Ohio data from OEPA and others to make data available on a CD-ROM, as well as the development of a comprehensive GIS/wellhead protection prototype demonstration project.

Gap Analysis Program Activities

None reported.

Nonstate Government Activities

The ***Ohio State University*** has image processing and GI/GIS capabilities and projects in various departments, with many affiliated with the ***Center for Mapping.*** The university is one of the foremost in the country regarding geodesy, and it is actively involved in such activities in and outside Ohio. The Center for Mapping and its affiliates have been actively involved in state government GI/GIS activities. For example, its director was one of the founding members of OGRIP and has served as chair of the OGRIP Council in the past.

One of the most important activities of the Center for Mapping regarding state government is the development of a statewide digital data base at the 1:24,000 scale, known as GISOM (Generating Information from Scanning Ohio Maps). Four state agencies contributed to the effort, and Federal support was provided by NASA and the USGS. This project produced DLG-3 Standard files for the state's 800 quadrangles to meet the USGS's requirements in the cooperative mapping program. However, unlike other states participating in this USGS program, the work was conducted by Ohio State University rather than Federal staff. Scanning and new in-house software were used for hydrography and hypsography data development and processing. These data are being distributed by the state GIS Support Center (see above).

Oklahoma

State GI/GIS and Satellite Data Contacts

* Bob Springer, State Geographer and GIS Coordinator
Oklahoma Conservation Commission
2800 N. Lincoln, Suite 160
Oklahoma City, OK 73105-4210
(405) 521-4831
(405) 521-6686 (fax)
springer@occgis.osmre.gov

Dr. Jayne Salisbury, Director
Spatial and Environmental Information Clearinghouse
Environmental Institute
002 Life Sciences East
Oklahoma State University
Stillwater, OK 74078-0628
(405) 744-9229
(405) 744-6763 (fax)

Mary Banken, Director
Center for Spatial Analysis
University of Oklahoma
100 E. Boyd, Room 510
Norman, OK 73019
(405) 325-0381
(405) 325-3180 (fax)

Gap Analysis Program Contact

Dr. William L. Fisher
Cooperative Fish and Wildlife Research Unit
404 Life Sciences West

Oklahoma State University
Stillwater, OK 74078
(405) 744-6342
(405) 744-5006 (fax)
wfisher@osuunx.ucc.okstate.edu

State Government Context

GI/GIS activities in Oklahoma are coordinated on a statewide basis through a statewide ***GIS Council*** established by the 1994 legislature. The council has 11 members from state government agencies and academia. The 1994 legislation specifies that the ***Oklahoma Conservation Commission*** is the chair of the council. As a result of this legislation, the commission serves as the lead agency for state GI/GIS coordination in state government, including the location of a full-time state geographer, who also serves as the state GI/GIS coordinator.

No state agency conducts GI/GIS services for state or other agencies. However, the GIS Council has several efforts under way, including the development of a GIS strategy published in May 1996. The council is also working to produce a CD–ROM of base data layers for use with GIS in Oklahoma. In addition, ***Oklahoma State University*** has a Spatial and Environmental Information Clearinghouse, which manages some data resources for use with GIS and has assisted state agencies regarding GI/GIS, particularly metadata (see below).

Satellite Data Use

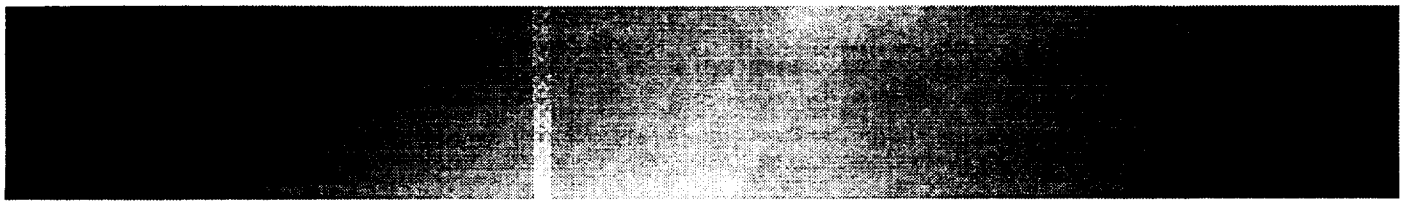
The vast majority of satellite data work in Oklahoma is conducted at academic institutions (see below). GI/GIS use began relatively recently in Oklahoma's state government. However, various state agencies are expanding their GI/GIS activities and have increasing interest in satellite data. Natural resources and environmental responsibilities are shared by various agencies. The ***Water Resources Board***'s Engineering Division was one of the first GIS users in state government, beginning its efforts in 1991 to address water quality needs with some support from the ***U.S. Environmental Protection Agency (EPA)***.

The ***Forestry Division*** in the ***Department of Agriculture*** is the only state agency known to have used some satellite data in house. This work was conducted with Oklahoma State University's ***Range Department*** to evaluate the use of satellite data to conduct forest inventory and analysis efforts. Both SPOT and Landsat TM data were investigated as part of this effort.

Gap Analysis Program Activities

The Gap Analysis Program (GAP) has been under way since 1991 by the ***Cooperative Fish and Wildlife Research Unit*** of Oklahoma State University. Other participants include the state ***Biological Survey,*** the ***University of Oklahoma,*** and other state and Federal agencies. Efforts accelerated in the last couple of years, with a recent focus on the production of the vegetation, animal distribution, and land ownership and management data layers. This phase of the project has been challenging, mainly because of the size and complexity of the data and analyses.

A land-cover classification scheme was prepared in 1995, and it has been modified to incorporate recent changes made by state botanists. Statewide Landsat TM data were acquired from the U.S. Geological Survey's EROS Data Center, covering 16 different scenes or locations, including 11 scenes with data of a single date and five scenes with multitemporal data. In addition to the TM data, hyperclustered data of 6 and 12 channels were also received for most of the scenes. Processing and analysis are now under way. Airborne videography data have also been received, consisting of geocoded images from 17 north-south transects covering Oklahoma, flown in June



and July 1994. These data are being used to interpret vegetative cover types and verify the TM analysis. The land-cover data layer is expected to be completed in 1997.

The central data base of vertebrates has been created and populated with species element codes, scientific names, common names, state and Federal ranks and status, descriptions of habitat and environmental associations, and related information. Except for a few species, geographic ranges of mammals, birds, reptiles, and amphibians have been mapped, verified, and digitized. Locational data bases are being compiled. Habitat associations have been encoded for all reptiles and amphibians and are being completed for birds and mammals. A pilot study was conducted using a preliminary vegetation/land-cover map to test procedures for overlaying vegetative cover, vertebrate distributions, and land ownership/management layers.

Efforts included digitizing 379 public and private managed land units, including all 44 school land parcels. This represents about 95 percent of the public and private managed areas, open spaces, and wild lands in Oklahoma. The remaining major task is to code each managed land unit using either the existing or revised national GAP land classification system. Reviews of these code designations will be solicited from individual landowners.

Nonstate Government Activities

The largest satellite data efforts in academia are located at Oklahoma State University and in coordination with its new ***Environmental Institute,*** such as Oklahoma's GAP work (see above). The institute operates the Spatial and Environmental Information Clearinghouse, which provides data management services in coordination with the state GIS Council and has assisted state agencies (see above). The university's ***Center for Applications in Remote Sensing*** has been working in remote sensing since 1979 as a NASA technology transfer site. Since then, GIS facilities and capabilities were developed, with projects including the development of soils information with the ***USDA Natural Resources Conservation Service.*** These data have been used for **erosion, conservation, and land management** applications. Work has also been conducted with EPA to help with **water quality** applications, including sampling at selected sites and point source discharges. **Watershed analyses** have also been conducted for clean lakes projects. The Range Department has worked with the state Department of Agriculture's Forestry Division to evaluate the use of satellite data for forest inventory and analysis. The ***Geography Department*** also uses satellite data on a project basis and provides extensive training on GPS use.

The ***University of Oklahoma*** has a ***Center for Spatial Analysis*** that was established in 1994. It is coordinated with the state ***Geological Survey,*** also located at the university. It provides GI/GIS services and expertise in various projects.

Oregon

State GI/GIS and Satellite Data Contacts

* Theresa Valentine, Manager
State Service Center for GIS
Information Resources Management Division
Department of Administrative Services
155 Cottage Street N.E.
Salem, OR 97310
(503) 378-4163
(503) 986-3242 (fax)
theresa.j.valentine@state.or.us

Milton Hill
Donavin Lechenby
Department of Fish and Wildlife
2501 S.W. 1st Avenue
Portland, OR 97201
(503) 229-6967/5410

Alan Maul
Kevin Birch
Department of Forestry
2600 State Street N.E.
Salem, OR 97310
(503) 945-7334/7405

Gap Analysis Program Contact

Dr. Blair Csuti
US Fish and Wildlife Service
2600 SE 98th Ave, Suite 100
Portland, OR 97266
(503) 231-6179
(503) 231-6195 (fax)
blair@manatee.geo.orst.edu

State Government Context

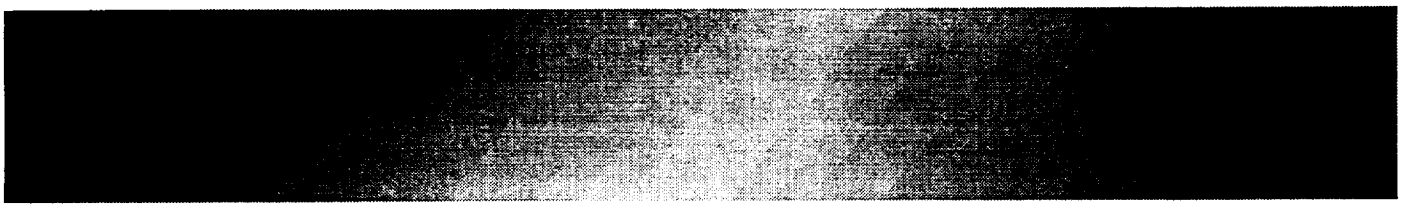
Oregon has had a statewide approach to GI/GIS for many years. The ***State Service Center for GIS*** was officially recognized by executive order in 1989 as the central entity to provide statewide GI/GIS services and data coordination. It has been subsequently reauthorized by executive orders in 1994 and 1996. Previously located in the Department of Energy, the center moved to the ***Information Resources Management Division*** in the ***Department of Administrative Services*** in 1994. It provides data development, management, and dissemination, as well as some GIS services and assistance on a fee-for-service basis.

Statewide GI/GIS policy and planning direction is provided by the ***Oregon Geographic Information Council,*** which has also been authorized by these executive orders. Additional state GI/GIS groups help facilitate GI/GIS coordination, such as the ***GIS Project Leaders*** group, which consists of the GI/GIS managers or coordinators in state agencies. Oregon's ***GIS Association*** is primarily composed of representatives of local governments who use or are interested in GI/GIS. These groups are staffed by the State Service Center for GIS. Various activities are under way by these groups.

Satellite Data Use

Some state agencies in Oregon have used satellite data for internal needs. The State Service Center for GIS has several data initiatives, but it is not using or providing access or services regarding satellite data. However, the center has received requests for satellite data, and some applications have been investigated because it is envisioned that statewide land-cover data could be helpful in many ways.

Current statewide data development initiatives include Baseline 97, a project to complete statewide coverage for the Public Land Survey, boundaries, hydrography, transportation, topography (digital elevation models), and scanned images of U.S. Geological Survey 1:24,000-scale quadrangle sheets. Several Federal, state, and local agencies are contributing to this effort, including the ***Bureau of Land Management*** and the ***USDA Forest Service.*** A unique data base that is available through an agreement with Etak Corporation is a standardized, statewide file of Oregon's addresses and street and highway network. The data base was originally developed to support E911 emergency service, but it can be used for other purposes. Part of the agreement is that these data will be maintained and available for all state agencies and political jurisdictions in the state.



Natural resources and environmental activities are conducted by a variety of agencies, most of which are using GI/GIS for internal needs. Two efforts represent the primary state users of satellite data at this time: the Gap Analysis Program (GAP) and the development of a state vegetation data layer (see below).

The ***Department of Fish and Wildlife*** is an active participant and user of satellite data as part of the state GAP (see below). This effort has strong departmental support because there is a long-term commitment to develop a full **wildlife information system** for the state. This project is overlaying known occurrences of plant and animal species, vegetation, and other layers to identify habitat associations in upland areas. A determination of occurrences and relationships between habitat and species will be used for a variety of purposes, including various environmental assessments. The department and other GAP cooperators are working under a $550,000 grant from the ***U.S. Environmental Protection Agency*** titled "Multiscale Biodiversity Conservation: A Prototype Process for Oregon." Part of this funding is being used to conduct more detailed Gap Analysis work than the existing GAP effort.

Some other department projects have taken advantage of satellite data. For example, satellite data were used in research to understand **relationships between wildlife and domesticated animals,** such as deer, elk, and livestock, habitat impacts, and how these animals use and compete for the plant community.

The ***Department of Forestry*** was one of the earliest users of automated mapping in the state, beginning in 1972. It has used GI/GIS to assist in fire management, particularly in fire response efforts. The department contracted with Pacific Meridian Resources Inc. to develop a **vegetation data layer** using Landsat TM data and field reconnaissance. This work was done in a similar manner to work conducted for the USDA Forest Service in Oregon, Washington, and northern California in response to concerns and to help determine the impacts of logging on wildlife in the Pacific Northwest.

Other Oregon agencies are considering the use of satellite data. For example, the ***Water Resources Department*** has used GIS since 1986 to meet agency needs. It has considered using satellite data to complement existing water basin planning processes and to determine water availability, use, and rights. Satellite data could help determine the place of use and potential water rights violations by cross-referencing this information with the water rights map.

Gap Analysis Program Activities

The ***U.S. Fish and Wildlife Service*** is the lead organization for the Oregon GAP. It is working with the state Department of Fish and Wildlife and other cooperators in this regard. A new vegetation map was developed based on the 23 full or partial Landsat TM scenes that cover the state. This map was completely classified and labeled in 1996. An accuracy assessment is planned for 1997. Land ownership and managed area data layers have also undergone minor updates. By the end of 1997, plans are to complete 420 vertebrate distribution maps, based on vegetation cover type polygons and ancillary data, such as digital elevation models and hydrography.

Work is conducted in close cooperation with the Biodiversity Research Consortium. Several analyses of current Oregon data layers have been conducted, including a preliminary Gap Analysis of 66 aggregated vegetation types. Five cover types were not represented in natural areas, and another 12 had less than 2 percent of their area in natural areas. These were mostly desert shrub and oak woodland cover types. Four of six types with more than 50 percent of their area in natural areas were high-elevation

forests and alpine communities. Efforts are under way in cooperation with the U.S. Fish and Wildlife Service's Klamath Basin Ecosystem Restoration Strategy. In response to their needs, the first TM scenes in the Klamath region have been labeled, and higher resolution mapping may be undertaken for the area.

In cooperation with researchers in Australia and the United Kingdom, the Biodiversity Research Consortium species distribution data base has been used to compare the efficiency and spatial outcomes of 19 reserve selection algorithms. Linear integer programming, only recently applied to this problem, provides optimal solutions to "cover the set" within a reasonable run time. Surprisingly, far simpler heuristic algorithms also perform very well. Most species (90 percent) are represented in five areas (EMAP 635-square-kilometer hexagons), but 23 areas are needed for complete coverage. Species peripheral to the state tended to guide the selection of the last dozen areas. This finding underscores the need to carry out bioregional analyses. A paper describing this research is in press in *Biological Conservation*.

Much time and effort during 1995 went to the preparation of a book-length manuscript, "Atlas of Oregon Wildlife." This is a natural product of GAP species distribution maps and will make one of the GAP products available to a general audience. Most reference works on Oregon vertebrates are more than 50 years old, so this new synthesis of ecological and distributional information on Oregon species is a major contribution. Negotiations are under way to have it published by Oregon State University Press.

Nonstate Government Activities

The Geosciences Department at ***Oregon State University*** has worked with satellite data and GI/GIS for some projects. For example, they have been used to determine and analyze lands available for development, including work to distinguish the classification of these lands. The department is also working on the state GAP project (see above). The Geosciences Department recently created a new GI/GIS laboratory called Terra Cognita to support this type of research.

Pennsylvania

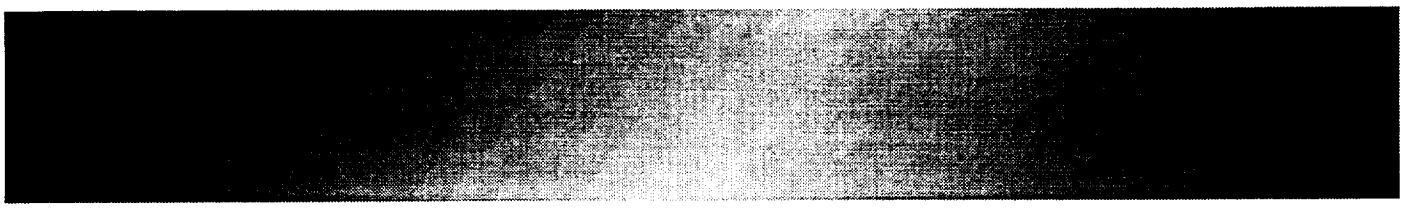
State GI/GIS and Satellite Data Contacts

* Tom Baldwin, Director
Mike Gagnon, GIS Coordinator
Bureau of Information Services
Department of Environmental Protection
P.O. Box 8761
Harrisburg, PA 17105-8761
(717) 772-5851
(717) 772-1676 (fax)
gagnon.michael@a1.dep.state.pa.us

* Todd Bacastow
Environmental Resources Research Institute
Land and Water Building
Pennsylvania State University
University Park, PA 16802
(814) 863-0049
(814) 865-3378 (fax)
bacastow@gis.psu.edu

Gap Analysis Program Contact

Dr. Wayne Myers
211 Ferguson Building
Pennsylvania State University
University Park, PA 16802
(814) 865-8911



(814) 865-3725 (fax)
wlm@psuvm.psu.edu

State Government Context

Pennsylvania is in the process of reinvigorating its statewide GI/GIS coordination effort. A statewide GI/GIS committee has existed in various forms since 1988. At times, these efforts had official support, while at other times GI/GIS coordination has been more informal.

A new GI/GIS group known as the ***Pennsylvania Mapping and Geographic Information Consortium*** was initiated in 1996. It is a nonprofit organization composed of representatives from multiple sectors. At the same time, the ***GIS Planning Committee*** is a forum at which state agency representatives working with GI/GIS meet regularly to conduct coordination activities, with primary efforts focused on the annual GIS conference.

No state agency has an official role to lead or support statewide GI/GIS coordination among state or other entities. At the same time, GI/GIS activities in state agencies have been limited compared to many other states. Staff at ***Pennsylvania State University*** have facilitated some coordination among GI/GIS users, and they recently have been charged and funded to serve as a data clearinghouse.

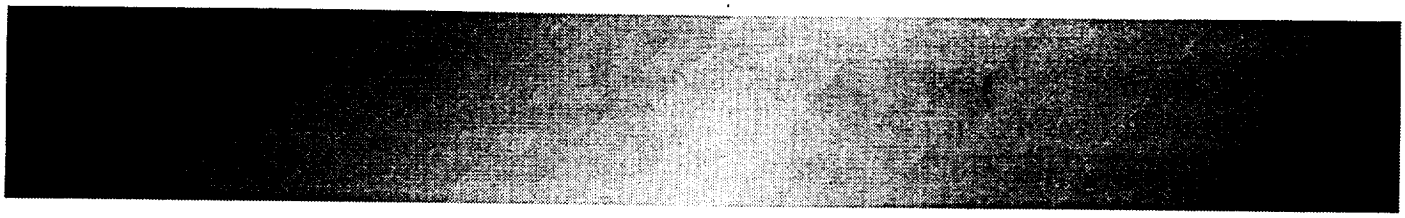
Satellite Data Use

Pennsylvania's state agencies have had little use of satellite data, as well as a lower level of GI/GIS use and coordination than several other states. However, efforts have recently been under way to provide information about and access to data for use with GIS. The ***Department of Environmental Protection (DEP)*** established a 5-year contract with the ***Environmental Resources Research Institute*** at Pennsylvania State University to serve in a clearinghouse role for DEP and other state data. Accordingly, the institute has been using this initial funding provided by DEP since 1996 to begin creating the Pennsylvania Spatial Data Access (PASDA) System. Participants are gathering data and metadata for PASDA, and an online system is expected to be operational in 1997.

DEP's above initiative regarding a geographic data clearinghouse has not specifically included satellite data, nor has it used satellite data in house. DEP has existed since July 1995, when Pennsylvania reorganized its environmental and natural resources functions. The state previously had a Department of Environmental Resources that handled most of these roles. That department was dissolved in 1995 to establish DEP and the ***Department of Conservation and Natural Resources (DCNR)***. The Department of Environmental Resources had been developing an agencywide approach to GI/GIS, with a GIS center located in the Bureau of Information Services. This focal point and GIS facilities were retained by DEP after the reorganization, although DCNR also uses them.

GIS development in DEP, DCNR, and the Department of Environmental Resources before them has been limited until recent years. Recent DEP efforts have defined data needs and built expertise and technology capabilities, but interest in satellite data has been limited. A CD-ROM was produced in 1995 of all available data sets, many of which were developed for analyzing the best location for a low-level radioactive waste facility and are now being used by DEP's Bureau of Radiation Protection. In addition, DEP is funding initial work at Pennsylvania State University to establish a state data clearinghouse (see above).

DCNR's Bureau of Topographic and Geologic Survey, Bureau of Forestry, and Bureau of State Parks are the largest GI/GIS users within this agency. However, none of these bureaus or other state agencies are making significant use of satellite data, except the ***Pennsylvania Game***



Commission, which has contributed its Fish and Wildlife Database to the Gap Analysis Program (GAP) effort.

Gap Analysis Program Activities

The Pennsylvania GAP is being conducted at Pennsylvania State University. Work is expected to be completed in 1997. Efforts are under way with other entities to acquire useful data and become aware of and avoid overlap among the data bases. For example, the Pennsylvania Game Commission contributed data to the project. The *Pennsylvania Bird Atlas* was a major source of information for this data base as well.

GAP is viewed as a step toward a cooperative and comparative multiscale landscape information infrastructure initiative. The assessment of conservation status and opportunities for vertebrate habitats is only one among many motives for undertaking the initiative. The overarching goal of the initiative is one of landscape understanding. An initial biodiversity plan for Pennsylvania was prepared by the ***Pennsylvania Biodiversity Technical Committee.*** Efforts to implement the plan will utilize Gap Analysis results in Pennsylvania's conservation programs.

Rather than choosing among various technological approaches to spatial information, a progressive scenario of spatial technologies and information sources was conceived, whereby analytical alternatives become mutually reinforcing. As the scenario proceeds from finer spatial scale to coarser scale, thematic content and landscape insight grow deeper. Thematic errors and/or uncertainties occurring earlier in the scenario can be redressed at later stages in different modes. The Gap Analysis itself does not require that full informational vision be realized, so the Gap Analysis timeframe is one stage in a developmental odyssey of indefinite duration. Funding has been secured for a sequel to Gap Analysis that is concerned with statistical approaches to multiscale analysis of critical areas in watersheds and landscapes.

Digitized range maps have been superseded by ***The Nature Conservancy*** compilation that shows the level of evidence for species occurrence in each of the U.S. Environmental Protection Agency (EPA) 635-square-kilometer hexagons in Pennsylvania as part of a pilot project sponsored by the Biodiversity Research Consortium. These data sets have been recompiled to show species richness by hexagon for selected groups of taxa. A new approach has been developed for representing and analyzing these data as a surface having at least ordinal metrics. The results from this approach are referred to as "echelons." For example, the representation of species richness as a surface is one echelon.

An initial comparison is that of combined echelons for all vertebrates against separate echelons for mammals, birds, and fish. These comparisons show obvious regional differences among the major groups of taxa. These differences are consistent with general knowledge of the respective taxa. The contrasts are sufficient to negate prospects of finding any single group of species that can serve to guide conservation work in general. From this initial comparison; it is suggested that those conducting an analysis of conservation gaps revisit this issue carefully. The occurrences of birds were compiled from *Pennsylvania Bird Atlas* information into EPA's EMAP hexagon grid. For the avian taxa, then, the hexagons provide a coarser scale view that is consistent with views for other taxa.

Land ownership GIS data layers compiled by consultants for low-level nuclear waste siting in Pennsylvania provided a base of information for GAP work, but some cooperators have expressed a desire for finer land management categories. The status of relatively small tracts is often of interest, particularly in a larger landscape context. To ensure a thorough consideration of alternatives and their merits, an internal task force was formed on land management status. Meeting GAP standards is not an issue, but the need exists to accommodate the needs of cooperators and promote research. The best

course may lead toward multiscale architectures accommodating incomplete information.

Habitat models are one sphere in which attempts to expand the knowledge envelope are very selective. Consistency with New York and New England states relative to habitat models is an important objective. Current New England work is being shared with Pennsylvania. The prospective models are operable and respond primarily to generalized landscape variables. Much is taken for granted with respect to habitat elements at a finer scale. Apparent habitat as seen by these generalized models will provide a reference against which to compare more incisive models arising from research. More sophisticated habitat modeling is under way in related projects for the bobcat and woodcock. As components of the multiscale landscape information infrastructure become available, they are being steadily incorporated into the advanced habitat modeling research.

Nonstate Government Activities

Several parts of Pennsylvania State University use GI/GIS and have assisted in coordinating GI/GIS activities in the state. Most recently, the university's Environmental Resources Research Institute has a 5-year contract with the state DEP to serve in a clearinghouse role for DEP and other state data (see above). The university is also the leading organization where the GAP work for the state is being conducted. Some Pennsylvania State University researchers have investigated the potential of using SPOT data to develop digital elevation model data for the North Slope of Alaska (see under Alaska). In addition, the ***Institute of State and Regional Affairs*** in Harrisburg serves as the State Data Center (the state's Census data center), and this institute has been involved with several GI/GIS activities. Discussions are under way to use satellite data for some state needs.

Rhode Island

State GI/GIS and Satellite Data Contacts

* John Stachelhaus, GIS Coordinator
Division of Planning
Department of Administration
One Capitol Hill
Providence, RI 02908-5872
(401) 277-6483
(401) 277-3809 (fax)
stach@rigis.doa.state.ri.us

Lynn Carlson
Environmental Regulatory Information Center
Department of Environmental Management
291 Promenade Street
Providence, RI 02903-5767
(401) 277-3961
(401) 521-4230 (fax)

Dr. Peter V. August, Director
Environmental Data Center
Department of Natural Resources Science
University of Rhode Island
210B Woodward Hall
Kingston, RI 02881
(401) 792-4794
(401) 792-4017 (fax)

Gap Analysis Program Contact

For Connecticut and Rhode Island, see under Massachusetts.

State Government Context

GI/GIS activities in Rhode Island are coordinated through the ***Department of Administration's Division of***

Planning, where the state's GIS coordinator is located. The division also funds some GI/GIS activities within the Department of Natural Resources Science's Environmental Data Center (EDC) at the University of Rhode Island. EDC has served as the leading center for GIS technology, data, and technical expertise since the Rhode Island GIS (RIGIS) was established in 1986 and authorized by the 1990 legislature. EDC provides data management and dissemination for Rhode Island data resources for use with GIS, although the data are uniquely managed as a proprietary data base. EDC provides technical support, assistance, and educational programs for many entities, including state, Federal, and local agencies.

RIGIS operates with an ***Executive Committee*** that was established by the 1990 RIGIS legislation and is staffed by the Division of Planning. The committee includes four state agencies and the university, and it sets direction for GI/GIS in the state. Discussions are under way to also have a state GI/GIS users group to facilitate coordination.

Satellite Data Use

State agencies in Rhode Island have not had much experience with satellite data. However, RIGIS was established in 1986 and has extensive GIS data resources for the state. For example, statewide land-cover/use data were developed using 1988 black-and-white aerial photography with 34 categories of land use and land cover based on a modified version of the Anderson *et al.* land classification scheme. This data layer is maintained in RIGIS, and municipalities are required to assist in updating the land-use data. Efforts are made to update these data, and some interest has been expressed in using satellite data for future land-cover work.

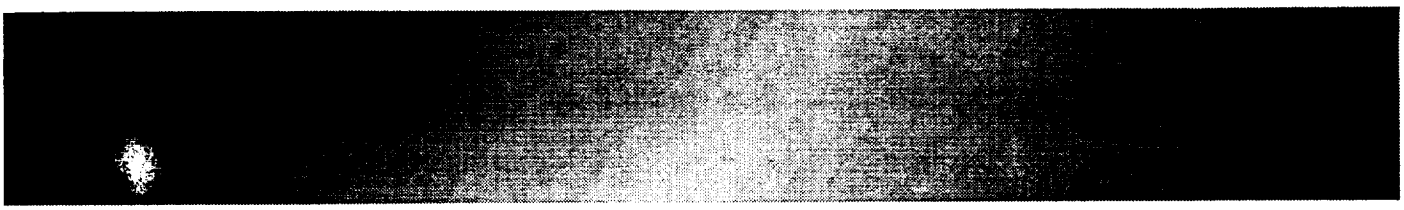
Virtually all the natural resources and environmental programs are conducted at the ***Department of Environmental Management,*** which has the majority of GIS applications in the state government and has a GIS coordinator located in its ***Water Resources Division.*** The Department of Environmental Management and the Division of Planning of the Department of Administration, the location of the state GI/GIS coordinator, fund various GI/GIS activities at the University of Rhode Island's EDC. The official location of RIGIS and its data, EDC has conducted various GI/GIS efforts for and with many entities, including state, Federal, and local agencies. Projects have been undertaken for both statewide coverage and smaller areas. For example, a leading GI/GIS project is the protection and monitoring of Narragansett Bay, which is a cooperative effort with the ***U.S. Environmental Protection Agency,*** EDC, and other state agencies.

Gap Analysis Program Activities

For Connecticut and Rhode Island, see under Massachusetts.

Nonstate Government Activities

The Department of Natural Resources Science's EDC at the ***University of Rhode Island*** is the official location of RIGIS and its data, and several GI/GIS projects have been conducted with state and other agencies (see above). In addition, faculty at the Universities of Rhode Island and Connecticut are working on a regional Coastal Change Analysis Project (C-CAP) with the ***National Oceanic and Atmospheric Administration*** to examine issues concerning coastal land-cover classification and change detection in the Northeast. Detailed GIS data on coastal wetlands in Rhode Island derived from aerial photography were used to establish coastal wetlands signatures for input to a digital classification of Landsat TM data. This work helped assess the extent to which an existing coastal wetlands data set, such as the National Wetlands Inventory, can be used to establish a



classification for a larger TM data set. Other areas of importance include assessments of classification approaches best suited to characterize wetlands in southern New England, techniques for monitoring coastal wetlands change in the Northeast using several change detection techniques to look at TM data from the same location for 1988 and 1982, and multistate, multi-institutional collaboration in southern New England.

South Carolina

State GI/GIS and Satellite Data Contacts

* Martin Roche, GIS Manager
Department of Commerce
1201 Main Street, Suite 1600
Columbia, SC 29201
(803) 737-0446
(803) 734-9200 (fax)

* James D. Scurry, Information Systems Manager
D.J. Smith, State Climatologist
Water Resources Division
Department of Natural Resources
1201 Main Street, Suite 1100
Columbia, SC 29201
(803) 737-0800
(803) 765-9080 (fax)
scurry@water.dnr.state.sc.us

* Richard Lacy, Remote Sensing Director
Land Resources and Conservation Districts Division
Department of Natural Resources
2221 Devine Street, Suite 222
Columbia, SC 29205
(803) 734-9114
(803) 734-9200 (fax)

* Mark Perry
South Carolina Geodetic Survey
Budget and Control Board
5 Geology Road
Columbia, SC 29210
(803) 896-7703
(803) 896-7695 (fax)

Jeannie Edison, GIS Manager
Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201
(803) 734-4515
(803) 734-5407 (fax)

* Dr. David Cowen, Director
Lynn Shirley, GIS Manager
College of Liberal Arts Computing Laboratory
University of South Carolina
Gambrell Hall, Room 003
Columbia, SC 29208
(803) 777-4590
(803) 777-7489 (fax)
lynn@sc.edu

Dr. James Jensen
Department of Geography
University of South Carolina
Columbia, SC 29208
(803) 777-1699
(803) 777-4972 (fax)

Gap Analysis Program Contact

Dr. David Otis
Cooperative Fish and Wildlife Research Unit
Clemson University
G08 Lehotsky Hall
Clemson, SC 29634-0362
(864) 656-0320

State Government Context

South Carolina does not have an official entity charged with or providing statewide GI/GIS coordination, data management, or dissemination. However, the state has a statewide, comprehensive GI/GIS coordination effort through its reorganizing ***State Mapping Advisory Committee (SMAC)*** and the GI/GIS committee of the ***Department of Natural Resources (DNR),*** which was established with the formation of DNR in 1994. SMAC has had a substantial involvement of several GI/GIS users in the state over the years. Coordination efforts have grown, particularly since Hurricane Hugo in 1989, which stimulated overall GI/GIS dialog and activities in the state (see below). Recent efforts have focused on enhancing SMAC's direction and authorization, and a new executive order has been proposed since 1994. SMAC is also organizing a remote-sensing subcommittee in addition to its other active subcommittees. SMAC has been chaired by the GIS manager of the ***Department of Commerce (DOC)*** (formerly the State Development Board) since the fall of 1996. DNR has the majority of the state's GI/GIS and remote-sensing activities. DOC and DNR are the informal leading agencies for GI/GIS in the state.

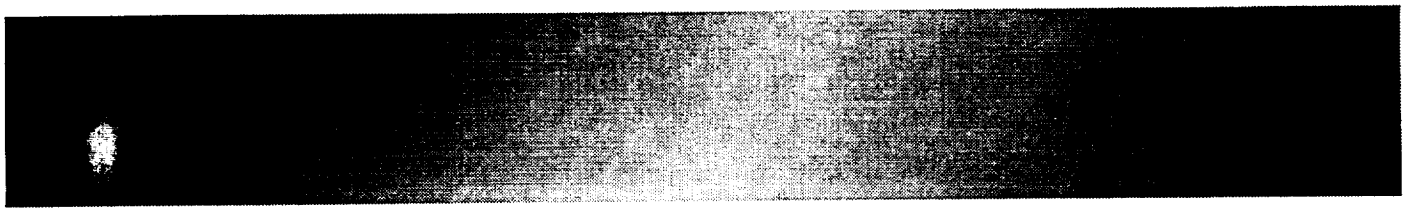
In addition, the Governor's Office asked the director of the College of Liberal Arts Computing Laboratory at the ***University of South Carolina*** to prepare a study with recommendations concerning statewide GI/GIS coordination. This report was submitted to the Governor's Office in early 1996, but actions in response to the report have been limited to date because of external factors. A state ***Information Resources Council*** was established in 1996, and several other general information technology evaluations are under way from a statewide perspective. It is anticipated that a GI/GIS group could be formed under the auspices of the council after it becomes organized.

Satellite Data Use

Compared to many states, South Carolina has made extensive use of satellite data. These activities were largely initiated for natural resources applications, but satellite data have also been used for other government functions, such as economic development as described below. Much satellite data work has been conducted in coordination with GIS activities, which have grown during the 1990s, particularly since Hurricane Hugo in 1989.

Natural resources and environmental programs are primarily located in the new DNR, the Forestry Commission, and the Department of Health and Environmental Control. DNR was formed in 1994 through a merger of various agencies with natural resources responsibilities. In addition, the Budget and Control Board has some land information management and natural resources data responsibilities, including at the South Carolina Geodetic Survey (see below). DNR has the majority of the state's GI/GIS and remote-sensing activities. DNR's Water Resources Division (known as the Water Resources Commission until 1994) has evolved to be a de facto lead entity in South Carolina for GIS.

DNR's ***Land Resources and Conservation Districts Division*** (known as the Land Resources Conservation Commission until 1994) evolved to be the lead entity regarding the state's extensive remote-sensing activities. The division is responsible for soil and water conservation planning, education and technical assistance, and regulation. This includes the implementation of programs for erosion and sediment control; flood control; nonpoint source pollution control for agriculture, construction, and urban stormwater runoff; dam and reservoir safety; the regulation of mining and mined land reclamation; and land resource planning. Several efforts have been under way using satellite data.



The division has two centers: the ***Southeastern Remote Sensing Center (SERSC)*** and the ***Land Resources Information Center.*** The division is involved in various programs, including serving as the lead for the state's participation in the National Aerial Photography Program (NAPP) with the ***U.S. Geological Survey (USGS)*** and other agencies. NAPP has conducted two overflights of the state. Satellite data and NAPP program data have been linked to recent statewide GPS points developed by the state ***Geodetic Survey*** to reference these data to 5-meter accuracy. The division is also working with the National Cooperative Soil Survey in coordination with the ***USDA Natural Resources Conservation Service.*** The soil survey program provides for field mapping, cartography, and laboratory analysis for preparing published soil surveys. The Land Resources Information Center includes the Earth Science Information Center in coordination with USGS.

SERSC began an automated land use inventory system in the late 1970s, and the center later developed an initial statewide land-cover data base using SPOT 20-meter multispectral satellite data in the late 1980s. The land-cover data base was funded by DOC and initially developed to support DOC's **economic development** applications (see below). Eight classifications were developed using the SPOT data. Efforts were aided by researchers at the University of South Carolina. The satellite data have been used for several purposes—in particular, to identify the location of roads and land cover to assist in facilities siting.

The satellite data have also been used by several agencies for **emergency management and response,** such as for Hurricane Hugo in 1989. Postdisaster SPOT data were obtained to compare conditions before Hugo and determine the extent of damage. Satellite data were also used to help determine Hugo's impact on trouble spots, such as the state's reservoirs and mines. DOC's GI/GIS and satellite data resources were used in rebuilding infrastructure after the hurricane. The ***South Carolina Forestry Commission*** and others used the satellite data to determine **forestry** conditions before and after Hugo, such as to specify forest losses on public and private lands (see below).

These satellite data were complemented by more recent satellite data work. The Land Resources and Conservation Districts Division was the lead entity in the state's acquisition of Landsat TM data in 1990 and 1992. These satellite data were acquired with funding from the ***U.S. Environmental Protection Agency (EPA)*** for the division's work, but the satellite data were also made available to other agencies according to EOSAT's Statewide Purchase Program.

The primary reason the satellite data were purchased was to assess, track, and protect **wetlands.** All of the states in EPA's Region 4 (the southeastern states) have participated in a similar effort to use Landsat data regarding wetlands. Both leaf-off and leaf-on coverage were acquired, and middle infrared bands 5 and 7 were used for the primary purpose of wetland identification and mapping. The resulting land-cover map has 17 classifications as compared to the 10 classes developed using the SPOT data. The TM classification included six for wetlands from the Landsat data as compared to two from the SPOT data. The division previously digitized National Wetlands Inventory maps of the coastal region of South Carolina in coordination with the ***U.S. Army Corps of Engineers*** and EPA to conduct advance identification studies of Carolina Bay wetlands in the state.

SERSC used additional funding from EPA in 1996 to acquire statewide SPOT panchromatic image data from 1995. Recent efforts will use these satellite data to help identify and prioritize potential **wetland conservation** parcels. This will be used in the designated Coastal Ecosystems Focus Areas of South Carolina. SERSC is working in cooperation with the ***Coastal Services Center***

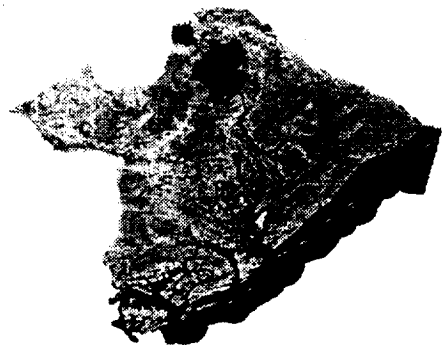
of the *National Oceanic and Atmospheric Administration (NOAA),* located in Charleston, which is newly responsible for the Coastal Change Analysis Project (C-CAP) at a national level (see below). SERSC will be converting the 17 class state land-cover data base previously developed with the Landsat TM data to the standard 14 class C-CAP classification scheme being used throughout the country. Other efforts are also under way with the Coastal Services Center to use satellite data for **coastal change detection** in the past and anticipated in the future.

The division also has a *NASA*-funded project titled "Twenty Year Time Series Analysis of Satellite Remote Sensing Data to Detect Change along Georgia and South Carolina Coast," in coordination with the University of South Carolina, the ***Georgia Institute of Technology (Georgia Tech),*** and the ***Georgia Wildlife Federation.*** This project is in its third phase, which includes the development of local uses. For example, efforts are under way to assess **urban growth** near Charleston, including the development of a multitemporal urban change map for the area. As shown in Figure B7, Landsat MSS images from 1973 and 1981 and TM images from 1982 and 1994 show the tremendous population spreading out from the City of Charleston during the span of 21 years. The map includes Charleston County and nearby Dorchester and Berkeley Counties. This multitemporal map was

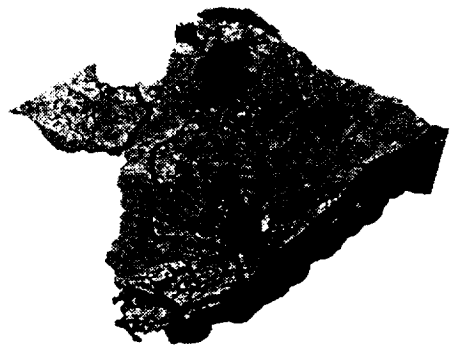
Urban Change in South Carolina Counties

Figure B7

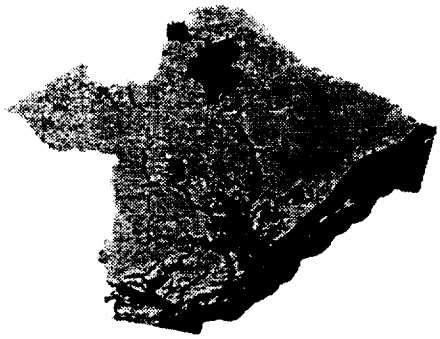
These four maps are derived from Landsat MSS and TM imagery and show the population growth spreading out from the City of Charleston on the coast throughout Charleston County and neighboring Dorchester and Berkeley Counties during a 21-year period between 1973 and 1994. (courtesy of Richard Lacy, Land Resources and Conservation Districts Division, South Carolina Department of Natural Resources, (803) 734-9114)



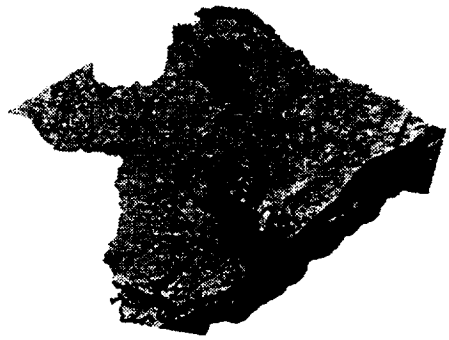
MSS Image Date: April 10, 1973



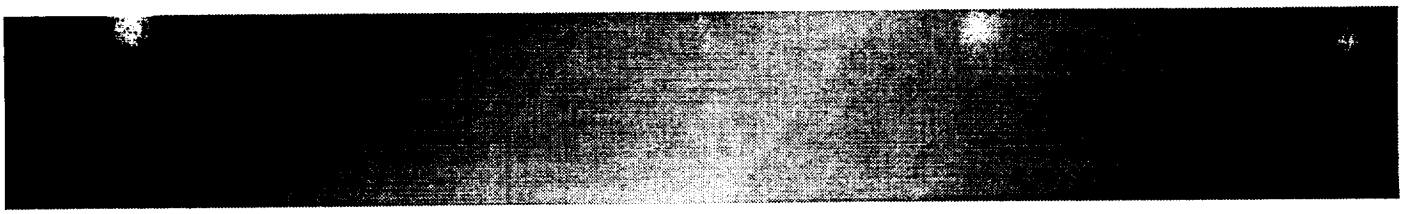
MSS Image Date: March 26, 1981



TM Image Date: November 9, 1982



TM Image Date: February 3, 1994



produced by SERSC, in conjunction with the ***Berkeley/Charleston/Dorchester Council of Government*** and the ***Remote Sensing Laboratory*** of the ***Department of Geography*** at the University of South Carolina, for NASA's Mission to Planet Earth.

Over the years, satellite data and GIS have been used for several efforts in addition to those identified above—for example, **watershed and water quality studies, soil resources evaluations** (including interpretative maps and the analysis of soil erosion and sediment producing problem areas), **natural areas identification,** and **land-use and zoning studies** and maps for several localities. Additional specific projects included data base development of "large contiguous land holdings" for natural resource identification and mapping with the Nongame and Heritage Trust Program, a water quality modeling study for the 319 Clean Lakes Program, the development of data for the Congaree Swamp National Monument with the ***National Park Service,*** and ***York County***'s 20-year growth management forecast and plan.

While DNR's Land Resources and Conservation Districts Division evolved to be the lead entity in the state for satellite data, DNR's ***Water Resources Division*** (known as the Water Resources Commission until 1994) has been an informal lead entity in South Carolina for GIS. The division is responsible for surface water and groundwater resources planning and management, as well as all climatology in the state. Its initial GIS efforts were funded through an NOAA National Research and Demonstration Grant, including the development of 1:24,000-scale data for coastal areas. These data have been used in various projects, including wetlands evaluation and management. GIS efforts originally focused on the Natural Resources Decision Support System (NRDSS), conducted in cooperation with NOAA's ***National Geodetic Survey*** for specific areas, including the Edisto subbasin, the Combahee-Coosawhatchie subbasin, and the Santee and Ashley-Cooper basins. Various data have been used, including land-cover data based on 1989 NAPP photography. More recent efforts have extended to the remaining portions of the state.

Other parts of DNR have also used satellite data. For example, the former Department of Wildlife and Marine Resources, now the ***Division of Marine Resources,*** used satellite data to help develop a comprehensive **coastal resources** data base for the area known as South Atlantic Bight. This area covers from Cape Canaveral in Florida northward to Cape Hatteras in North Carolina and extends to the continental shelf. The data base consists of bathymetry, bottom type and condition, and various attribute data from the sea surface as well as within the water column. Satellite data helped in problem solving related to regional resource identification and allocation.

Some other agencies have used satellite data in coordination with DNR's Land Resources and Conservation Districts Division. DOC used satellite data as its initial source for **land-cover** data to be used with GIS for its **economic development** efforts. Beginning work in the mid-1980s, South Carolina was the first state in the country to use remote sensing and GIS for this purpose. SPOT data were registered to the ***U.S. Census Bureau***'s TIGER files and used to update the TIGER data for roads at the 1:100,000 scale in addition to developing the land-cover data. An extensive data base for other infrastructure was also developed. DOC used these data to assist companies in making their **facilities siting** decisions, but also for a variety of other applications. Currently, DOC has the most extensive use of these technologies for economic development of any state agency in the country.

The state Forestry Commission has also worked with DNR to evaluate the usefulness of satellite data and GIS in **forest resources management** and to help respond to Hurricane Hugo, although it is not an extensive user of

satellite data today. A past cooperative effort was conducted with DNR to test various applications. The Forestry Commission also considered the use of satellite data to monitor, manage, and mitigate pests. Efforts have also been conducted with the ***USDA Forest Service*** to investigate the use of fire and smoke behavior models with remote sensing and GIS to identify potential smoke-sensitive areas near prescribed fires and wildfires. Satellite data were specifically used by various entities to help determine forestry conditions before and after Hurricane Hugo, including on state, private, and Federal lands. Forest losses from the hurricane were determined for specific areas of the state, such as the USDA Forest Service's Francis Marion National Forest.

South Carolina also has a unique, state-funded Geodetic Survey, which is an important part of some state satellite data activities. Located in the Research and Statistical Services Division of the ***Budget and Control Board,*** it includes South Carolina's geodetic advisor, who is partially funded by NOAA's National Geodetic Survey. The state survey maintains a statewide data base of all geodetic marks and supports a field crew to set additional markers and replace those marks damaged or destroyed. South Carolina is an active user of GPS, including the development of a statewide GPS network. GPS has been used to positionally locate and rectify NAPP products to the accuracy of GPS control points.

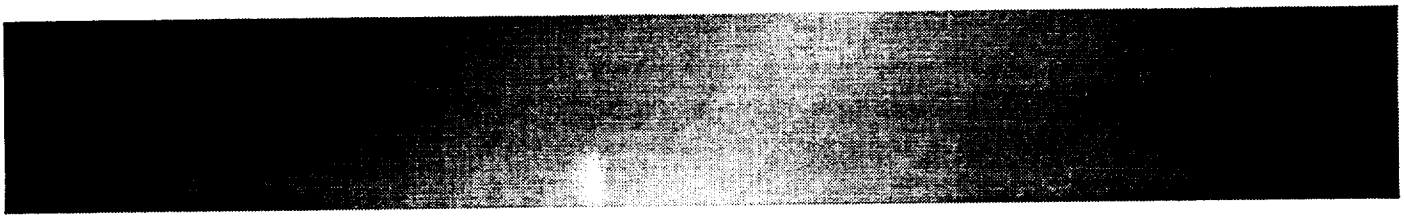
Gap Analysis Program Activities

The Cooperative Fish and Wildlife Research Unit at ***Clemson University*** was funded in 1997 to begin the South Carolina Gap Analysis Program (GAP). Efforts are under way with the DNR, including that department's satellite data activities as described above. It is anticipated that the project will include a biodiversity analysis of surface vegetation, vertebrate species distribution, and protected lands.

Nonstate Government Activities

NOAA's Coastal Services Center in Charleston was established in 1994 to address critical coastal resource issues and improve coastal ecosystems health across the country. The center makes extensive use of remote sensing and GIS to identify, develop, and facilitate the use of technologies and information that support the sustainable use and management of coastal resources. Among other efforts, the center is developing GIS applications to support coastal management decision making as it relates to land-use planning, economic development, coastal hazards assessment, ecotourism planning, and other issues that confront resource managers at state and local levels. Remotely sensed information and field measurements are being collected and integrated through the Coastal Ocean Remote Sensing (CORS) program and the Coastal Change Analysis Program (C-CAP). CORS will provide managers with immediate information on current status and trends of the coastal environment. The Coastal Services Center was recently assigned agencywide responsibility for C-CAP. Through C-CAP, scientists are comparing satellite aerial observations and detecting and correlating changes over time in terrestrial and aquatic vegetation. South Carolina's C-CAP project is being conducted at the University of South Carolina (see below). A recent project was the development of an ecological characterization of Otter Island, South Carolina, which included some satellite data and resulted in a CD-ROM, including viewing and interactive analysis tools, maps, and a management plan for the region.

The University of South Carolina has been actively involved with geoprocessing since the 1960s, and it has had an active role in the development and support of remote-sensing and GIS work in the state. The focal point of these activities is the ***College of Liberal Arts Computing Laboratory,*** which is used by multiple departments at the university. The laboratory and its affiliates have conducted several projects with state government



over the years. For example, the laboratory recently helped the City of Columbia to develop a zoning and parcel data base for use with GIS. In addition to contract work, many former students are now employed by state government. The director of the laboratory was asked to prepare a plan for the improved coordination of state GI/GIS activities; it was submitted in 1996.

Efforts have been under way with other universities in the state on various projects using satellite data. For example, the university worked with Clemson University and the ***College of Charleston*** to jointly purchase new SPOT data for the state in 1996. The satellite data will be used in several GI/GIS projects at the campuses, but the purchase agreement does not permit distribution to localities or state agencies. Activities at these universities are also conducted in collaboration with those at NOAA's Coastal Services Center.

The University of South Carolina's ***Geography Department*** also has several GI/GIS and satellite data activities. For example, it has been the focal point for the state's C-CAP with NOAA, which initially included a detailed investigation of the geographic area centered on two 7.5-foot USGS quadrangles along South Carolina's coastal plain (see above). The project identified optimum parameters for conducting accurate coastal change detection, including but not limited to an optimum wetlands classification scheme, optimum type of remotely sensed data, optimum digital image processing pattern recognition algorithms for C-CAP land-cover classification, the applicability and utility of including ancillary data (for example, the U.S. Fish and Wildlife Service's National Wetlands Inventory) in the classification process, optimum change detection algorithm logic, and detailed error evaluation.

In addition, the Geography Department established a ***Hazards Research Laboratory*** in 1995, which is developing new processes such as GIS to help evaluate environmental hazards. In one of several projects, the laboratory is integrating National Weather Service Doppler radar data with hydrologic data in GIS to improve flood forecasts and to investigate the threat of dam failures by merging high-resolution precipitation data with the National Weather Service DamBreak model.

Clemson University's Department of Forestry is working in cooperation with the USDA Forest Service, the South Carolina Forestry Commission, the state's ***Department of Parks, Recreation, and Tourism,*** the University of South Carolina, and NASA on several projects. Faculty at Clemson have also worked with a wetlands mapping program sponsored by NASA. Clemson is also the lead for the South Carolina GAP (see above). Researchers at Clemson cooperate with the state's ***Department of Education*** and DNR's Land Resources and Conservation Districts Division on SC MAPS, which is a unique geographical curriculum in all the state's public school districts. Students are exposed to aerial photography, satellite data, various maps, and other geographic information through the program.

South Dakota

State GI/GIS and Satellite Data Contacts

* Ron Woodburn, Senior Data Analyst
Bureau of Information and Telecommunications
Executive Management Office
523 East Capitol Avenue
Pierre, SD 57501-3181
(605) 773-4750
(605) 773-4068 (fax)
ronw@denr.state.sd.us

Kevin J. Dalsted
Engineering and Environmental Research Center
South Dakota State University

2220 Harding Hall
Brookings, SD 57007-2220
(605) 688-4148
(605) 688-5880 (fax)
dalstedk@mg.sdstate.edu

Gap Analysis Program Contact

Dr. Jonathan Jenks
Cooperative Fish and Wildlife Research Unit
Wildlife and Fisheries Sciences
South Dakota State University
Box 2140B, NPB 138
Brookings, SD 57007-1696
(605) 688-6121

State Government Context

The Governor's Office established a new ***Bureau of Information and Telecommunications*** in South Dakota's Executive Management Office in December 1995. This bureau was created to lead information, technology, and GI/GIS policy and coordination among state agencies, and it has served as the leading agency in terms of GI/GIS since then. Leading GI/GIS and other information technology users from state agencies in South Dakota were transferred to this bureau after it was established. Prior to the bureau's establishment, the ***Department of Environment and Natural Resources (DENR)*** served as the lead agency for GI/GIS coordination. This role had also been established by the Governor's Office. The person who served as the state GI/GIS coordinator at DENR is now the lead contact for GI/GIS at the Bureau of Information and Telecommunications.

South Dakota has both a ***GIS Steering Committee*** and a ***GIS Advisory Committee*** to facilitate interagency and interorganizational GI/GIS coordination. The GIS Advisory Committee has existed since 1988, while the GIS Steering Committee was organized in 1996 to provide policy direction for the advisory committee.

Satellite Data Use

South Dakota has had rather limited and recent use of GI/GIS and satellite data compared to other states. Satellite data use has been even more limited in state government than GIS. However, the state had some innovative satellite data work in the late 1970s, and efforts emerged again in 1996 after a dormant period to make satellite data accessible to and usable by government agencies (see below).

Most of the natural resources and environmental activities in South Dakota's state government are conducted by DENR. This agency also has the majority of the state's GI/GIS activities. Initial applications concentrated on groundwater quality and the monitoring of underground storage tanks, with funding and equipment provided by the ***U.S. Environmental Protection Agency.***

GIS efforts in the state began with DENR and other state agencies providing funding for the ***Engineering and Environmental Research Center*** at ***South Dakota State University*** to develop initial statewide map bases at the scale of 1:500,000 and 1:100,000 from U.S. Census Bureau TIGER files. In addition, a grant was received from the ***U.S. Economic Development Administration (EDA)*** to develop socioeconomic data registered for use in GIS. A second EDA grant was awarded to make these data available to the state's five regional planning districts for use in economic development efforts.

While state agencies have not been using satellite data in recent years, some efforts were initiated by state government and the ***EROS Data Center*** of the ***U.S. Geological Survey*** in 1996 to enable governmental agencies to use satellite data. For example, EROS staff recently developed

statewide land-cover data from a composite of 1992 Landsat TM data. The new Bureau of Information and Telecommunications received a grant from the ***Federal Geographic Data Committee*** in 1996 to establish a clearinghouse node for South Dakota. The clearinghouse and associated World Wide Web site are expected to be operational in 1997. The land-cover data base will be accessible from a pointer through the clearinghouse, and it is expected to be used by various state and other agencies.

Gap Analysis Program Activities

The ***Cooperative Fish and Wildlife Research Unit*** at South Dakota State University began work on the Gap Analysis Program for the state in 1996. this work is being conducted in coordination with the EROS Data Center.

Nonstate Government Activities

South Dakota State University's Engineering and Environmental Research Center has a ***Remote Sensing Office*** that conducts some satellite data work, although few efforts have been conducted so far in this regard with state agencies. However, GIS efforts in the state began when DENR and other state agencies funded the center to develop initial map bases for use with GIS (see above).

Tennessee

State GI/GIS and Satellite Data Contacts

* Bill Hawkins, Database Administration Director
Office for Information Resources
Department of Finance and Administration
10th Floor, Nashville City Center
511 Union Street
Nashville, TN 37243-0288
(615) 741-7077
(615) 741-6164 (fax)

* Cliff Whitehead
Tennessee Wildlife Resources Agency
Wildlife Resources Building
Ellington Agricultural Center
P.O. Box 40747
Nashville, TN 37204
(615) 781-6599
(615) 741-4606 (fax)
cwhitehead@mail.state.tn.us

* Brenda Brandenburg
Office of Management Services
Comptroller of the Treasury
James K. Polk Office Building
505 Deaderick Street, Suite 1400
Nashville, TN 37243-0261
(615) 741-7704
(615) 532-2224 (fax)

* Kirk Pickering
Information Systems Division
Administrative Services Bureau
Department of Environment and Conservation
15th Floor, L and C Tower
401 Church Street
Nashville, TN 37243-0435
(615) 532-0249
(615) 532-0275 (fax)

Gap Analysis Program Contact

Clifton J. Whitehead
Tennessee Wildlife Resources Agency
Wildlife Resources Building
P.O. Box 40747
Nashville, TN 37204
(615) 781-6599
(615) 741-4606 (fax)
cwhitehead@mail.state.tn.us

State Government Context

Tennessee has been developing a statewide GI/GIS coordination effort through the ***Tennessee Geographic Information Council (TNGIC).*** It is not officially authorized within state government, but it is increasing its efforts and level of participation. While many of the initial participants were from Federal agencies, state agencies have strengthened their involvement in recent years. In addition, the state ***Office for Information Resources (OIR)*** in the ***Department of Finance and Administration*** has conducted some inventories of state activities in past years, and the office supports some GI/GIS coordination activities. OIR had previously considered developing a separate GI/GIS coordination group, but it now participates in TNGIC. The lead contact for GI/GIS at OIR currently serves on TNGIC's board and can be considered as the statewide GI/GIS coordinator. However, this position is also the designated state data base administrator, with limited time to address GI/GIS coordination. Other staff resources for GI/GIS coordination in OIR and other agencies are also limited.

Other agencies have a statewide GI/GIS role. The ***Tennessee Wildlife Resources Agency (TWRA)*** was the earliest agency in the state to use GI/GIS and satellite data, and it was directed by the legislature in 1984 to have the operational responsibility for statewide GIS. TWRA's GI/GIS service bureau role, according to this legislative direction, has diminished during recent years, but assistance and services have been provided for others in the past (see below). A recent effort has been under way by the ***Comptroller of the Treasury*** with other agencies to acquire legislative funding in 1997 to develop digital orthophotos for the state that would assist in property taxation.

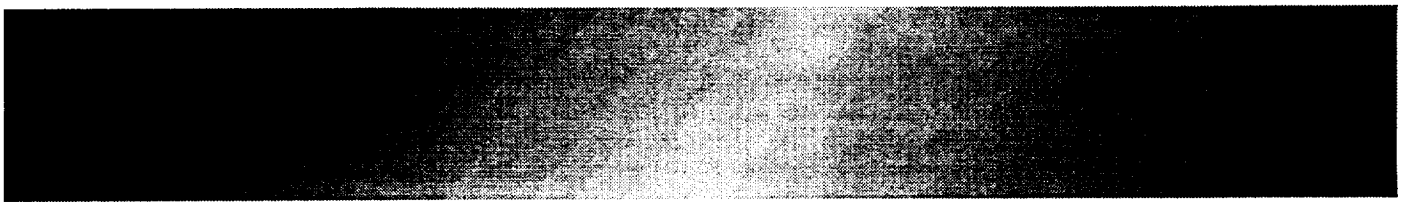
Satellite Data Use

Tennessee's satellite data use has primarily been concentrated in TWRA, which has also been the oldest and most extensive GIS user among Tennessee's state agencies. Natural resources and environmental activities are primarily located in the ***Department of Environment and Conservation (DEC),*** while wildlife activities are the responsibility of TWRA.

DEC began its GIS activities in the early 1990s, and it formerly had a departmentwide GI/GIS coordination effort located in its Information Systems Division. This coordination function is now dormant with staff vacancies, and GI/GIS activities exist in individual programs. For example, DEC's ***Natural Heritage Program*** is using GI/GIS to help monitor amphibians in the state and is working with and received funding from the ***Biological Resources Division*** of the ***U.S. Geological Survey*** in this regard. DEC has not had significant efforts with satellite data to date, although it has used some TWRA services in the past.

TWRA has been using GI/GIS and satellite data to accomplish agency needs since 1983. It was one of the first state wildlife agencies in the country to use geoprocessing—and particularly known as the first state wildlife agency to use GIS with satellite data. It also has had an important role in statewide GI/GIS activities. Following consideration by the General Assembly and its designated committee, it was decided in 1984 that TWRA would have the operational responsibility for statewide GIS. TWRA primarily conducts its work to meet the agency's wildlife management needs, but it has also provided some assistance and services for others in the past, including DEC, Federal agencies, and ***The Nature Conservancy*** in their land acquisition efforts.

TWRA's GI/GIS service bureau role, according to this legislative direction, has diminished during recent years, but the agency continues to have an important interagency role. It supports the statewide ***Biodiversity Team,*** whose members represent several related state and Federal



agencies, as well as large private landowners. Data and applications are being developed by TWRA to support **biodiversity planning,** specifically related to **wildlife resources.** Over the years, Tennessee has also had a strong effort to inventory and protect **wetlands,** including a percentage of real estate transfer tax funds dedicated by the General Assembly to purchase wetlands. The ***Tennessee Interagency Wetlands Committee*** has used satellite data and GIS to conduct wetland and habitat inventories and to monitor and model loss and gain. These resources were also used to help develop the state's Wetlands Conservation Map, to determine which lands to protect and acquire and to notify localities about wetlands areas that should be considered in zoning and subdivision plans and regulations. TWRA has used satellite data for several projects.

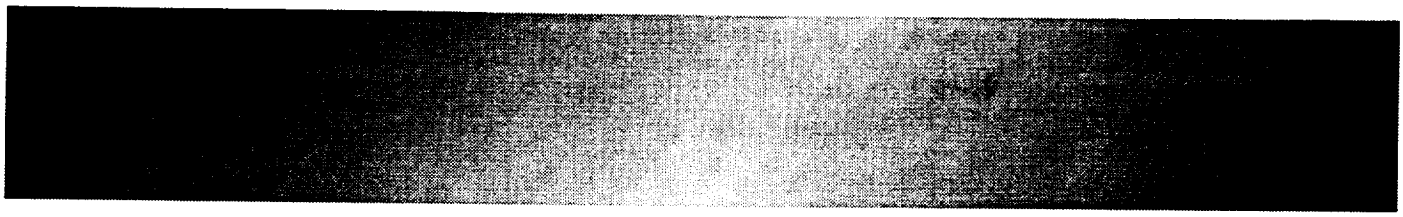
A statewide **vegetation data layer** was completed in 1995 using Landsat TM data. This project has been a collaborative effort with others, and the results are also being used in the Gap Analysis Program (GAP) for the state (see below). The ***Tennessee Valley Authority*** provided funds for the satellite data. Twelve Landsat TM scenes from 1990 to 1993 were used to produce the Anderson Level II classification with an overall accuracy of 85 percent. A hybrid unsupervised/supervised classification method was used, and further work will provide Anderson Level III data. TWRA's previous data efforts, including a digitized version of the National Wetlands Inventory, are being incorporated into this effort (see below).

Satellite data have also been used in an effort to reveal and understand changes over time in the Appalachian Mountains in eastern Tennessee and western North Carolina, as well as influences on wildlife resources, particularly the black bear population. Various satellite data have been acquired, and the project includes forest practice monitoring, road development, recreation, and other conditions. This work is being conducted with researchers at the ***University of Tennessee.***

The Interior Low Plateau Song Bird Management Model is a partnership for wildlife project in coordination with the ***U.S. Fish and Wildlife Service.*** Areas in Tennessee, Alabama, and Kentucky are included in the project area, with most of the work conducted at TWRA. The project has been conducted over a 5-year period and uses GAP and other data.

TWRA has various related data development efforts, including general-purpose data at the 1:24,000 scale, such as boundaries, hydrography, transportation, land use/cover, and forest inventory. TWRA's data holdings related to wildlife and for use with GIS include publicly owned wildlife lands, a digital version of the National Wetlands Inventory, a wildlife inventory by species and county, designated special interest areas (scenic rivers, trails, state natural areas, cultural areas, archaeological sites, endangered species habitats, and so on), significant local recreational lands, priority acquisition areas, and land ownership and parcels for selected proposed state wetland acquisition areas.

In addition, TWRA has actively developed tabular data bases that are geographically referenced and used with GIS and satellite data, including the Tennessee Aquatic Database System (TADS) and the Tennessee Animal Biography System (TABS). TWRA was one of the first state fish and wildlife agencies in the country with these types of systems as well as with GIS capabilities. TADS provides site-specific information on fisheries, water quality, habitat, and environmental associations for aquatic resources throughout the state, including data on 8,000 stream reaches in the state that were developed to be compatible with the River Reach stream identification system of the ***U.S. Environmental Protection Agency (EPA)*** and the Western Energy and Land Use Team's (WELET) River Reach Fisheries Data Base from the ***U.S. Fish and Wildlife Service.*** TABS is a wildlife inventory system stored in ARC/INFO, describing more than 500 resident and common migrant land and aquatic



species in Tennessee, including species-habitat relationships, species distribution, occurrence, and life requirements. It is available with online queries, updating, and analysis. The system was designed using standard definitions and classifications developed by Federal agencies and associations, and it is used by Federal and state agencies, universities, and environmental consulting firms for a variety of purposes. Some examples include the preparation and review of permits for surface mining, powerplant siting, point source discharge, solid waste disposal, and research and analysis regarding waterways, wildlife. and others.

The state was one of the first to participate in the North American Waterfowl Plan developed for the Nation by U.S. Fish and Wildlife Service. The Lower Mississippi Valley Joint Venture was developed by TWRA as a national pilot project for the plan; it was undertaken to meet the variety of needs of independent state and Federal programs and authorities established to address wetlands conservation and has been complimented by many of its participants. The project developed an institutional and technical mechanism capable of consolidating various state, Federal, and private activities into comprehensive wetlands plans. Pilot Demonstration Wetland Conservation Strategy Plans in the Lower Mississippi Valley were developed, including one for the State of Tennessee as a first example plan. Tasks accomplished in the project included a 1:3,000,000-scale data base for North America showing important waterfowl areas and special areas of concern, a 1:2,000,000-scale data base of the 11 states in the Lower Mississippi Valley area, and a 1:24,000-scale data base for some quadrangles in Tennessee's part of the Lower Mississippi Valley. This document includes a description of data base status in the area, as well as resource status, opportunities, goals, objectives, and strategies related to restoring waterfowl populations to 1970s levels, protecting and enhancing migration and wintering habitat and carrying capacities, and increasing the coordinated action of governments, private organizations, landowners, and other citizens.

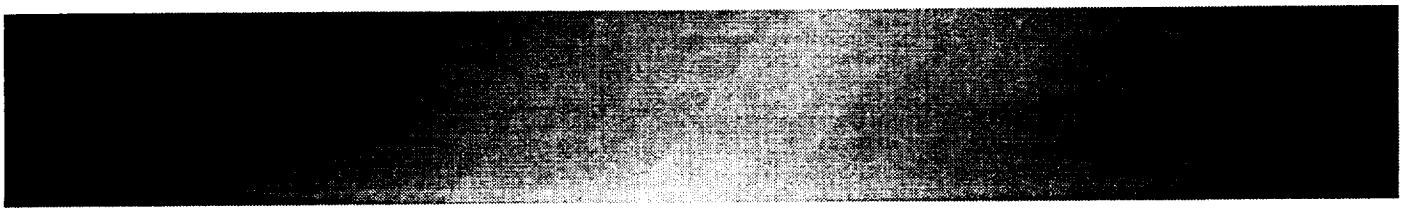
Gap Analysis Program Activities

Tennessee's GAP is being conducted in a cooperative effort between TWRA and ***Tennessee Technological University.*** Progress has been made in several respects, and the project is expected to be completed in 1997.

The initial land-cover map for the entire state was completed in 1995 (see above). The refinement of the vegetation and forest categories into a plant community-based map is under way using aerial videography. Approximately 4,600 kilometers of video transects were flown over the forested lands in Tennessee, and almost 400 sites were visited. The interpretation of the video footage is currently under way. Video interpretation and additional classification of the TM scenes are being performed by physiographic province to take advantage of variations across the state.

Interpreted video for the Mississippi Alluvial Plain and the Loess Plain of West Tennessee were used to complete the labeling process of the unsupervised forest classification. The refinement of the spectral classification is being performed to code-confused spectral classes using information about the surrounding pixels (maximum, minimum, diversity, and majority values) as well as ancillary data (National Wetlands Inventory, digital elevation models, geology, soils, and buffered streams). The plant community classification developed by The Nature Conservancy's regional office is being used for general guidance. The limitations of the methodologies and differences in scale make it difficult to conform strictly to that classification.

Distributions for the state's terrestrial vertebrate species were based on the county, physiographic province, and



watershed of occurrence and then translated to the EPA's EMAP hexagonal grid. Range data from TWRA's TABS and the Vertebrate Characterization Abstracts (VCA) were used to produce range maps for the 70 mammal, 55 reptile, and 65 amphibian species in the state. Range maps for 1,709 breeding birds were produced from the *Tennessee Breeding Bird Atlas* data, TABS, and VCA. Distributions of rare species are based on buffered point data provided by the DEC's Natural Heritage Program. The reviews for rare species data will be done in cooperation with the authors of *Tennessee's Rare Wildlife*, while the reviews for the nonrare species will be conducted by state biologists.

Work on the habitat relationship models for west Tennessee has begun. The models will be cross-walked for each physiographic province as the vegetation classification becomes available. Data sources for the habitat model include TABS, VCA, and *The Land Manager's Guide to Birds of the South* (P. Hamel).

The public land coverage has been updated through a cooperative effort between the DEC's ***Recreation Planning Division*** and TWRA. A subcommittee of the ***Tennessee Biodiversity Team*** has categorized the majority of the lands in terms of their management status. A pilot project was recently initiated with the team to conduct extensions of GAP with the ***Tennessee Conservation League.***

Nonstate Government Activities

The Tennessee Valley Authority has been actively working with Tennessee state agencies in recent years. It has served as the manager of a digital orthophoto pilot project with the ***Comptroller of the Treasury*** and is preparing digital versions of 1:24,000-scale quadrangle maps for the state, which have been purchased by some state agencies.

Several of Tennessee's universities have been actively working with GI/GIS and remote sensing, and some have been involved with state agencies in this regard, including having cooperative agreements for data sharing. ***Middle Tennessee State University*** was originally involved with GIS in the early 1980s and worked closely with state government at the time that the state's GIS center was established at TWRA. Middle Tennessee State has a remote-sensing center, and the Geography Department is coordinating GIS activities at the university. The ***University of Tennessee at Knoxville*** supports several GIS activities through its Computing Center. It is working with TWRA on some of the projects discussed above. Tennessee Technological University is sharing the GAP leadership with TWRA (see above).

Texas

State GI/GIS and Satellite Data Contacts

* Dr. Drew Decker, GIS Coordinator
Statewide Planning Division
Department of Information Resources
300 W. 15th Street, Suite 1300
Austin, TX 78701
(512) 463-7314
(512) 475-4759 (fax)
drew.decker@dir.state.tx.us

* Roddy Seekins, Natural Resources Information Division Director
Water Development Board
Stephen F. Austin Building
1700 N. Congress Avenue
Austin, TX 78701
(512) 475-0933
(512) 463-9893 (fax)

* Dr. Charles Palmer, TNRIS Director
Water Development Board
Stephen F. Austin Building
1700 N. Congress Avenue
Austin, TX 78701
(512) 463-8402
(512) 463-7274 (fax)
cpalmer@tnris.twdb.state.tx.us

Dr. Kim Ludeke, GIS Manager
Parks and Wildlife Department
4200 Smith School Road
Austin, TX 78744
(512) 389-8070
(512) 389-4394 (fax)

Lee Smith, GIS Manager
General Land Office
Stephen F. Austin Building
1700 N. Congress Avenue
Austin, TX 78701
(512) 463-0743
(512) 463-5029 (fax)

Barry Allison, GIS Coordinator
Information Resources Branch
Natural Resource Conservation Commission
12100 Park 35 Circle, Building A
Austin, TX 78753
(512) 239-0850
(512) 239-0888 (fax)

Gap Analysis Program Contact

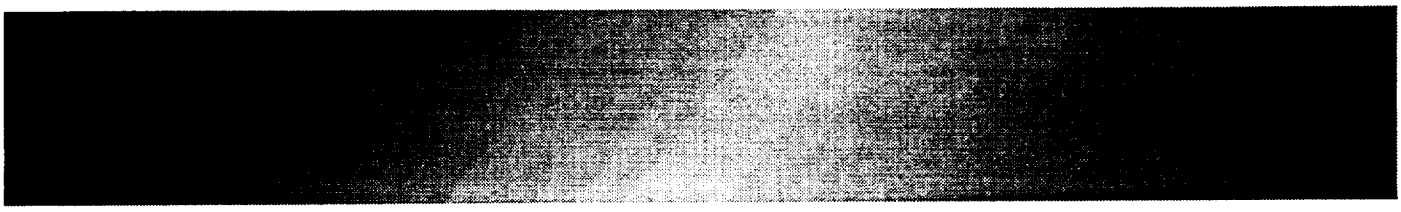
Raymond Sims
Cooperative Fish and Wildlife Research Unit
Texas Tech University
MS 2120
Lubbock, TX 79409-2120
(806) 742-2851
(806) 742-2946 (fax)
ray.sims@ttu.edu

State Government Context

Statewide GIS coordination in Texas is conducted through the ***GIS Planning Council*** that was created by executive order in 1992. It is staffed by the ***Department of Information Resources (DIR)***, which has a GIS coordinator and additional staff resources as needed for specific initiatives. DIR concentrates on the coordination and development of statewide information policies and standards, including for GI/GIS, but it does not provide GI/GIS service center functions.

The GIS Planning Council and DIR have had an active role in soliciting funding from state, Federal, and regional agencies for data acquisition. A large effort was the establishment of the Texas Orthoimagery Program (TOP), for which Texas state agencies contributed $1.4 million and Federal agencies contributed $2.9 million to develop digital orthophotography for part of the state. Plans are under way to acquire additional funding to complete TOP for the remainder of the state, as well as complete statewide data bases for water features, elevation contours, transportation, public land survey, survey and marker control, political boundaries, and soil survey. The GIS Planning Council has a remote-sensing subcommittee, but it primarily concentrates on these digital orthophotography efforts.

While no state entity provides data clearinghouse functions for GI/GIS, the ***Texas Natural Resources Information System (TNRIS)*** serves as a clearinghouse and referral center for natural resources data and information, including some geographic information and satellite data (see below). The ***TNRIS Task Force*** provides direction to TNRIS staff, and efforts have been under way since



1996 to merge the TNRIS Task Force into the GIS Planning Council.

Satellite Data Use

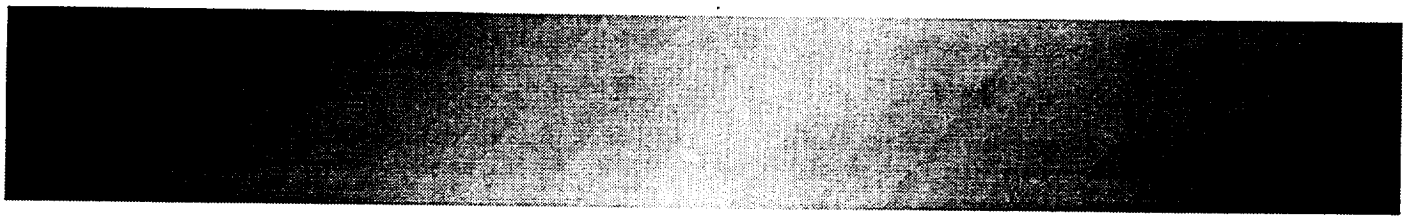
Texas is known for having some of the earliest uses of remote sensing and geoprocessing of any state in the country; these efforts have been documented back to the 1960s. The state continues to have a mechanism to provide access to satellite data and other data that can be used with GIS through the TNRIS. However, while numerous now have GI/GIS activities, satellite data use has been more limited in recent years.

The ***Texas Water Development Board*** has been the organizational home for TNRIS since 1985. The board is directed, according to statute, to plan for state's long-range water needs and to conduct topographic and geologic mapping in the state. Various parts of the Texas Water Development Board have used satellite data to help meet **water resources** needs. While no state entity acts as a service center or data clearinghouse for GI/GIS, TNRIS serves as a clearinghouse and referral center for natural resources data and information, including some geographic information and satellite data.

TNRIS is one of the earliest systems of its kind among the states. The 1967 legislature authorized what evolved to be known as TNRIS in 1973. TNRIS has a staff that provides natural resources data management, clearinghouse, and dissemination services to state and other agencies, as well as some limited GI/GIS service center activities. TNRIS data resources are extensive, including tabular data, digital data for use with GIS, satellite data, and aerial photography. TNRIS also fosters coordination among natural resources agencies regarding related information—and more recently concerning GIS.

TNRIS provides information services through various systems. TNRIS's Remote Sensing Data and Indexing System (RSDIS) includes an extensive lending library containing more than 700,000 aerial photo prints and more than 500 satellite images in both digital and paper formats. One of TNRIS's busiest activities is managing aerial photography and conducting photography projects. Satellite data are less in demand because the most recent products are from the early 1980s, and available satellite data are primarily Landsat MSS data. However, TNRIS also provides assistance in locating satellite data not available onsite, such as indices and price lists. Other data are also available at TNRIS and are listed in an annual data catalog that is available in hard copy and online through the Earth Science Data Directory of the ***U.S. Geological Survey (USGS)***. In 1976, TNRIS was the first state affiliate of USGS's ***National Cartographic Information Center***. TNRIS also has online access to materials in USGS's ***EROS Data Center*** in Sioux Falls, South Dakota. TNRIS was also the first USGS state-level affiliate of the National Water Data Exchange and it provides access to WATSTORE and STORET data. Weather data from the ***National Weather Service*** are also available. TNRIS is also a core affiliate of the Texas State Data Center for ***U.S. Census Bureau*** data, including TIGER line files. These and other data are distributed to state agencies and others as requested.

Currently, the ***Parks and Wildlife Department*** is perhaps the largest user of satellite data among state agencies. The department's ***Resource Protection Division*** began using GIS in 1990 to support wildlife inventory efforts, and it previously used Landsat MSS data to develop vegetation cover maps for more than half the state. Efforts are under way to create a new **vegetative cover** data base for **wildlife habitat** using Landsat TM data and extensive field work. The initial focus is on "sensitive areas," including coastal areas, and on helping determine net habitat loss for various species. This work is being coordinated with the Gap Analysis Program (GAP), with the goal of converting the old vegetation maps to a more usable format (see below). During the last few years, the Parks and Wildlife Depart-



ment has worked extensively on various projects with the ***National Oceanic and Atmospheric Administration (NOAA),*** such as COMPAS, the Coastal Change Analysis Project (C-CAP), and CoastWatch, including providing data on water quality, fisheries abundance, and coastal water rights permits review.

The Parks and Wildlife Department has also participated in a C-CAP) with NOAA in the Galveston Bay area to determine land-cover and habitat change in coastal areas, classify and inventory habitats, determine change, and provide resource data for **coastal resources management.** The project has performed a change detection analysis for a two TM scene areas. Department personnel are conducting the work with assistance from the ***Oak Ridge National Laboratory.*** Two 1988 scenes were classified, and the conditions were compared with those in a 1992 scene. This classification has been aided by an abundance of ground reference data and digital ***U.S. Fish and Wildlife Service*** National Wetlands Inventory data that are available for most of the Texas coast.

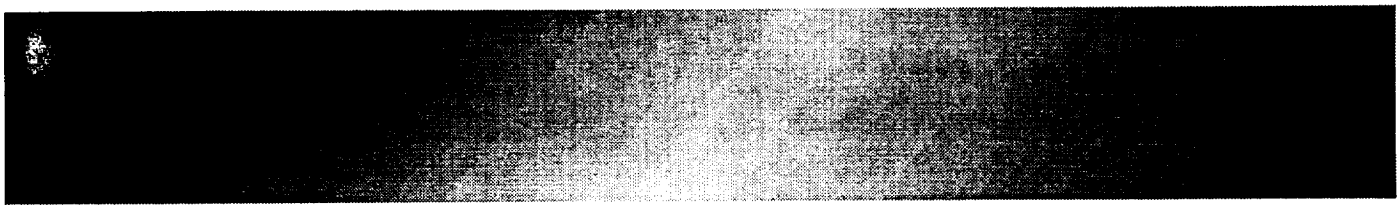
Work has been under way with the National Wetlands Inventory program to classify and survey wetlands habitats and provide associated environmental data on habitats for the **wetlands** data layer for use with GIS. The Parks and Wildlife Department compiles and maintains data bases on National Pollution Discharge Elimination System permits regulated by the ***U.S. Environmental Protection Agency (EPA),*** Section 404 wetlands permits regulated by the ***U.S. Army Corps of Engineers,*** and Section 10 endangered species permits regulated by the U.S. Fish and Wildlife Service for environmental monitoring and assessment purposes. The department also acquires digital data and aerial photography from USGS for the analysis of natural resources. In addition, estuarine modeling efforts are under way at the Center for Research in Water Resources at the ***University of Texas at Austin.***

Other state agencies in Texas have natural resources and environmental responsibilities, and some of them have used satellite data. Also, the Texas/Mexico Borderlands Information Center is a new TNRIS effort that is funded by EPA. The center's holdings include Landsat TM data for Mexico near the border.

The ***Texas Natural Resource Conservation Commission*** was created in 1990 from a merging of other agencies. It now has the most omnibus natural resources and environmental responsibilities of any state agency in Texas; it facilitates program coordination within various related agencies, some of which have used satellite data in the past. The commission has a departmentwide approach to GI/GIS, including a full-time GI/GIS coordinator, but it currently does not use satellite data for internal purposes.

The Texas ***General Land Office*** is a unique agency compared to other states because it is primarily responsible for the state's extensive public land and their management. However, the 1991 legislature provided that the office is also responsible for the interagency coordination of **oil spill prevention and response.** The Oil Spill Prevention and Response Act of 1991 established special funding for efforts to prepare for and respond to spill disasters, including research and development projects. The General Land Office was directed to develop a state contingency plan, with assistance from the Texas Natural Resource Conservation Commission and the Parks and Wildlife Department, that details emergency procedures for spill containment, removal, and cleanup on the Texas coast.

The General Land Office is developing an in-house GI/GIS network to support this effort—specifically to identify responders and provide information about the closest sources of oil spill response equipment and personnel. Satellite data and image-processing software are being incorporated into the system. To augment the network, a



spill trajectory model, Spillsim, is being developed to display and project the movement of an oil spill and the estimated areas affected by it. The results are being mapped with coastal resources at risk and to deploy resources. Prioritized data sets include oil and gas well locations, pipelines, facility locations, wetland distributions, species locations, environmental sensitivity index maps, and base map information. Various research projects are under way at universities to enhance the General Land Office's efforts.

Gap Analysis Program Activities

The Texas Cooperative Fish and Wildlife Research Unit at ***Texas Tech University*** is the lead for the Texas GAP. A contract was issued with ***Texas A&M University*** to help conduct some of the GAP work.

Land-cover classification and mapping efforts are progressing at both universities. Texas A&M University was contracted to conduct vegetation mapping for the eastern portion of the state, and Texas Tech University is doing this work for western Texas. A MMU of 40 hectares has been chosen for the entire vegetation map, with an accuracy target of 80 percent. Vegetation classification will follow the UNESCO format with the addition of lower levels. To date, 29 Landsat TM images have been received in raw format and 21 clustered TM images in Spectrum format. In total, 52 images are planned to be received. The projected completion date for the vegetation map is June 1998.

More than 90 percent of Texas consists of privately owned lands. Accordingly, access for ground-truthing and accuracy assessment is limited. Airborne videography has provided a method of acquiring periodic georectified high-resolution images that can be utilized as a ground-truthing and accuracy assessment tool. SkyKing software, developed at Texas A&M's ***Mapping Sciences Lab,*** is used to interactively assign vegetation cover types to points within contiguous vegetated areas on georectified video frames. SkyKing writes files containing UTM points and the corresponding cover type. This file is then read into an enhanced version of Spectrum. Spectrum applies the cover types to all similar clusters in the hyper-clustered TM files and reports errors. The final classified images are then aggregated up to the 40-hectare MMU.

Texas A&M's image-processing work to develop the vegetation map for the eastern portion of the state did not begin until 1996 because of delays in receiving satellite data, processing contracts, and utilizing Spectrum software. However, the Mapping Sciences Lab accomplished several key goals, including collecting ancillary vegetation data, loading and compiling Spectrum 1.5, converting clustered data to Spectrum format, developing a framework for state-mandated metadata files, checking and archiving TM raw and clustered satellite data received to date, developing a vegetation photo key from airborne videography, and conducting several presentations on current efforts.

Of the federally managed lands in Texas, only ***National Park Service*** parks and U.S. Army Corps of Engineers lands have developed and provided boundary data. Boundary data for state forests are complete, while state park and refuge boundary data are expected to be provided by state Parks and Wildlife Department.

Experts in the various fields of Texas vertebrates have been contacted, and cooperators have been identified. Animal scientists and ecologists from universities and state and Federal agencies are among the cooperators identified thus far. Ancillary data are being collected, and the mapping of vertebrate species distributions commenced in 1996.

Utah

State GI/GIS and Satellite Data Contacts

* Dennis B. Goreham, Manager
Automated Geographic Reference Center
Information Technology Services
Department of Administrative Services
5130 State Office Building
Salt Lake City, UT 84114
(801) 538-3163
(801) 538-3550 (fax)
asagrc.dgoreham@email.state.ut.us

* Lloyd B. Johnson, Manager
Information Technology Services
Department of Natural Resources
1636 West Temple, Suite 316
Salt Lake City, UT 84116
(801) 538-7244
(801) 538-7315 (fax)

David Mann
Division of Wildlife Resources
Department of Natural Resources
1636 West Temple, Suite 316
Salt Lake City, UT 84116
(801) 538-4700

Joe Borgione
Dam Safety Section
Division of Water Rights
Department of Natural Resources
1636 West Temple, Suite 316
Salt Lake City, UT 84116
(801) 538-7240
(801) 538-7315 (fax)

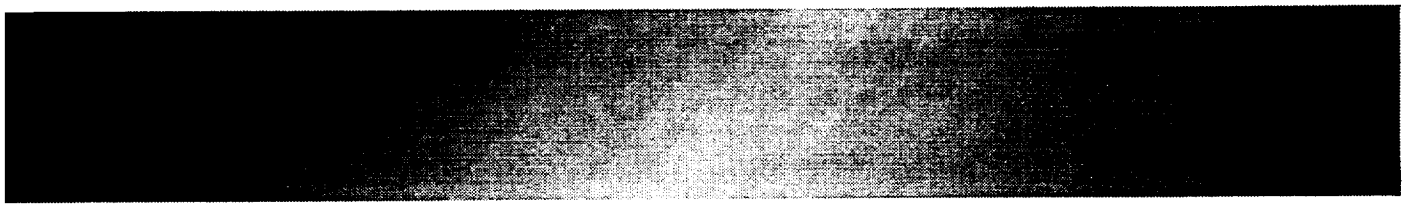
Dr. Allan Falconer, Chair
Department of Geography and Earth Resources
College of Natural Resources
Utah State University
UMC 5240 USU
Logan, UT 84322
(801) 797-1334
(801) 797-4048 (fax)
als@rsgis.nr.usu.edu

Gap Analysis Program Contact

Dr. Thomas C. Edwards
Cooperative Fish and Wildlife Research Unit
College of Natural Resources
Utah State University
Logan, UT 84322-5210
(801) 797-2529
(801) 797-3798 (fax)
tce@nr.usu.edu

State Government Context

The ***Automated Geographic Reference Center (AGRC),*** located within the ***Division of Information Technology Services*** in the ***Department of Administrative Services,*** provides GI/GIS coordination, data base management, and services for Utah. A statewide GI/GIS approach and service center has existed continuously since 1982. Utah is one of the few states with statutory direction regarding GI/GIS, but remote sensing is not mentioned in this statute. The 1991 legislature authorized AGRC's work and the State Geographic Information Database (SGID), and it required agencies to participate in SGID's development by AGRC. The legislature also mandated that SGID is to "serve as the central reference for all information contained in any GIS database by any state agency, serve as a clearinghouse and repository for all data layers required by multiple users, and serve as a



standard format for geographic information acquired, purchased or produced by any state agency." Subsequent legislatures have provided funding to support AGRC's role and data development.

AGRC has actively developed SGID, which now has more than 150 available data sets for use with GIS. Utah was the first state to provide access to its data for use with GIS on a CD-ROM. Most of these data are contributed by state agencies creating data for ongoing activities and programs, although AGRC also receives direct funding for critical and base data.

Statewide GI/GIS and AGRC activities are led and coordinated by the ***GIS Advisory Committee,*** the ***Technical Interchange Group,*** and the ***Utah Geographic Information Council.*** The GIS Advisory Committee is composed of primarily state agency officials, including representatives of 10 agencies. It concentrates on overall GI/GIS policy and coordination issues among state agencies. The Utah Geographic Information Council participants represent various sectors in the state, and it focuses on other geographic information areas in addition to GIS. For example, its subgroups include a GPS Users Group and the state Geographic Names Board. The Technical Interchange Group is composed of GIS users from various sectors. AGRC staffs all three of these organizations.

Satellite Data Use

Utah state agencies have had limited use of satellite data compared to a long history of GI/GIS use. However, some agencies have used them and are expressing increased interest as Landsat TM data from the Gap Analysis Program (GAP) is now available through AGRC and SGID. Satellite data have been used for data sets, including land cover, ownership, vegetation, and wetlands (see below). Otherwise, AGRC has had limited use of satellite data to date, except as a backdrop for other data sets. Most of AGRC's remote-sensing efforts have concentrated on digital orthophotos, and approximately 25 percent of the state is expected to have digital orthophotos in 1997 if adequate funding is available.

Natural resources and environmental programs are primarily shared by the ***Department of Natural Resources (DNR)*** and the Department of Environmental Quality. DNR is the leading agency in state government using satellite data and GIS. It has a departmentwide approach to and architecture for GI/GIS, and several divisions and field offices use GI/GIS.

The ***Division of Wildlife Resources*** has been the leading user of satellite data within DNR. The division has used Landsat TM data in the state's GAP for various wildlife resources applications with ***Utah State University***, the ***U.S. Fish and Wildlife Service,*** and other agencies (see below). The satellite data were used to map vegetation and specifically wetlands data. Funding from the ***U.S. Environmental Protection Agency*** has also been used for wetlands mapping. The division provided wildlife data to GAP from its tabular Fish and Wildlife Information System. It has also mapped the locations of all threatened and endangered species in the state, as well as critical habitat areas for big and upland game. The division is also digitizing the U.S. Fish and Wildlife Service's National Wetlands Inventory maps and all properties owned by the division. These data resources will be used with the satellite data procured to conduct the GAP work.

The ***Division of Water Rights*** is using satellite telemetry at the state's dams to help determine and analyze the potential impacts of earthquakes. This approach is determining which dams are most susceptible to damage, both in general and in response to specific earthquakes. It is anticipated that other parts of the division could use satellite data that has a higher resolution than is currently available to help enforce water rights and regulate water use.

Gap Analysis Program Activities

Utah was second state in the country to have a GAP project, beginning work in 1990 and completed in 1995. This work has been conducted by the Cooperative Fish and Wildlife Research Unit located at Utah State University. The project has been a collaborative effort with the DNR's Division of Wildlife Resources, the U.S. Fish and Wildlife Service, the ***USDA Forest Service,*** the ***National Park Service,*** the ***Bureau of Land Management,*** and other agencies. Researchers at Utah State have had additional roles regarding GAP beyond the state project, including conducting the GAP work for the state of ***Nevada*** and working with the national GAP office in Idaho concerning the national program.

Utah's GAP results consist of a large report, four hard-copy maps published by the U.S. Geological Survey, and two CD–ROMs containing digital information. The project generated 425 spectral classes that were modeled into 31 vegetation cover types and five land-use classes. The GAP data base consists of a Landsat TM mosaic for the state, a vegetation map developed from TM data, a land ownership map, and a wildlife habitat relationship data base that identifies potential habitat by relating to the vegetation map. See Figures B8a and B8b for two examples of maps from the SGID CD–ROM. A 75-percent accuracy was recorded in the land-cover vegetation map at a resolution of 1 hectare. Recent efforts have focused on completing manuscripts and making presentations. Current work is emphasizing the optimal placement of reserves, given the existing reserved land, and assorted analyses of wilderness areas for Utah.

Nonstate Government Activities

Several remote-sensing activities are conducted at Utah State University. Its ***College of Natural Resources*** has GIS and remote-sensing laboratories, and it is working with AGRC and DNR regarding its satellite data efforts. Utah State worked with AGRC to help produce a CD–ROM for digital data available for the state. Utah State is also responsible for the GAP work for Utah and is integrating GAP data from other states (see above).

Utah State University has other projects involving satellite data. For example, the university is working with the ***U.S. Department of Defense*** in its efforts to protect the ecology of its various training areas. It is working with ***Hill Air Force Base*** to use satellite data and GIS to map potential habitat for threatened, endangered, and sensitive species on the Air Force training ranges in western

Utah Land Cover Map



Figure B8a

This map from Utah's State Geographic Information Database CD–ROM displays the state's advanced GAP project. Utah was the second state to have such a project. The GAP data base includes this statewide land-cover map. (courtesy of Dennis Goreham, Automated Geographic Reference Center, Utah Department of Administrative Services, (801) 538-3163, *asagrc.dgoreham@email.state.ut.us*)

Roads and Trails in Grand County, Utah

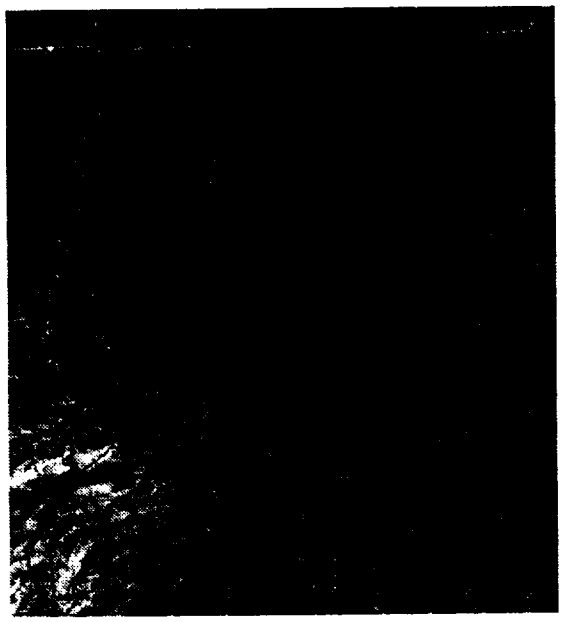


Figure B8b

This map from Utah's State Geographic Information Database CD-ROM shows the network of roads and trails in Grand County, which is located in the eastern part of the state and contains a stretch of the Colorado River. (courtesy of Dennis Goreham, Automated Geographic Reference Center, Utah Department of Administrative Services, (801) 538-3163, *asagrc.dgoreham@email.state.ut.us*)

Utah. The objective of this effort is to identify potential habitat for these species and verify their existence so the potential damaging effect of military maneuvers on the flora and fauna can be mitigated. Utah State is also working to develop the National Environmental Database for the ***National Guard Bureau*** office in Washington, D.C. The purpose of this project is to develop a user interface for individual guard installations and this office to help plan training maneuvers in a manner consistent with the environmental constraints for each installation.

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Vermont

State GI/GIS and Satellite Data Contacts

* Bruce Westcott, Executive Director
Vermont Center for Geographic Information, Inc.
206 Morrill Hall
Burlington, VT 05405-0106
(802) 656-4277
(802) 656-0776 (fax)
brucew@vcgi.uvm.edu

John Dudley, Chief
Information Management Services Division
Agency of Natural Resources
103 South Main Street
Waterbury, VT 05671-0301
(802) 241-3489
(802) 244-1102 (fax)
johnd@anrimsgis.anr.state.vt.us

Harry Roush, Mapping Specialist
Vermont Orthophoto Program
Division of Property Valuation and Review
43 Randall Street
Waterbury, VT 05676-1512
(802) 241-3507
(802) 241-3510 (fax)
hroush@state.vt.us

Gap Analysis Program Contact

Dr. David Capen
Cooperative Fish and Wildlife Research Unit
School of Natural Resources
University of Vermont
Burlington, VT 05405-0088
(802) 656-3007
(802) 656-8683 (fax)
capen@gavia.snr.uvm.edu

State Government Context

Vermont has a statewide GI/GIS program known as Vermont GIS (VGIS) that is managed by the ***Vermont Center for Geographic Information, Inc. (VCGI).*** The General Assembly first authorized statewide geographic information activities in 1988 through the state's Growth Management Act and has provided GI/GIS direction in actions taken since then. It subsequently created VCGI in 1992 with a 2-year "sunset" unless further action was taken. Act 204 of 1994 reauthorized VCGI for 5 years and established it as a public, not-for-profit corporation and a "body corporate and politic, and a public instrumentality of the state," establishing public purposes, but allowing governance by an independent board. There is no statutory reference to remote sensing or satellite data.

VGIS and VCGI are directed by a ***Board of Directors.*** Its membership is defined in Act 204 of 1994 to include nine members, with four of these individuals representing state agencies. Vermont also has a ***GIS Technical Advisory Committee,*** which has 13 members, including professionals and technicians from public agencies and the commercial sector.

VCGI's mission is to provide data management, dissemination, products, and services for state agencies, regional planning commissions, and local governments. It is physically located at the University of Vermont and has six staff members. VCGI also conducts contract work for various state and other agencies. Approximately half of its funding is from government, and the other half is from contracts.

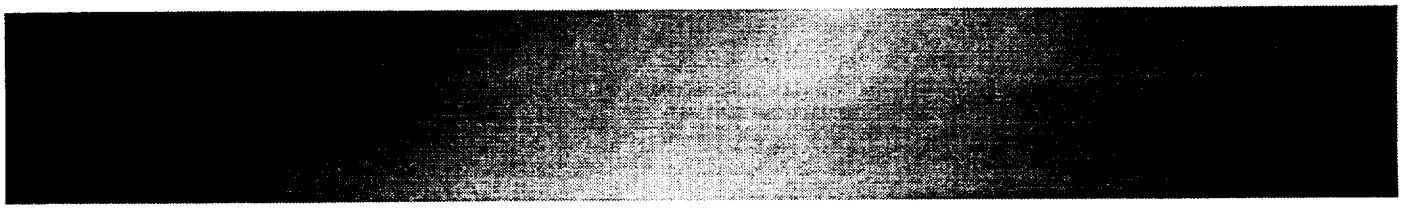
Satellite Data Use

Vermont agencies are increasing their use of satellite data. Such use was initiated from two projects authorized and funded by Congress: the Lake Champlain Basin Program and the Northern Forest Lands Project. This funding provided for a **land-cover** data base to be developed from Landsat TM data for two parts of the state.

The purpose of the Lake Champlain Basin Program was to develop a plan for the basin portions of both New York and Vermont. The program was later expanded to include Quebec. VCGI has served as the GIS service center for this effort, and it produced a *Lake Champlain Basin Data Catalog* late in 1996, which includes data for all three jurisdictions. The satellite data are being used to conduct **water pollution** prevention efforts, including monitoring nonpoint pollution sources and developing a restoration plan for Lake Champlain.

The goal of the Northern Forest Lands Project was to gain an understanding of the forested lands within a 26-million-acre area located in Maine, New Hampshire, New York, and Vermont. This project is managed by the ***USDA Forest Service.*** The satellite data were used to assist in assessing **forest cover and resources** in Vermont's portion of the project area. This work follows a decision made in the late 1980s to concentrate GIS data development on a statewide collection of orthophotographs at the 1:5,000 scale, and subsequent funding was authorized to develop digital orthophotos.

VCGI has a leading role regarding satellite data. It has managed the development of the statewide land-cover classification and data base and is widely distributing



these data. This work was initiated in 1994 when VCGI awarded a contract to **Mt. Holyoke College** to process Landsat TM data to meet the needs of the two projects. This work provided coverage for approximately 75 percent of the state. After substantial effort, state funding was secured in 1996 to complete a land-cover classification and data base for the remaining 25 percent of Vermont. The final product includes spectral enhanced classes established by a variety of techniques. In addition to providing land-cover classifications, it also has some land-use classes. All of the 1,400+ accuracy field observation points data are available, including the GPS coordinates of each point, a digital photo of the site, the classification category for the site, and a textual description of the site. A statewide land-cover classification and data base is expected to be completed in 1997. Expected uses of these data include monitoring forest and crop types and facilitating the understanding of growth and other changes to the landscape.

Most of Vermont's departments handling natural resources and the environment are located within the ***Agency of Natural Resources (ANR),*** except the Department of Health. Its chief of Information Management Services also serves as ANR's GIS coordinator. According to the state's past GI/GIS plans and agreements, ANR is responsible for developing certain data, similar to other agencies, conforming to the state's established policies, standards, procedures, and requirements. Many parts of ANR have developed and used digital data since the agency first prioritized its geographic information needs in 1989, but recent efforts have been more limited to specific projects because of resource limitations. ANR has produced CD-ROMs with data for use by its regional offices. ANR's ***Department of Forest, Parks and Recreation*** has been one of the leading users of the land-cover data, particularly for the Northern Forest Lands Project. Its ***Department of Fish and Wildlife*** is working with the Gap Analysis Program (GAP) for the sate (see below).

Gap Analysis Program Activities

The ***Cooperative Fish and Wildlife Research Unit*** at the ***University of Vermont*** is coordinating the GAP project for New Hampshire and Vermont. Work is expected to be completed in 1997. The New England GAP was formerly one project for all six states. A major recent effort of the Vermont-New Hampshire project has been to gather and process aerial videography that is being used for a supervised classification of Landsat TM data for land-cover maps of the two-state region. Transects were flown over Vermont and New Hampshire during the late fall, early spring, summer, and early fall of 1994 and 1995. GPS codes, linked to time codes on the videotapes, were corrected with base station data, then converted to ARC/INFO and ERDAS files. The quality of the videography is quite satisfactory and has been used for detailed vegetation classification. The interpretation of videography for Vermont is under way, with the classification of two scenes of TM data from the Multi-Resolution Land Characteristics (MRLC) acquisition.

GAP staff have held several meetings with cooperators in the two states. Both states have now initiated biodiversity projects that complement Gap Analysis. In Vermont, the Department of Fish and Wildlife has funded a pilot project in the four southern counties that will bring Gap Analysis to a scale more useful for identifying conservation lands within the state, exclusive of a bioregional context. Private organizations, such as the ***Vermont Land Trust,*** also are cooperating in the project. Efforts include an assessment of the accuracy of predicting vertebrate distributions. Several cooperators have agreed to compile thorough lists of species in the hexagonal analysis units used in predicting species occurrence.

Virginia

State GI/GIS and Satellite Data Contacts

* Charles E. Tyger
Systems and Software Management
Council on Information Management
1100 Bank Street, Suite 901
Richmond, VA 23219
(804) 786-8169
(804) 371-7952 (fax)
ctyger.cim@state.va.us

* David Wyant, GIS Manager
Department of Transportation
P.O. Box 4546
Charlottesville, VA 22905-4546
(804) 293-1964
(804) 293-5412 (fax)

* Jean Tingler
Economic Development Partnership
901 East Byrd Street, W19
Richmond, VA 23218-0798
(804) 371-0340
(804) 371-8272 (fax)

David C. Nutter
Office of the Secretary of Natural Resources
9th Street Office Building, Room 734
202 North 9th Street
Richmond, VA 23219
(804) 786-0044
(804) 371-8333 (fax)

Re Liu
Department of Forestry
Box 3758
Charlottesville, VA 22903-3758
(804) 977-6555

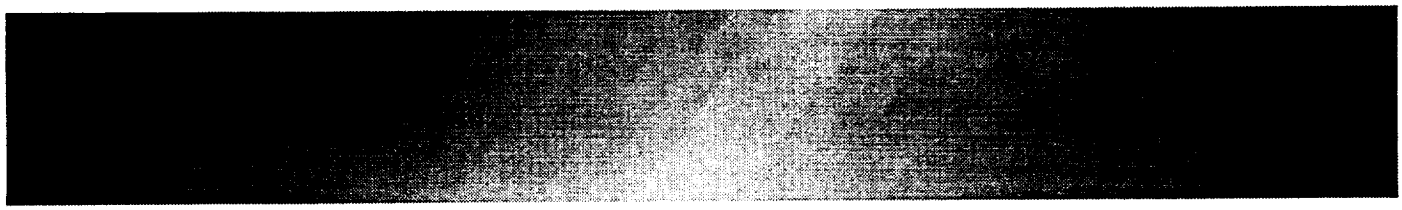
Dr. Ian J. Duncan, Geologist Supervisor
Division of Mineral Resources
Department of Mines, Minerals and Energy
Box 3667
Charlottesville, VA 22903
(804) 963-2307
Jerry Schowalter
Marine Resources Commission
P.O. Box 756
Newport News, VA 23607
(757) 247-2226

Karl Huber, Environmental Engineer
Department of Conservation and Recreation
203 Governor Street, 2nd Floor
Richmond, VA 23219
(804) 371-7484
(804) 786-6141 (fax)

Carl Herschner
Virginia Institute of Marine Science
The College of William and Mary
Gloucester Point, VA 23062
(804) 642-7080
(804) 642-7097 (fax)

Gap Analysis Program Contact

* Jefferson L. Waldron, Manager
Fish and Wildlife Information Exchange
Department of Fisheries and Wildlife Sciences
Virginia Tech
205 B Washington Street
Blacksburg, VA 24060
(540) 231-7348
(540) 231-7019 (fax)
fwiexchg@vt.edu



State Government Context

Virginia has experienced various initiatives to establish a lead entity and coordinate GI/GIS direction and activities in the state. However, no state office or group is currently charged with this role or responsibility, and formal statewide GI/GIS coordination efforts are currently dormant. Activities have been under way since 1996 to establish an informal coordinating group of agency-level GI/GIS managers and coordinators. In addition, staff of the General Assembly have been investigating the potential for a new Geographic Information Authority as directed during the 1996 session. Some legislative action might occur in this regard during the 1997 session.

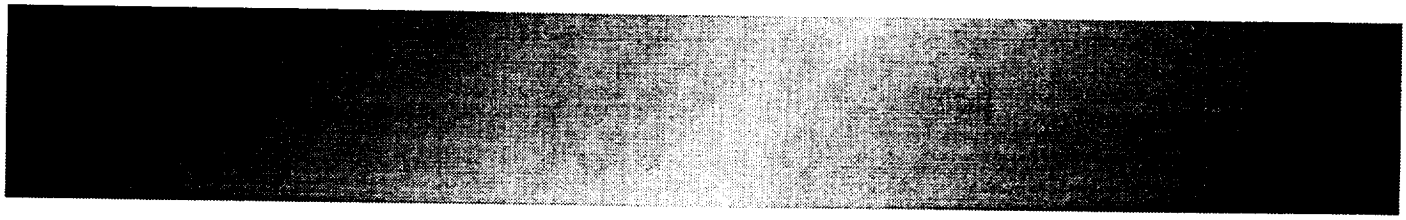
The executive branch lead for GI/GIS coordination is now informally shared by staff at the ***Council on Information Management (CIM)***, the ***Virginia Department of Transportation (VDOT)***, and the ***Economic Development Partnership***. Other state entities are also working to facilitate GI/GIS coordination within and among state agencies. CIM provides information policy direction, coordination, and oversight for state agencies, but it does not operate information technology or GIS services. The Economic Development Partnership is working with state, regional, and local governments to facilitate economic development.

The most recent of past statewide GI/GIS initiatives was the Virginia Geographic Information Network (VGIN), which was authorized and funded by the 1994 General Assembly. VGIN was directed and coordinated by the ***Department of Planning and Budget***. The department hired a GIS manager, acquired equipment and data (including satellite data), and began to implement plans, but VGIN itself and subsequent funding were eliminated by the General Assembly in 1995 (see below). Accordingly, the department dismantled its GI/GIS infrastructure and currently does not have an official role in statewide GI/GIS coordination. CIM had served as the lead for statewide GI/GIS coordination before VGIN was authorized, and it now essentially serves in this role again since VGIN was canceled. Virginia also formerly had an ***Advisory Commission on Mapping, Surveying and Land Information Systems*** to facilitate statewide GI/GIS coordination. It was established by statute in 1988 and had dedicated staff to support its work until 1990. At that time, funding for the commission's staff ceased, and CIM provided staff resources until the commission was eliminated in June 1996.

Satellite Data Use

While formal statewide GI/GIS coordination have been dormant in Virginia until action is taken by the General Assembly, past efforts resulted in the acquisition and increased use of GI/GIS, including satellite data. Specifically, VGIN was authorized and funded by the 1994 General Assembly, including funding for data acquisition and development. A primary result of VGIN before its funding was canceled by the 1995 General Assembly was the acquisition of SPOT data for the entire state. According to the purchase agreement with SPOT Corporation, all political subdivisions and academic institutions in the state are able to acquire copies of the satellite data for the cost of reproduction, and numerous entities are taking advantage of this opportunity.

The satellite data initially resided with the Department of Planning and Budget, which was the lead for VGIN, but it was transferred to VDOT when VGIN was canceled and the Department of Planning and Budget's coordinating role ceased. VGIN's funding for the satellite data was initially and continues to be supplemented by VDOT. Accordingly, VDOT is currently processing the satellite data to create a network of vector data at the 1:24,000 scale for all of the primary and secondary roads maintained by the state. VDOT is using this road base with



GIS for several **transportation planning** purposes. VDOT selected an official GIS coordinator in 1996. His role includes facilitating coordination with other agencies and distributing copies of the SPOT satellite data to interested entities.

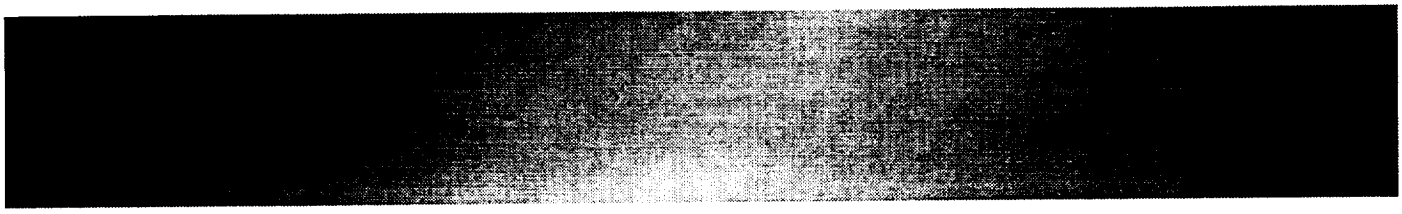
Several other state, regional, and local agencies in Virginia use GI/GIS and are receiving copies of the satellite data. Most of the state's natural resources and environmental activities are located under the ***Secretary of Natural Resources*** and the ***Secretary of Commerce and Trade,*** which jointly have most of Virginia's state government GI/GIS activities. Several departments operate under these secretariats. The former ***Council on the Environment*** included the Environmental Conditions Management, Analysis and Planning (EcoMAP) System. It used GI/GIS and served in a coordinating role. EcoMap was subsequently transferred to the ***Department of Environmental Quality*** under the Secretary of Natural Resources, but EcoMAP later ceased operations, and its GI/GIS facilities were transferred to the Department of Planning and Budget. EcoMAP had previously acquired, developed, and used various data, including aerial photography and satellite data for various projects. Some of EcoMAP's primary efforts included wetlands classifications and inventories in the coastal areas. The Department of Environmental Quality has subsequently acquired a copy of the SPOT data.

Also under the Secretary of Natural Resources, an early user of the satellite data to date has been the ***Chesapeake Bay Local Assistance Department.*** It has used satellite data with GIS in various local projects east of Interstate 95. The department has worked with the ***National Oceanic and Atmospheric Administration (NOAA)*** and its Coastal Change Analysis Project (C-CAP). The department evaluated C-CAP's Landsat data, but found the SPOT data more useful for several efforts. For example, the department used SPOT data to develop land-use/land-cover data with some localities to help their **land-use planning** efforts. The department also used the satellite data for some **watershed management** projects and to assist a local soil and water conservation district to identify agricultural fields in Hanover and Caroline Counties.

Others with GI/GIS and satellite data applications under this secretariat include the ***Department of Conservation and Recreation,*** which was one of the earliest users of GI/GIS in state government. Its ***Division of Soil and Water Conservation*** has been developing the VirGIS data base since 1985, with initial emphasis on pollution causes and impacts in Chesapeake Bay. It has also used some remote sensing for its projects in the past, and it recently acquired the SPOT data. In addition, the ***Marine Resources Commission*** and the ***Department of Game and Inland Fisheries*** use GI/GIS, and both have acquired the SPOT data. The Department of Game and Inland Fisheries is also working closely with Virginia's Gap Analysis Program (GAP) and is developing vertebrate distribution maps for all vertebrates and some invertebrates in Virginia. The department is developing a review process and metadata guidelines for final map development (see below).

Departments under the Secretary of Commerce and Trade also use GI/GIS. The ***Department of Forestry*** has been one of the most extensive users of the SPOT data to date. The department has had a large project to develop a **forest cover** data base that is used to identify harvestable timber in the state. The ***Department of Mines, Minerals and Energy*** is using the satellite data as a backdrop for other GI/GIS work.

Additional state departments are also making use of GI/GIS with the SPOT data. The Economic Development Partnership is developing a system to help in its **economic development** efforts, particularly for siting



industrial development facilities. It is anticipated that the satellite data and GI/GIS will be used to assist in this effort. The ***Department of Health*** reviews sewage systems sites and permits subdivision plats for local governments. It also notifies state and Federal agencies concerning the development of onsite sewage disposal systems and wells. It has used remote-sensing products in this work.

Gap Analysis Program Activities

The Virginia GAP is being conducted by the ***Fish and Wildlife Information Exchange,*** which is located at the Department of Fisheries and Wildlife Sciences of ***Virginia Tech.*** These efforts started in September 1994 and now involve several graduate students and others. In addition to the main project, two associated projects were initiated with the ***U.S. Department of the Army*** at Fort Pickett and Fort A.P. Hill to collect verification data for vegetation and vertebrate distributions. Considerable support and data have been provided from cooperators, especially the Virginia Department of Game and Inland Fisheries. Several state coordination meetings have been held, and the GAP mailing list now contains more than 60 biologists and land managers in Virginia. GAP participants attended a recent Southern Appalachian Gap Analysis Coordination Meeting, and they agreed to cooperate with the other states in the Southern Appalachian Man and the Biosphere (SAMAB) region on classification consistency and edge-matching.

All Landsat data available through the Multi-Resolution Land Characteristics (MRLC) Consortium has been received and preprocessed, and efforts are under way to pursue additional scenes through SAMAB. All SPOT panchromatic satellite data for Virginia were also received from the VGIN program and preprocessed (see above). Complete copies of the 1:100,000 DLG transportation and hydrography layers, all available National Wetland Inventory maps, the best available public lands layer, and a variety of other coverages are maintained. Approximately 15 cover type maps from public lands in Virginia were received and processed. Nine of these areas were chosen as intensive test areas for vegetation model development. A test run of airborne videography was recently completed. The first simple classified maps of study areas were also completed, and efforts are under way to work through the process of model development.

Nonstate Government Activities

NOAA's C-CAP staff conducted its prototype and first regional project in the Chesapeake Bay Region at the ***Oak Ridge National Laboratory.*** A land-cover classification was completed for a four-scene area using MSS data. Some TM data were also used, and change detection work was conducted. Data bases are now available to the public. The ***Virginia Institute of Marine Sciences*** at the ***College of William and Mary*** assisted in this effort and has been conducting photographic mapping of submersed vegetation for the entire Chesapeake Bay beginning in 1978 and annually since 1984. The institute's methodology was used as a base for the C-CAP protocol.

The ***Virginia Remote Sensing Center,*** also located at the College of William and Mary, has conducted research initiated in 1988 to assist the state regarding economic development. Satellite data, GPS, GIS, and image processing have also been used to produce maps and products needed to address the management of **resource conservation** and consumption addressing **environmental impacts.** Various applications have been developed, including land-use monitoring and change detection, vegetation analysis, water density monitoring, and rivers inventorying.

Washington

State GI/GIS and Satellite Data Contacts

* Jeff Holm, Coordinator
Washington State GI Council
Department of Information Services
1110 Jefferson Street
P.O. Box 42445
Olympia WA 98504-2445
(360) 902-3447
(360) 902-2982 (fax)
jeffh@dis.wa.gov

* Ron Holeman, GIS Applications Supervisor
Larry Sugarbaker, Assistant Manager
Information Technology Division
Department of Natural Resources
P.O. Box 47020
Olympia, WA 98504-7020
(360) 902-1532/1546
(360) 902-1790 (fax)

* Doretta Collins
Forest Practices Division
Department of Natural Resources
P.O. Box 47012
Olympia, WA 98504-7012
(360) 902-1426
(360) 902-1784 (fax)
dcqq490@wadnr.gov

* Elizabeth Lanzer
Aquatic Lands Division
Department of Natural Resources
P.O. Box 47027
Olympia, WA 98504-7027
(360) 902-1074
(360) 902-1786 (fax)

Jim Eby
Shelly Snyder
Department of Fish and Wildlife
P.O. Box 43200
Olympia, WA 98504-8711
(360) 902-2512/2483

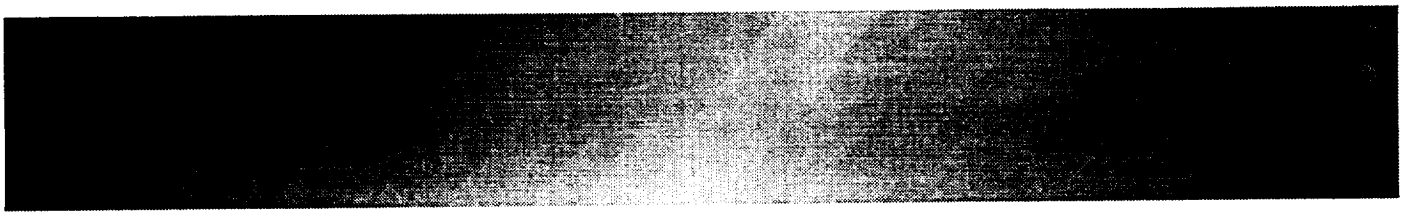
Lynn Singleton
Environmental Investigation and Lab Services Program
Department of Ecology
P.O. Box 47710
Olympia, WA 98504-8711
(360) 407-6699
(360) 407-6884 (fax)

Gap Analysis Program Contact

Dr. Christian Grue
Cooperative Fish and Wildlife Research Unit
School of Fisheries
Box 357980
University of Washington
Seattle, WA 98195-7980
(206) 543-6475
(206) 685-7471 (fax)
cgrue@fish.washington.edu

State Government Context

Statewide GI/GIS coordination in Washington is led by the ***Washington State Geographic Information Council (WSGIC).*** The council was established in 1990 by the director of the ***Department of Information Services (DIS)*** to serve as a policy and coordinating body for GI/GIS in the state. WSGIC membership is composed of representatives of state agencies and local governments, but it also includes other members. WSGIC is staffed by DIS, with primary staff support provided by DIS's full time geospatial coordinator. Additional DIS staff assist the council in several ways, such as developing data and



metadata guidelines and other products for all state entities to use. Washington does not have an entity that provides statewide GI/GIS services.

However, numerous agencies have internal GI/GIS activities, and some have their own GI/GIS centers, including those described below. In particular, the ***Department of Natural Resources (DNR)*** has one of the largest and oldest GIS installations of any state agency in the country. In addition, according to legislation adopted in the 1970s, DNR was designated as the lead agency to develop a statewide land-use data base and was given authority for statewide base mapping, although funding was not provided for these purposes. DNR has not actively served in this role, even though it has developed some statewide data bases (see below).

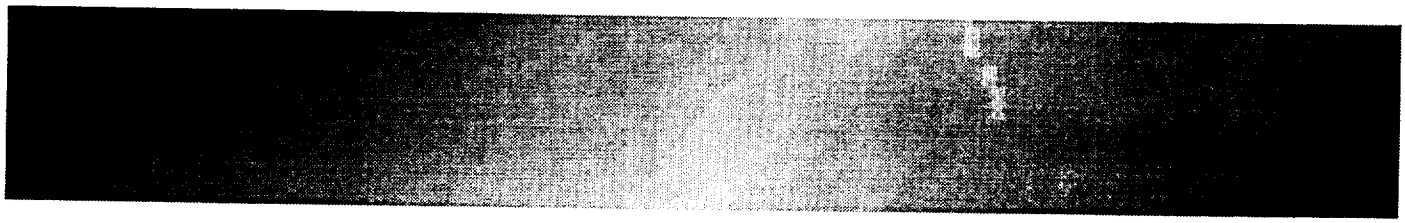
Satellite Data Use

Several state agencies in Washington have GI/GIS capabilities, and many of these organizations have natural resources and environmental responsibilities. DNR is the leading and oldest state agency with GI/GIS activities. Other agencies with environmental and natural resources responsibilities and having GIS facilities include the Department of Fish and Wildlife, the Department of Ecology, the Energy Office, and the Puget Sound Water Quality Authority.

Unlike other state agencies with this name, Washington DNR's primary function is to manage 3 million acres of public lands owned by the state and held in trust for forest, agricultural, urban, and recreational use. DNR's primary mission is to productively manage these trusts to provide financial support to state institutions (mainly schools) through the lease of lands and the sale of timber. Another 2 million acres of land covered by water (rivers, lakes, Puget Sound, and coastal lands out to the 3-mile limit) are part of DNR's resource management responsibility. DNR applies GI/GIS to meet these requirements.

DNR has a longer history using geoprocessing than most states. It first developed a forest-type mapping program in 1955, and a departmental air photo and resource mapping program has been in place since before 1965. This activity supports the department and the public with extensive air photo, orthophoto, and mapping products across the state. An orthophoto mapping program for state forest lands was initiated in the 1970s. DNR has invested more than $7 million in GIS since 1984. Its GIS activities are managed by the ***Information Technology Division,*** while system use is decentralized. Seven regional offices access the system, as well as other state and Federal agencies. DNR's data base is not in the public domain and is proprietary by state law as the lands are managed to derive revenue for the state. Efforts have been made to have data compatible and seamless with other landowners, such as the USDA Forest Service, and data have been made more available to users outside the department in recent years.

While the Information Technology Division has been the lead office within DNR for GI/GIS, it does not necessarily have this role for satellite data, nor has it been an extensive satellite data user. However, DNR uses a variety of data layers with GIS, some with statewide coverage, others covering forested lands regardless of ownership, and others for lands it manages (about five-eighths of the state). For example, it facilitated the development of statewide digital elevation model data. It has had a land-use/cover data base for state lands for several years, including land-use, land-cover, and natural resource inventory summary data for the lands managed by the department. These data were collected from aerial photography and field survey notes, and they have been updated regularly at the field level by DNR's seven regions. Recent efforts have been to update this data base based on orthophotography, and consideration had been given to using satellite data. Subsequently, a program known as Habitat Conservation Planning was initiated by the commissioner of the department in 1996 for state and other lands. This program is using thematic maps derived from satellite data and other



sources, as described below, to facilitate **habitat conservation and timber permit evaluations.**

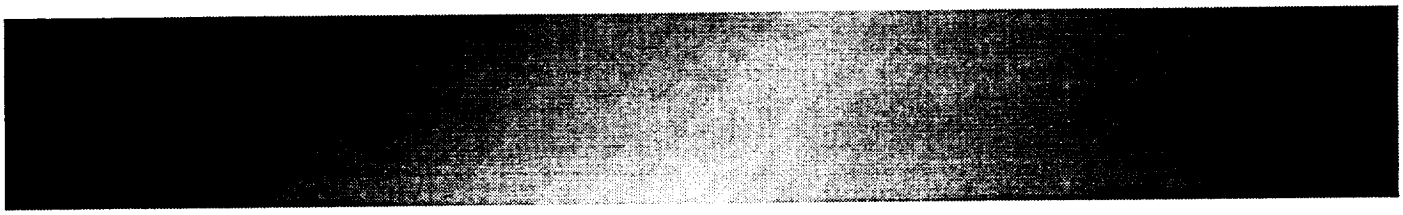
To date, DNR's ***Forest Practices Division*** has been the leading division using satellite data. Landsat TM data from 1988 were initially used by the division under a contract to Pacific Meridian Resources. The satellite data were used to develop a **forest canopy coverage** for all of the state's forested lands except those managed by the ***USDA Forest Service.*** The Forest Service had also contracted with Pacific Meridian Resources to develop a similar data layer for their lands using satellite data of the same date. This work was performed in a compatible manner with the ***State of Oregon,*** and the forest canopy data are still used and complemented with more recent satellite data work.

After this purchase, DNR acquired Landsat TM data from 1991, 1993, 1994, and 1996 through EOSAT's Statewide Purchase Program. The cost for the 1991 acquisition was shared with the University of Washington, which used the satellite data for Washington's Gap Analysis Program (GAP) project. The costs were primarily assumed by the Forest Practices Division, with the ***Department of Fish and Wildlife*** paying for the remaining cost of this and subsequent acquisitions (see below). The division has used the satellite data to conduct forest change detection and to plan, monitor, and evaluate logging permits and timber harvests. It has helped in facilitating **forest resources sustainability,** determining forest management impacts on watersheds and other environmentally sensitive areas, and **reducing the environmental impacts** of timber harvesting and other forest practices. The division has also used the satellite data with the Division of Fish and Wildlife to inventory hardwoods in the state (see below). Plans are to acquire satellite data in the future for each of every 2 years.

Other DNR divisions have used satellite data, but primarily as a backdrop for GIS. For example, the ***Aquatic Lands Division*** has made some use of satellite data for habitat conservation planning, and it is considering the potential uses of satellite data for habitat inventory.

The Department of Fish and Wildlife is an active user of satellite data with GI/GIS for **wildlife resources.** As described above, the department has partially funded the acquisition of Landsat TM data with DNR. The Department of Fish and Wildlife has used satellite data in various efforts for more than a decade. The first use was initiated in 1986 for a study of **old-growth trees** and **wildlife habitat** in western Washington. This old-growth and forest stand mapping effort was conducted by the department's Remote Sensing Program. This project was initiated because forest stand type mapping was needed for use in spotted owl habitat preference research, as well as management applications for elk and mountain goats. The study area for this project was 11.3 million acres and included two regions of western Washington: the west slope of the Cascade Mountains and the Olympic Peninsula. The lands within the study area were divided into major ownership categories by digitizing administrative boundaries. Elevation zones were identified using digital terrain data. The old-growth and forest stand mapping was performed with digital analysis of Landsat MSS data. The satellite data and radiotelemetry were used with GIS to facilitate wildlife habitat evaluations, particularly for spotted owl preference. As part of these efforts, changes in sun incidence angle related to mountainous terrain variations were evaluated, and it was determined that they cause changes in the reflectance levels of infrared light from coniferous forests as sensed by Landsat. An analysis of field observations, Landsat data, and digital terrain data was used to model this relationship to enhance the mapping of old-growth stands. Satellite data have also been used in some habitat studies and subsequent efforts for other parts of the state.

The ***Department of Ecology*** is responsible for environmental protection programs in Washington. It has used



Landsat data for vegetation mapping in various efforts and locations, such as to support plant community distribution mapping for environmental monitoring at the Hanford Superfund site. Efforts have been under way to explore the use of SPOT data as a backdrop for improving and verifying spatial coordinate accuracy and to use Landsat, SPOT, and radar data to conduct comprehensive analysis of forested wetlands and to improve existing National Wetlands Inventory data.

Gap Analysis Program Activities

Washington's Gap Analysis Program has been conducted by the Cooperative Fish and Wildlife Research Unit located at the ***University of Washington.*** This work, completed in 1996, includes a statewide land-cover and land ownership map, vertebrate data layers, and predicted distribution maps for each species. Analyses of the gaps in conservation for land-cover types and vertebrate species were also completed.

Nonstate Government Activities

The University of Washington also uses satellite data. It helped fund the acquisition of statewide Landsat TM coverage that was used in Washington's GAP and other projects.

West Virginia

State GI/GIS and Satellite Data Contacts

* Craig Neidig, State GIS Coordinator
Geological and Economic Survey
c/o DEP, Office of Air Quality
Suite 104-106
1615 Washington Street, East
Charleston, WV 25311
(304) 558-4218
(304) 558-1222 (fax)
neidigcr@wvlc.wvnet.edu

* Larry Evans, GIS Manager
Office of Information Services
Division of Environmental Protection
Bureau of Environment
10 McJunkin Road
Nitro, WV 25143
(304) 759-0519
(304) 759-0565 (fax)

Gap Analysis Program Contact

Dr. Sue A. Perry
Cooperative Fish and Wildlife Research Unit
Division of Forestry, Box 6125
West Virginia University
Morgantown, WV 26506-6125
(304) 293-3794, ext. 2432
(304) 293-2441 (fax)
sperry@wvnvm.wvnet.edu

State Government Context

West Virginia has been developing a statewide approach to GI/GIS since 1990. Following the completion of a consultant's study in 1992, an executive order was adopted in 1993 to establish a statewide GI/GIS program. Legislation was adopted in 1995 to initiate a Mineral Lands Mapping Program, create and fund the position of state GIS coordinator, and establish a ***GIS Technical Support Center*** at ***West Virginia University (WVU).*** Funding has been approved to support these efforts for each year since then.

With this GI/GIS direction and funding, the state hired its first statewide GIS coordinator in 1995. In accordance

with the legislation, the position is administratively located within the ***Geological and Economic Survey (GES),*** which is located at WVU in Morgantown. However, the GIS coordinator is physically located in the ***Division of Environmental Protection (DEP)*** of the ***Bureau of Environment*** near the state capitol to facilitate relationships with other state agencies. The legislation also provided that the GIS Technical Support Center be developed at WVU's ***Department of Geology and Geography.*** With efforts under way since 1995, the center provides technical support in GI/GIS, including data development and access, data base designs, education and technical assistance, and contracted GI/GIS services. The majority of the legislative funding has been provided for modernizing coal and other resource taxation through the Mineral Lands Mapping Program (see below).

West Virginia has three GI/GIS coordination groups established by the 1993 executive order. The ***West Virginia GIS Policy Council*** consists of cabinet officers and department supersecretaries, and its ***GIS Steering Committee*** includes the GI/GIS contact people in state agencies. In addition, the ***GIS Coordinating Committee*** is composed of government and private sector members. These groups have been strengthening, particularly since 1995.

Satellite Data Use

Environmental, natural resources, and satellite data activities are primarily located in the ***Bureau of Commerce*** and the Bureau of Environment. The largest concentration of GI/GIS activities in state government was in the Bureau of Environment until the legislature authorized a statewide program in 1995 (see above). The legislation directed and funded Bureau of Commerce's GES to expand its GI/GIS activities, thereby having a leading role in GI/GIS data development and coordination, including serving as the administrative location for the state GIS coordinator.

The 1995 legislation initiated a Mineral Lands Mapping Program in the state and created a GIS Technical Support Center at WVU, as well as the state GIS coordinator. The majority of the legislature's authorized GI/GIS funding is for the Mineral Lands Mapping Program, which is a partnership between the ***Department of Tax and Revenue,*** GES, and the Department of Geology and Geography at WVU. The objective of the program is to modernize taxation systems by revising the process by which mineral resources, especially coal, are evaluated and assessed for taxation. The program is assigned to these agencies as three concurrent projects: GES is responsible for coal bed mapping, the Department of Tax and Revenue for parcel mapping, and WVU for producing 1:24,000 DLGs. Other state agencies are also working with this project through statewide GI/GIS coordination efforts (see above). The initial data integration efforts were conducted for Fayette County. Some investigations are under way to evaluate the potential for satellite data to assist in the Mineral Lands Mapping Program. Color infrared National Aerial Photography Program (NAPP) flights for the state began in 1996 and are expected to be completed in 1997, with efforts under way to produce orthophoto quadrangles using this photo base. West Virginia is unique because it has complete 7.5-foot digital elevation model coverage available and online.

While the Mineral Lands Mapping Program has not used satellite data to date, state agencies are also working on the Gap Analysis Program (GAP) with WVU (see below). The focus of this effort has been to develop a statewide land-cover data base using Landsat TM data. While the primary purpose, based on funding, for the land-cover work has been to meet GAP requirements, other uses have been developed and are anticipated. For example, the data show wetlands, wildlife habitat, and gypsy moth infestation and will be used for state land-use planning. The Bureau of Environment has been an active participant in this effort, as has the Bureau of Commerce's ***Division of Natural Resources,*** which has assisted with

collecting locational data for the hexagons-of-occurrence for each species in the state. The Division of Natural Resources also has some GI/GIS activities for internal purposes.

The Bureau of Environment had the largest concentration of GI/GIS activities in state government until the legislature authorized the statewide program in 1995 (see above). DEP has a GIS coordinator located in its ***Office of Information Services***. This office has virtually all of DEP's GI/GIS activities using ARC/INFO, while others in DEP are developing ArcView applications in coordination with the office. The Bureau of Environment has used satellite data with GI/GIS for selected projects, such as for **water quality monitoring** and public water supply delivery. For example, some SPOT data were acquired for the Governor's Stream Restoration Program. Another example of satellite data use was to help determine the best site for a new paper mill.

Gap Analysis Program Activities

The GAP work in West Virginia is being conducted by the ***Cooperative Fish and Wildlife Research Unit*** in the Division of Forestry at WVU. Efforts are under way in coordination with neighboring states, other facilities at the university, and state agencies. Work is expected to be completed in 1997.

Land-cover mapping efforts are completed in an intensive study area that was used for methods development (Allegheny Mountain Transition subsection), and efforts are now under way with the rest of the state. Methods for videography in the mid-Appalachian area were developed, and West Virginia and some areas in contiguous states were filmed in 1995. A unified airborne video project covering West Virginia and neighboring states was initiated in 1996. The ecoregion map that will be used for stratifying the state was updated. The utility of supervised versus unsupervised classification for the Allegheny Mountain Transition subsection was evaluated, and it was determined that a strategy of postclassification sorting, with elevation and slope/area index included as derived bands, is the most efficient use of the limited ground data for community alliances in this area. When the fall videography has been processed, efforts will proceed with a "hybrid" classification for the rest of the state. Ground vegetation surveys were completed in 1995; the data are being used to improve ***The Nature Conservancy*** alliances for West Virginia. Additional surveys were conducted in 1996 for ground checks of the videography images. Talks and training sessions have been presented on methods for remote sensing to the Smithsonian Institution Conservation Research Center, at a USDA Forest Service course on methods for ecosystem management, at conferences, in several classes at WVU, and at an Earth Day booth.

The vertebrate species/habitat relationship data base structure for West Virginia is complete. The data base from the ***Virginia Department of Game and Inland Fisheries*** was converted and merged with the GAP data base, and the data from DeGraaf *et al.* (1992)—New England wildlife: management of forested habitats—have been entered. The wildlife data base is based on the Society of American Foresters forest cover types, The Nature Conservancy classification scheme (in progress), and the Cowardin *et al.* (1979) wetland classification scheme. Society of American Foresters types are being used because The Nature Conservancy classification is not complete. As The Nature Conservancy data are made available, they will be incorporated into a cross-walk, so the data base can be converted when all The Nature Conservancy types are completed for West Virginia. The West Virginia Division of Natural Resources and The Nature Conservancy are assisting with collecting locational data for the hexagons-of-occurrence for each species in the state. The Division of Natural Resources has finished collecting the locational data on all species except butterflies and skippers.

Efforts are under way to inventory the level of aquatic diversity within certain drainages in West Virginia and to identify stream reaches or watersheds that offer high conservation potential. The initial study area includes the Monongahela and Potomac River Basins, which together cover the northeastern third of the state. Data have been compiled for 94 watersheds within the study area for a number of environmental and human influence variables, such as land use, elevation, bedrock geology, and population density. In addition, a fish collection data base has been created to incorporate collection records from the Division of Natural Resources, the ***USDA Forest Service,*** the ***U.S. Environmental Protection Agency (EPA),*** the ***U.S. Army Corps of Engineers,*** WVU, and museum records into both the EPA River Reach coverage and the watershed coverage. An initial analysis of the watershed-level data indicated that mining activities and limestone bedrock geology are related to fish species diversity at the watershed scale.

Nonstate Government Activities

WVU is the site of the state GIS Technical Center and is the lead for GAP (see above; contact Charles Yuill).

Wisconsin

State GI/GIS and Satellite Data Contacts

* Doug King, Executive Director
Wisconsin Land Information Board
Department of Administration
17 South Fairchild Street, 7th Floor
Madison, WI 53703-3204
(608) 267-2707
(608) 267-2707 (fax)
kingd@mail.state.wi.us

Loren Huffmann, Manager
Wisconsin GIS Service Center
Technology Management Division
Department of Administration
101 East Wilson Street, 9th Floor
Madison, WI 53704
(608) 261-6633
(608) 264-9500 (fax)
hoffml@mail.state.wi.us

Ted W. Koch, State Cartographer
Bob Gurda, WISCLAND Manager
State Cartographer's Office
Room 160, Science Hall
550 North Park Street
Madison, WI 53706-1491
(608) 262-3065
(608) 262-5205 (fax)
tkoch@facstaff.wisc.edu

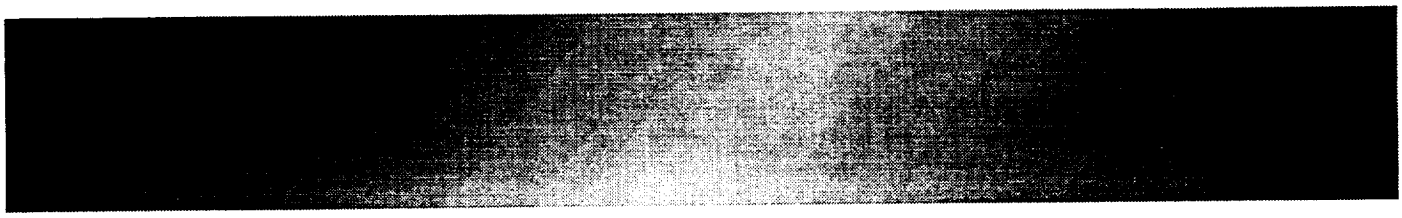
* Paul Tessar, Geographic Services Section Chief
Robert Goldman, Land Cover and Forestry Project Leader
Ron Gatti, Wildlife Habitat Restoration Project Leader
Bureau of Information Management
Department of Natural Resources
101 South Webster
P.O. Box 7921
Madison, WI 53707-7921
(608) 266-3054
(608) 261-6419 (fax)
tessap@dnr.state.wi.us

Gap Analysis Program Contact

For Minnesota and Wisconsin, see under Michigan.

State Government Context

Wisconsin has a unique statewide GI/GIS coordination effort compared to other states. Components of the



Wisconsin approach include a unique statewide, county-based geographic information coordinating effort known as the ***Wisconsin Land Information Program (WLIP)***, a ***GIS Service Center***, and a ***State Cartographer's Office***. Wisconsin also has extensive GI/GIS efforts in its comprehensive environmental and natural resources agency, the ***Department of Natural Resources (DNR)***, as well as at the University of Wisconsin. Work is under way among state agencies to develop shared data and distributed data custodianship for various data layers.

WLIP was established and funded by the legislature beginning in 1989. The program is administratively attached to the ***Department of Administration***. The ***Wisconsin Land Information Board*** directs the program, and a small staff manages it. Since 1990, the board has awarded 160 grants, totaling more than $11.1 million, to local governments for the development of integrated land information systems. With funding derived from an increase in land recordation fees, Wisconsin's 72 counties are also empowered to retain additional program revenue in excess of $20 million that is collected in their own county. Funding has been applied in several areas, including land information system modernization plans, GPS control stations, base and image mapping, GIS or computer-aided drafting systems (in 85 percent of the state's counties), and various other data initiatives, including parcel, soils, zoning, and wetlands mapping.

The state GIS Service Center was created in the Department of Administration's ***Technology Management Division*** in July 1995. It acts as a service bureau and provides GI/GIS assistance on a contract basis to state and local agencies. The center also provides data distribution services for various data.

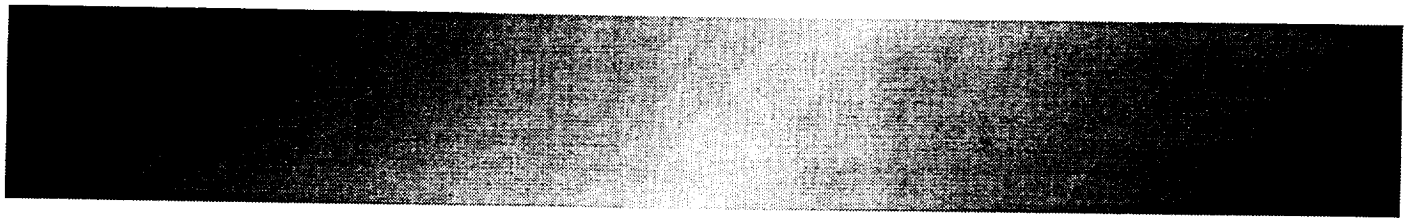
Wisconsin is one of the few states with a State Cartographer's Office, particularly one that is fully funded by state government. Established in 1973 and authorized by statute, the office is a unit of the University of Wisconsin at Madison and has five staff members. The office provides several functions for the state, including serving as a clearinghouse for geographic information and offering advice regarding mapping practices, methods, accomplishments, and expertise.

The state has four GI/GIS coordination groups that work with these three offices. These groups include the Wisconsin Land Information Board (see above), the ***Wisconsin Land Information Association***, the ***State GIS Managers Council***, and, as of 1996, the ***County Land Information Offices Council***. The board is the only group established by statute, but all four groups are very active. In addition, the state has a ***Wisconsin Initiative for Statewide Cooperation for Land cover ANalysis and Data (WISCLAND) Steering Committee***, which is composed of state, Federal, local, and academic organizations that are actively using satellite data and other information to develop various data resources for the state (see below).

Wisconsin also has an ***Interagency Land Use Council***, which was formed in 1994 to improve land-use planning in the state. It has also addressed geographic information issues and needs. Composed of secretaries of several state agencies, this council advocates more and better geographically referenced information that would support more robust statewide planning. Policy-level discussions and legislation regarding land-use planning in 1997 may affect the Wisconsin Land Information Board and its programs.

Satellite Data Use

Wisconsin has made extensive use of satellite data as compared to many other states. A statewide focal point for much of this activity is WISCLAND, which was initiated in 1993. Managed by the State Cartographer's Office, WISCLAND is a voluntary partnership of public and private entities in Wisconsin that seek to facilitate



landscape data development and analysis using GIS. More than 25 organizations are now official signatories to WISCLAND's Articles of Participation. These entities include nine state entities, such as DNR, the ***Department of Transportation,*** the ***Department of Administration,*** the ***Department of Revenue,*** and the ***Department of Health and Social Service;*** various Federal agencies, including the ***USDA Natural Resources Conservation Service,*** the ***USDA Forest Service,*** the ***Great Lakes National Program Office*** of the ***U.S. Environmental Protection Agency,*** the ***National Park Service,*** and various parts of the ***U.S. Geological Survey (USGS);*** several parts of the University of Wisconsin at Madison; and some regional planning commissions and counties. WISCLAND has evolved to serve as a virtual umbrella organization that is facilitating the creation of a "common market" within which GIS data users and producers are working collaboratively to better accomplish mutual objectives. This "brokerage" function has achieved several positive results.

Initial WISCLAND efforts focused on developing statewide **land-cover mapping,** and there are now a total of eight data layers under development for statewide use. Landsat TM data were acquired to develop these land-cover data through the Gap Analysis Program (GAP) now managed under USGS's ***Biological Resources Division.*** The land-cover information is based on spectral classifications of 1992 and 1993 Landsat TM data, with lowland areas delineated based on the Wisconsin Wetlands Inventory. These data are being digitally interpreted via advanced satellite data processing and GIS techniques. Pre- and postclassification work will include enhancement by a variety of GIS data sources. For example, DNR previously converted statewide land-cover data from 1:250,000-scale USGS "GIRAS" format to ARC/INFO coverages. The resulting data layer, titled Rural Land Cover Mapping, will be a statewide high-resolution (1-acre) vegetation map that includes a detailed data base of 40,000 visited sites. With this work now under way for more than 3 years by DNR, it is expected to be completed in November 1997.

Efforts have also been initiated to develop land-use mapping for urban, suburban, and exurban areas of the state to complement the rural land-cover mapping effort. A more intensive approach is under way for these areas, including supplying technical assistance to land-use and transportation planning efforts for developed areas. Other WISCLAND data layers include a 1:24,000-scale Landnet, which is a cartographic representation of the Public Land Survey System for the state. It is complete and available in the DNR database library. Further efforts are underway to develop information for section quarters, with a longer term goal to obtain survey accurate representation of the Public Land Survey System. Digital representations of the Wisconsin Wetlands Inventory are also available. The other four layers under development include hydrography, digital orthophotos and elevation models, floodplain mapping, and soil survey mapping. Much of this work is under way by DNR staff, with assistance provided by the University of Wisconsin at Madison's Environmental Remote Sensing Center (see below).

DNR is a comprehensive environmental and natural resources agency, and it is the largest user of GI/GIS and satellite data in state government. DNR has worked with GI/GIS since the early 1980s, and it now has an agency-wide approach to geographic information, with extensive use of satellite data and other information with GIS. DNR has a GIS Advisory Committee with representatives from various departmental bureaus. GIS activities are coordinated and managed by the ***Geographic Services Section*** of the Bureau of Information Management. The section now has approximately 20 staff and an additional 15 temporary staff; it provides services for and in coordination with various bureaus. These services include applications and data base development projects, as well as support services and information dissemination activities such as training and a quarterly newsletter. The

Geographic Services Section issued its first CD–ROM in 1996, which includes 18 of the statewide DNR GIS data sets that are most frequently requested.

Several DNR bureaus have their own GI/GIS facilities and expertise in addition to the Geographic Services Section. Much of their satellite data work has focused on developing and using WISCLAND's land-cover data, but various other satellite data projects have also been under way by the Geographic Services Section and the bureaus (see above).

DNR's ***Bureau of Forestry*** has some of the state's most extensive use of satellite data. A project was completed in 1994 with the Geographic Services Section to automate forest compartment stand maps for the six major state forests. These data are being used for various **forestry** applications, and they were developed using SPOT and aerial photography. Initial efforts focused on the Northern Highland/American Legion State Forest. The original forest stand maps were interpreted using unrectified aerial photography and drawn onto mylar film. The forest stand boundaries on the mylar maps were then digitized on screen into ARC/INFO using SPOT 10-meter panchromatic digital geocoded satellite data as a reference base. During 1995, the automated stand maps were installed at field offices in each of the state forests with appropriate hardware and software to give field foresters the ability to update and make changes to the automated stand maps and tabular data compiled for individual forest stands. These changes are being uploaded to DNR's central data base.

Satellite data have also been used by DNR for **wildlife management,** particularly to improve habitat restoration. For example, a project was initiated to restore grassland wildlife habitat in a 900-square-mile glacial habitat restoration area (see Figure B9). This effort required a GIS layer of current land cover, but traditional, manual methods were too labor-intensive and costly for a large area. Landsat TM data were classified into 16 cover types. The final layered classification used data from early May and late June 1990—the two dates individually and in a principal component analysis—and other data in GIS form to achieve a 90-percent landscape scale accuracy. A 3x3 pixel majority filer was used to smooth the final data before outputting them into a GIS data layer.

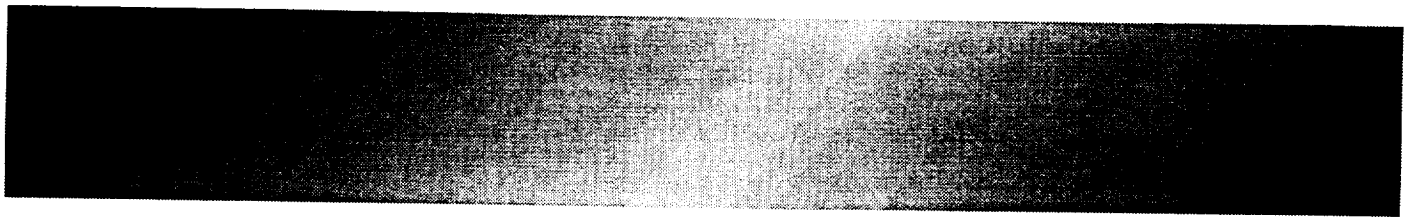
The land-cover data were used in combination with several other vector data layers in a GIS model of where to site habitat restorations that best benefit wildlife. The

Glacial Habitat Restoration in Southern Wisconsin



Figure B9

These are GIS vector data of land cover classified from two dates of Landsat TM data from 1990 for a township of southern Wisconsin. Satellite land-cover data are used as inputs to determine where to restore nest cover and wetlands that will benefit grassland birds. Satellite data are being updated every 5 years to quantify land-cover changes across the 900-square-mile project area. (courtesy of Ron Gatti, Wisconsin Department of Natural Resources, (608) 221-6348, *gattir@dnr.state.wi.us*)



results of the modeling are output as paper plots for planning, as slides for presentation at public meetings, and in desktop computer data bases for mapping and query. The end users are wildlife managers in field offices, who use the data bases and graphic output in their public contacts for education and land acquisition. The resolution of the TM data are best used at the survey township scale or broader. Numerous spinoff applications of the satellite land-cover data have emerged, ranging from other wildlife management planning to land-use planning at the county, town, and watershed levels by various government agencies, electric utilities, and nonprofit conservation organizations, as well as for defending the acquisition program in an internal review.

DNR's Nonpoint Source Priority Watershed Program has made use of satellite data for **water quality management** to help improve the accuracy and specificity of land-use classification for **nonpoint source pollution modeling.** Landsat TM data were used with zoning, housing density, and other data to determine land-use categories in Beaver Dam, Wisconsin, a city of approximately 15,000 residents. More categories were distinguishable because satellite data were used. These data helped estimate and model the type and concentrations of nonpoint source contaminants found in urban stormwater. It was concluded that satellite data use improved the accuracy of these estimates.

Other Wisconsin agencies are increasing their use of satellite data as WISCLAND becomes available. Eight other state agencies participate in this initiative.

Gap Analysis Program Activities

For Minnesota and Wisconsin, see under Michigan.

Nonstate Government Activities

The ***University of Wisconsin at Madison*** has several faculty and centers with geographic information activities. The primary place where satellite data work is taking place is the ***Institute for Environmental Studies,*** which includes the ***Environmental Remote Sensing Center.*** Several projects are under way using satellite data. In addition, the center was awarded a grant from **NASA** in 1996 to investigate the commercial applications of remote sensing. The Environmental Remote Sensing Center is only one of four centers nationwide that were chosen to participate through NASA's new Visiting Investigators Program (contact Dr. Thomas Lillesand at (608) 263-3251).

The State Cartographer's Office, which manages WISCLAND, is also located on the campus (see above). Various parts of the university are involved in this initiative, and the Environmental Remote Sensing Center provides scientific consulting and research and development support.

Other parts of the university system have also used satellite data. For example, researchers at the ***University of Wisconsin at Stevens Point*** worked with DNR to assess the prospects for recovery and growth of the wolf population in the upper Midwest and determine the economic effects of management scenarios for the wolf population.

The ***University of Minnesota at Duluth*** has a Center for Water and the Environment in its ***Natural Resource Research Institute.*** It has conducted some satellite data work for parts of Minnesota and the ***Chequamegon National Forest*** in Wisconsin. A detailed forest land-cover classification was created from satellite data, and it was used to help understand the relationship between regional forest landscape patterns created by land management approaches and the benefits and commodities that can be derived accordingly. In addition, the project helped develop an accurate ecoregion classification and a landscape simulation model.

Reference

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Wyoming

State GI/GIS and Satellite Data Contacts

* Nancy McCann
Water Rights Adjudication
State Engineer's Office
Herschler Building, 4E
Cheyenne, WY 82002
(307) 777-5958
(307) 777-5451 (fax)
nmccan@missc.state.wy.us

* Richard C. Memmel, GIS Coordinator
Information Technology Division
Ben Saunders, GIS Analyst
Ec mic Analysis Division
De ment of Administration and Information
Emerson Building
2001 Capitol Avenue
Cheyenne, WY 82002
(307) 777-5103
(307) 777-5120 (fax)
rick@ctprol.state.wy.us

Kirk Nordyke
Game and Fish Commission
5400 Bishop Boulevard
Cheyenne, WY 82002
(307) 777-4595

Gap Analysis Program Contact

Tom Kohley
Wyoming Water Resources Center
University of Wyoming
P.O. Box 3067, University Station
Laramie, WY 82071
(307) 766-2735
(307) 766-3785 (fax)
kohley@uwyo.edu

State Government Context

Wyoming is implementing a statewide approach to GI/GIS, as authorized by an executive order in 1994 and legislative action in 1996. The legislature authorized funding for a new ***Office of GIS*** in the ***Economic Analysis Division*** of the ***Department of Administration and Information.*** The office has one staff person and a coordination and support role to develop a GI/GIS clearinghouse, including a data dictionary and metadata catalog for state government. Efforts are under way to develop a state base map. No state entity provides GI/GIS services for other agencies at this time.

Various state agencies participate in the ***Wyoming Geographic Information Advisory Council*** that was authorized by the executive order in 1994. It has various subgroups, including a GIS User's Group and a Standards Committee. A new cabinet-level management team was organized at the end of 1996 to develop policy-level direction for geographic information. The team is being led by the state planning coordinator and the state engineer. The ***State Engineer's Office,*** which is responsible for water resources, was the first user of GI/GIS in state government and has a leading role in GI/GIS in the state. The Wyoming Geographic Information Advisory Council has been chaired by a representative of this office. The council and the management group are staffed by the Office of GIS.

Satellite Data Use

Natural resources and environmental responsibilities are shared by various agencies in Wyoming. Some of these agencies have GI/GIS activities, but there has been limited use of satellite data in Wyoming state government in recent years.

The state ***Water Development Commission*** undertook a large effort to evaluate the use of color infrared photography and Landsat MSS data to inventory irrigated lands in the Green and Bear River Basins of Wyoming during the mid-1980s. This work was conducted in a collaborative project with the U.S. Department of the Interior's ***Bureau of Reclamation,*** with assistance from ***Colorado State University.*** Multidate satellite data were useful for several **water resources** efforts—for example, it enabled participants to successfully determine reservoir surface area estimates and assess the extent of short supply irrigated lands for **agriculture** use. These data were primarily used for water resources management and development applications, but they were also used by these and other agencies to help determine land use and wetlands.

More recent state uses of satellite data have been through the Gap Analysis Program (GAP) for Wyoming (see below). The ***Department of Game and Fish*** has been an active participant with the ***University of Wyoming*** on this project for **wildlife resources** management and protection efforts.

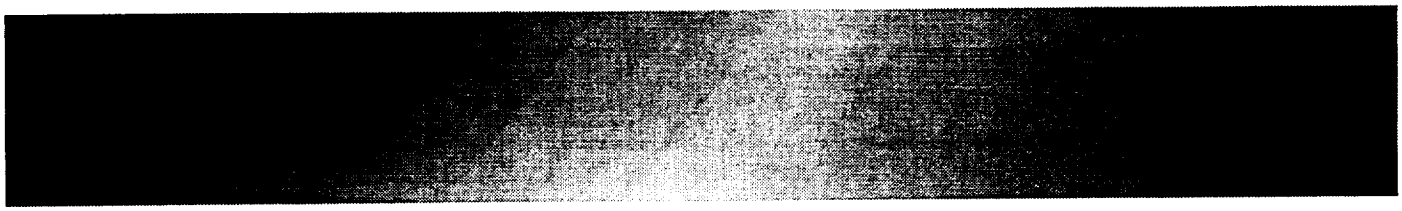
The State Engineer's Office is responsible for water resources in Wyoming. It was the first user of GI/GIS in state government, beginning in 1985 in a cooperative arrangement with the Water Resources Division of the ***U.S. Geological Survey*** to support water rights adjudication. GI/GIS is also being applied to other agency responsibilities.

Gap Analysis Program Activities

The ***Wyoming Water Resources Center (WWRC)*** at the University of Wyoming is the state repository for the Wyoming GAP data bases. Work was completed on the three major GAP data bases (land cover, land ownership/status, and species distributions) in 1996 with the Cooperative Fish and Wildlife Research Unit. These data bases are available on the national GAP's World Wide Web home page. Gap analyses were also completed in 1996, and a book of range maps was also produced in the form of a black-and-white atlas, along with habitat associations and references for each species. In addition, a full-color land-cover atlas for Wyoming has been developed. WWRC's GIS lab has petitioned to be a data node under the National Biological Information Infrastructure.

An expert review of the habitat associations and species range maps was conducted. The predicted distribution of 445 species in Wyoming was modeled using land-cover, elevation, and riparian associations to create final distribution maps. The review of these maps involved nearly 60 biologists and bird experts across the state. Several experts on a particular taxonomic group met to conduct the review to arrive at a general consensus on species distributions. In most cases, reviewers were satisfied with the maps but acknowledged that not enough is known about some species' distributions to produce a distribution map with much confidence. Predicted species distributions are being compared with published species lists for several areas around the state to have a better understanding of the amount of omission/commission error in model predictions.

A review of the assignment of protection status codes used as the key for categorizing land management developed by the New Mexico GAP project was recently completed. Land managers from different state, Federal, and private agencies were asked to evaluate the protection status



categories given to the lands under their jurisdictions. In most cases, the reviewers found the New Mexico key helpful in the categorization process. One exception occurred where mixed ownership and management objectives existed for the same area. For instance, private lands occurred within
the boundaries of national parks, recreation areas, and other management units. The private lands are not managed in the same manner as the Federal lands and, as a result, were given a different protection status.

A pilot project was recently initiated in coordination with the national GAP office to explore the utility of GAP in county land-use planning.

Nonstate Government Activities

The University of Wyoming has other departments involved with satellite data work in addition to GAP. For example, the ***Department of Botany*** is using satellite data for applications in addition to GAP. This and other departments work with the GIS lab at WWRC, which is becoming a focal point and resource center for GI/GIS and satellite data at the university (contact Jeffrey Hamerlinck at (307) 766-2736).