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Annotated Bibliography Developed for the Graduate Level Introductory GIS Classes Taught at EPA

National Center for Environmental Assessment–W
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This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

PREFACE

From September 1996 to December 1997, EPA's National Center for Environmental Assessment (NCEA) worked with George Mason University to present a semester long, graduate level class on "Introduction to Geographic Information Systems (GIS)" that was taught at EPA. The class was offered four times during this period and 100 EPA staff members took the class. Students taking the class for credit were required to submit an annotated bibliography covering various aspects of GIS. This document represents a compilation of the bibliographies submitted by the students. The abstracts are presented in alphabetical order, by author, and have only been edited for style, not content. References that were cited by more than one student will appear as duplicates in this document. Each duplicate contains a different student's abstract. The document is in Word Perfect 8.0 and can be searched by key words by going into the "Edit" menu and using the "find and replace" function. We are in the process of converting this document into a format compatible with Reference Manager so that it can be searched more easily. When this task is completed, we will put the revised version on the Internet.

Although this document does not represent an exhaustive literature search on the field of GIS, it does provide an excellent resource on a very broad range of topics including GIS used to study environmental impacts on land, water and air; GIS used in epidemiology studies; GIS used to study environmental justice; and GIS used to study changes in natural resources. Many references also cover issues concerning the set up of GIS systems and the collection and use of data from remote sensing and aerial photography for GIS studies. Approximately 510 different articles have been cited.

Unfortunately, NCEA does not have the resources needed to update and maintain this bibliography in a systematic manner. If you are interested in obtaining more recent references, you should conduct a literature search on GIS and GIS in combination with other topics of interest, such as air pollution and environmental justice. You also may want to select key words from this bibliography to use in your search. In an effort to provide the EPA GIS user community with useful information, NCEA will periodically post GIS-related references and other information to our web page. So stop by and visit our web site (http://www.epa.gov/ncea) and see what's new!

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Albert, DP; Gesler, WM; Wittie, PS. 1995.
Geographic information systems and health: an educational resource.
J Geogr 94:350–356.

This article is an excellent resource for background information on GIS and its applications. The authors state that the "article is intended as a bibliographic resource for university geography teachers and students." The article is presented in sections dealing with the definition of GIS, the use of GIS in medical studies, and studies that are further broken down into four categories: (1) advocate the use of GIS, (2) present cautionary literature, (3) present preliminary investigations, and (4) actual applications. The section on preliminary investigations of GIS was particularly interesting because of the two studies that were presented—one dealt with lead (Pb) exposure and poisoning and the other discussed "using GIS to assess reproductive outcomes in an area surrounding hazardous waste sites." The authors raised a point that is relevant to Dr. Wheeler's GECA 553 (EPA) course, specifically the required reading text. The authors note that Aronoff's text provides examples of GIS applications, but that "there are no examples that highlight applications of GIS to spatial aspects of health and disease." Applications that are relevant to the spatial aspects of public health might be of great interest to the class members. This article is a useful resource to point interested parties to those types of journal articles.

Albertson, PE; Bourne, SG; Hennington, GW. 1992.
An integrated groundwater and land-use GIS for impact assessment.
Photogrammetric Eng Remote Sensing 58(8):1203–1207.

The authors demonstrate the use of GIS to evaluate the effects of navigational pools on ground-water conditions and assess any actual postproject land-use impacts. The study was conducted around Alexandria, Louisiana, along the Red River, where the Corps of Engineers was building five locks and dams. The resulting navigational pools were expected to cause higher stages in the river during low- and medium-flow periods. Alexandria, the largest urban area adjacent to pool #2, was selected for study to evaluate the changes in ground-water levels and impacts to land use that have occurred since the rise of water in this pool. GIS was selected to demonstrate how this technology could store, access, analyze, and portray the vast amount of preproject, predictive, and actual postproject data. The input data included digitized values derived from ground surface elevation data and preconstruction potentiometric maps, as well as land-use maps identifying all land-cover classes, with particular emphasis on how specific crops were impacted by changing ground-water levels. They also used data water levels for each crop that would either reduce or increase crop yield. Postproject land use was derived from LANDSAT Thematic Mapper—digital data. The authors described how they processed the TM data to produce classified land-use maps. The authors also used Triangulated Irregular Network (TIN) to generate contour maps of surface elevation and water level. Preproject water elevation was compared with topography, and then the procedure was repeated for predicted postproject conditions. The two outputs were compared to determine how wet conditions will increase based on USGS model predictions. Comparison with actual postproject data indicated that in reality the real impacts were less than predicted. The authors concluded that GIS was a valuable tool for evaluation of ground-water impacts.

Al-Garni, AM. 1996.
A system with predictive least-squares mathematical models for monitoring wildlife conservation sites using GIS and remotely-sensed data.
Int J Remote Sensing 17(13):2479–2503.

The author developed a GIS-based system that can use remotely sensed Thematic Mapper (TM) data to monitor conservation areas. The GIS had 12 thematic layers important for wildlife conservation. Only the results of the vegetation analysis are discussed in this paper. It had four modules: an input module, a static GIS module, a data manipulation module, and an output module. Data preparation took about 3 months. Although it is difficult to tell from this article, it appears the author used TM data to update information that was already in the GIS. The author corrected the TM data for partial coverage and ground-truthed them using reference maps. The system was used to examine time trends in the vegetation cover.

Anderson, JR; Hardy, EE; Roach, JT; Witmer, RE. 1976.
A land use and land cover classification system for use with remote sensor data.
Geological Survey Professional Paper 964, U.S. Government Printing Office.

This article describes a basic land-use and land-cover classification scheme for the nation that uses nine separate categories.

Anonymous. 1997.
Exploit the web with geomedia web map, 1997.
Global Link/Intergraph, Winter 1996, 2:8–9.

GeoMedia Web Map provides smart, vector-based maps in active CGM format for creating dynamic maps and data on the World Wide Web.

Anthes, GH; Blodgett, M. 1996.
States eye online revenues: debate rages over who can see what for how much.
Computerworld 30(34):26(1).

Cash-strapped state and local governments are struggling to move vast databases to online access and facing the question of whether to charge fees for the information. The city of Phoenix charges commercial users of its $8 million GIS full commercial rates ranging from $25 for one map to $36,000 for the entire database. Los Angeles has a controversial plan to sell electronic access to court records to commercial information resellers. The Information Industry Association and other critics say public information should be free or priced to cover incremental cost of delivery rather than sold at a profit. Most state governments offer access to numerous databases at little or no charge. One major concern is individual privacy; privacy advocates worry about the rush to make motor vehicle, real estate, and court records available to anyone with an internet account. States are beginning to consider restrictions on who can access sensitive information. This article includes related articles on methodologies and privacy issues.

Aral, MM; Maslia, ML; Ulirsch, GV; Reyes, JJ. 1996.
Estimating exposure to volatile organic compounds from municipal water-supply systems: use of a better computational model.
Arch Environ Health 51(4):300–309.

The authors review the use of certain tools to "evaluate exposure of populations via water-distribution systems." Specifically, the tools are a GIS along with census information and

spatial environmental analysis techniques. The study area was in Southington, Connecticut, at the Solvents Recovery Services of New England site. The contents of the article were largely beyond the understanding of this student. The article was useful as a learning resource to gain an understanding of how GIS is applied and not so much as instruction in this specific application.

Aronoff, S. 1989.
Geographic information systems: a management perspective.
WDL Publications, P.O. Box 8457, Station T, Ottawa, Ontario K1G3H8, Canada.

Chapter topics: An introduction to geographic information systems [examples of GIS applications]; What is a geographic information system? [components of a GIS, georeferenced data, spatial data]; Remote sensing [steps to analyze remotely sensed data, energy sources and radiation principles, sensor systems commonly used in rs]; Data input and output [data entry, remotely sensed data, existing digital data] data output [hardcopy devices, softcopy devices]; Data quality [components of data quality, sources of error, accuracy issues]; Data management [data base approach,three classic data models, components of geographic features, spatial data models]; GIS analysis functions [GIS analysis, GIS functions, organizing geographic data for analysis, classification of GIS analysis functions]; implementing a GIS; Conclusion.

Aronoff, S. 1995.
Geographic information systems: a management approach.
WDL publications, P.O. Box 8457, Station T, Ottawa, Ontario K1G3H8, Canada

Topics covered: Examples of GIS application to a variety of problems with color plates showing examples; What is a GIS, what is it made of (logical and specific), and why one would want to use it; People must be responsible for setting objectives for which the technology and techniques can be applied; Remote sensing key input to GIS; Easy introduction into the physics of remote sensing technology and sensor types; Discussion of satellite bandwidth available and uses for each, including absorption spectrum (p. 67), lambda satellite (p. 77), lambda coastal zone, and NOAA GOES (pp. 84, 85); Simplified discussion of microwave/radar remote sensing; Examples of classical remotely sensed data; Data input/output, with sample discussion of input techniques/technology and digital data available; Data management, with good (brief) discussion of different types of data models and their strengths and weaknesses relative to GIS; Introduction to basic nature of geographic data; Discussion of raster and vector data models; Extensive discussion of various data encoding schemes for each data model; and Discussion of data model integration and geographic data with tradeoffs of different approaches.

Aronoff, S; Ross, GA. 1982.
Detection of environmental disturbance using color areal photography in thermal infra-red imagery.
Photogrammetric Eng Remote Sensing 48(4):587–591.

Describes use of color infrared (CIR) imagery, thermal infrared (TIR) night imagery, and color photography for detecting environmental disturbances. For example, siltation was detected with normal color photos, vegetation quality and quantity with CIR, and oil-covered water with TIR.

Ashton, PJ; van Zyl, FC; Heath, RG. 1995.
Water quality management in the Crocodile River catchment, Eastern Transvaal, South Africa. *Water Sci Technol 32:201–208.*

South Africa's Department of Water Affairs and Forestry has moved from effluent standards to receiving water quality. The authors used a GIS (ARC/INFO) to integrate information on catchment characteristics, including geology, soils, vegetation, climatic patterns, population distribution, land use, and hydrological and water quality features. The system allowed identification of sources of water quality problems and prediction of potential negative water quality impacts. Particular problems have been seen associated with periods of low flow. They used the system to calculate environmental capacity, defined as the ability of a river and its users to tolerate elevated concentrations of specific water quality variables. An added advantage was the used of the GIS for displaying information to all interested parties.

Augustine, JA; Woodley, WL; Scott, RW; Changnon, SA. 1992.
Using geosynchronous satellite imagery to estimate summer-season rainfall over the Great Lakes. *J Great Lakes Res 20(4):683-700*.

The quality of Great Lakes hydrologic monitoring and forecasting depends on how accurately components of the water cycle are estimated. Precipitation is the most important factor, but there is no way to directly measure the rain that falls over the lakes. This is a serious problem because the water area represents one-third of the drainage basin. Here, satellite-based rain estimates were combined with rain gauge measurements to estimate summer lake rainfall. Hourly estimates were made from GOES imagery for the summers of 1988, 1989, and 1990, and accumulated monthly and over summer seasons. Area-averaged gauge-measured rainfall from local rain gauge networks were used to adjust the satellite-based estimates. Resulting best estimates of mean summer rainfall for Lakes Michigan, Superior, and Huron were 22.66, 23.83, and 18.80 cm, respectively. These mean summer values were 1–5 percent different from those computed using the shoreline-gauge technique, which is the current operational method for estimating lake rainfall. Estimates for individual summers were 1–17 percent different from those computed using shoreline gauges. Considering the gauge measurements as the standard, the mean absolute error of monthly gauge-adjusted lake rainfall was 21 percent, whereas the mean monthly error was only 2 percent. These results suggest that gauge-adjusted satellite estimates of rainfall could provide a useful measure of summer lake rainfall that may improve input to Great Lakes water balance and hydrologic prediction models. Other analyses were used to quantify the effects of the lakes on summer rainfall. Generally, they revealed lake-induced rain minima over and downwind of the lakes.

Bachman, W; Sarasua, W; Guensler, R. 1996.
Geographic information system framework for modeling mobile-source emissions. *Transportation Research Record, November, 1551:123–132.*

The authors determined that a GIS would be well suited to modeling mobile-source emission, because vehicle activities and their emissions can be correlated with specific points in time and space. Emissions could be aggregated into grid cells for input to an airshed model and improve understanding of emissions impacts. GIS displays and maps would improve communication with decision makers and with the public. A prototype of such a system was developed at Georgia Institute of Technology.

Backman, L. 1993.
Computer-aided liability.
Civil Eng 63(6):41–43.

The article discussed liability from the point of view of structural engineering. The article has points that apply to all aspects of computer usage, including GIS. Several examples are presented in which an engineer was held liable for faults created by defects in the software used. The author questions whether the software developer should share liability. The author points out that the design engineers, who are ultimately responsible, should take steps to ensure accurate use of the software and should always question the results of any analysis based on their past experiences.

Bagheri, S; Dios, RA. 1990.
Chlorophyll-a estimation in New Jersey's coastal waters using Thematic Mapper data.
Int J Remote Sensing 11(2):289-299.

Eutrophication, or enrichment, of the natural water in New Jersey's coastal waters has an adverse impact on the economic welfare of the state. Since shipboard sampling is not cost-effective for providing data on coastal/estuarine water processes and materials, satellite remote sensing, with is synoptic and repetitive coverage, is used to obtain some of the data for eutrophication-related water quality analysis. For the purpose of this study, existing LANDSAT-5 Thematic Mapper digital data, acquired on 1 September 1985, along with the sea truth observations, were obtained for quantitative analysis via GIS. The goal was to establish a correlation between total plankton content and remote sensing signals indicating the relative degree of eutrophy and productivity in New Jersey's coastal waters.

Bagheri, S; Stein, M; Zetlin, C. 1995.
Utility of airborne imaging spectroscopy and videography in nearshore waters.
Proceedings, 2nd Annual Marine and Estuarine Shallow Water Science and Management Conference,Atlantic City, NJ, April 3–7. U.S. EPA, Philadelphia, PA, p. 56.

The study investigates the utility of the Airborne Geophysical Environmental Research (GER) Imaging Spectrometer and XYbion MSC-02 multispectral video camera in hydrological feature extractions in nearshore waters. The test site is the New Jersey estuarine and coastal waters, where the multiplatform and multitemporal remotely sensed data have been investigated with the goal of developing a cost-effective operational monitoring system. Estuarine/nearshore waters are very complex, dynamic, and productive bodies of water. Their complexity makes them spatially and temporally heterogeneous. The spectral characterization of these waters is mainly produced by the organic (e.g., phytoplankton pigments), inorganic (suspended sediments) and dissolved organic matter (DOM). The airborne systems used here provide spectral coverage from 0.4 to 1.1 µm (GER spectral coverage is 0.4–2.5 mm), which is the only electromagnetic spectral range in which signals from hydrological volume are originated (i.e., originating below the surface and thus directly from the water column). Multisensor remote sensing with narrow bandwidth characteristics provides an important tool for monitoring, mapping, and management of the nearshore environment. Hydrologic optical measurements and theory have both confirmed that spectrometers should dramatically improve the ability to identify and measure important water quality parameters. Present work is focused on the evaluation of airborne sensors (GER and MSC-02) to improve both qualitative and quantitative assessments of water quality conditions.

Such developmental use will greatly aid the forthcoming transition to the next generation of spaceborne systems for nearshore ecosystem monitoring and management.

Baker, V. 1996.
The geological approach to understanding the environment.
GSA Today 6(3):41–43.

This article discusses the complementary nature of geology and mathematics and physics, as well as applications to environmental problems such as the U.S. Global Change Research program.

Baker, CP; Panciera, EC. 1990.
A geographic information system for groundwater protection planning.
J Soil Water Conserv 45(2):246–248.

The drinking water of Rhode Island is heavily reliant on ground-water, and a GIS approach to managing its protection and monitoring was developed. Several uses were already demonstrated. The GIS was used extensively to provide information to local and state officials. Hazardous waste programs allowed for GIS to incorporate contaminant locations and risks with other data. The GIS was also used to classify four types of ground-water resources to assist in priorities and strategies for management. Aquifer extent, community wellheads, urban land-use patterns, and nonpoint source concentration areas were of special significance in developing these four classes and subsequently making management decisions. An additional advantage of the GIS was that it provided a medium for communication and data sharing among state, local government, and university research cooperators.

Baker, CP; Panciera, EC. 1990.
A geographic information system for groundwater protection planning.
J Soil Water Conserv 45(2):246–248.

This is a description of the Rhode Island GIS applications (RIGIS) and how they are used in the planning and protection of ground-water resources.

Ball, WE; Hutt, ME. 1991.
Determination of three-dimensional coordinates for future land information systems.
GIS, Technical Papers, Vol. 4:1–10, ACSM–ASPRS Annual Convention, ACSM–ASPRS, Bethesda, MD.

The authors advocate using a true physically based three-dimensional reference frame in much of the Land Information System work. This sets out a logical case; it does not go into much detail.

Balogh, ME; Fisher, LT; Bailey, A; Lunetta, RS. 1992.
Application of GPS and aircraft multispectral scanner data to a Puget Sound intertidal habitat study.
Proceedings, SPIE International Society of Optical Engineering 1930(2), p.695.

This project investigated the use of remote sensing technology to inventory nearshore habitats of the Puget Sound area. The research was part of a comprehensive estuarine management program administered by the U.S. EPA, and was a cooperative effort between the EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV), EPA

Region 10, The Washington State Department of Natural Resources, and the Puget Sound Water Quality Authority. High-resolution, aircraft-borne multispectral scanner (MSS) data provided optimal data resolution for classifying habitats of the nearshore zone in Puget Sound. Nearshore habitats of Puget Sound, however, do not have natural or cultural features that can be used as ground control to georeference MSS imagery. Therefore, MSS data acquisition included simultaneous collection of Global Positioning System (GPS) data. GPS data collected during MSS data acquisition provides accurate geopositional information at all times, and were used to rectify MSS image data to Earth coordinates. MSS imagery and GPS data were collected over the Commencement Bay area near Tacoma, Washington, in July 1991. Collection of field data also involved the use of GPS. Field experts in marine and estuarine nearshore habitats visited representative habitat types, recorded site positions with GPS, and characterized each site by substrate type, vegetation, and orientation to Puget Sound. Field data were used to assist identification of surface features visible on the MSS imagery and as data for conducting accuracy assessments. Use of GPS technology during collection of field data ensured geopositional accuracy of reference data for image analysis and verification data for assessing accuracy of MSS classifications.

Barnes, S. 1996.
Abundant harvest: managing Willapa's renewable resources.
Geo Info Sys 6(2)15–21.

Willapa Bay, in the southwestern portion of Washington state, is considered by many to be one of the cleanest estuaries in the continental United States. The Willapa ecosystem, approximately the size of Rhode Island, includes an estuarine bay covering 88,000 acres and 600,000 acres of watershed. The bay provides abundant natural resources, including timber, oysters, and fisheries, in addition to fertile soils. In 1992, local residents allied to find an effective means of stewarding the natural resources on which their local economy depends. The Willapa Alliance, formed to lead this effort, turned to GIS as a method to map and analyze the resources within the watershed. Once the initial database was completed, it could be used for a variety of applications. With the terrestrial data, the fisheries technical team is using a dataset to prepare a salmon recovery plan. The Alliance is also monitoring the spread of non-native grasses and their effect on native species. With the immense database in place, the data will certainly be used for many more applications in the future.

Barnes, S. 1996.
Northwest flood '96: GIS in the face of disaster.
Geo Info Sys 6(4):22–25.

In February, the Pacific Northwest endured its worst flooding in decades. During the disaster, agencies enlisted a variety of technologies to keep the public informed and to assess and map infrastructure damage. GIS technology was used to assess road damage in order to communicate the information to the public quickly. Public works crews assessed and mapped bridge and road safety status. The data were downloaded to AutoCAD software and then rolled into ARC/INFO. After overlaying the high water coverages on existing public works layers, the GIS team quickly mapped the infrastructure damage and provided that information to the police for road and bridge closure decisions and sign postings. These technologies are being used to help assess the devastation and plan for millions of dollars in damage repair yet to come. The region is also using SPOT satellite imagery to prepare a regional recovery plan, as well as using

GIS to re-evaluate their 100-year flood plain, which may be revised to a 20-year flood plain. The Oregon State Board of Forestry requested a study to determine why the flood caused so much damage to roads, bridges, and culverts. The agency hopes the study will help it to understand the effect of logging, road building, and other activities and to find constructive solutions to the problem.

Barrett, EC; Curtis, LF. 1992.
Digital data handling.
Introduction to environmental remote sensing, 3rd ed., Chapter 9. Chapman and Hall, NY, NY and London.

This contains helpful diagrams and pictures chosen from a number of papers. It ends with a section on remote sensing and GIS.

Barton, G. 1997.
NOAA and the federal geographic data committee.
Earth Syst Monitor 7(3):1–14.

An Executive Order was passed by President Clinton requiring that federal agencies participate in the National Spatial Data Infrastructure (NSDI). The Order encompasses policies, standards, and procedures with which organizations are to cooperatively produce and share geospatial data. The vision of the NSDI Strategy Document is: "Current and accurate geospatial data will be readily available to contribute locally, nationally, and globally to economic growth, environmental quality and stability, and social progress." Three major objectives were called for (1) creation of a distributed electronic network of data producers and users, known as the National Geospatial Data Clearinghouse; (2) development of standards for data documentation, collection, and exchange; and (3) promotion of procedures and partnerships to create a national digital geospatial data framework that would include important basic categories of data significant to a broad variety of users. The Federal Geographic Data Committee (FGDC) is the focal point for NSDI activities and leadership with the other sectors. The FGDC has developed a metadata standard for data descriptions and data transfer standard. The FGDC was awarded the National Performance Review "Hammer" Award.

Bates, T. 1996.
Cluster illustrates need to update cancer registry.
Asbury Park Press, Neptune, NJ, March 17, page 1.

The article discusses the need to combine the State of New Jersey's cancer database with a GIS in order to determine if and where clusters of cancer cases may occur within the state. The New Jersey Department of Environmental Protection was reported to have been developing a GIS that "maps environmental conditions and other land-use data" but the system had yet to be combined with the cancer registry for further analysis. The article was of interest because it provided a clear example of how public health goals and GIS technology can be linked.

Bates, T; McEnery, R. 1996.
Computer to begin crunching cancer data.
Asbury Park Press, Neptune, NJ, May 17, page 14.

This article builds from the article reviewed immediately above. This article, published 2 months after the previous one, reported the news that the state of New Jersey would soon begin the implementation phase of a project that would allow analysis of cancer data within a GIS.

Battaglin, WA; Goolsby, DA. 1996.
Using GIS and logistic regression to estimate agricultural chemical concentrations in rivers of the midwestern USA.
Proceedings, HydroGIS '96: Application of Geographic Information Systems in Hydrology and Water Resources Management, April,Vienna, Austria. IAHS Pub. no. 235, pp. 253–260.

The authors used logistic regression models to investigate empirical relationships between various drainage basin variables and the concentration of selected agricultural chemicals (alachlor, atrazine, cyanazine, metolochlor, nitrate) in 134 midwestern watersheds. GIS was used to manage and display information on county-level estimates of landuse, chemical use, crop acreage, livestock basin area, population density, hydrological soil variables, runoff, and hydrological parameters. In most cases, variables were normalized by dividing by basin area. The overall accuracy of the logistic regression models averaged about 66 percent. Results demonstrated a strong association between the concentration of selected chemicals in rivers and the amount of these chemicals used within associated drainage basins. Models that used crop land estimates worked nearly as well as the agricultural chemical use estimates which are harder to come by. Soil parameters were significant in most models. Pig density and basin topography also contributed predictive power.

Bauer, K. 1996.
Creating integrated rural resource land information systems.
J Soil Water Conserv 51(1):29–33.

In 1983, the National Resource Council proposed procedures and standards for design and implementation of land-related data systems. A multipurpose land information system is an integrated, land-related data bank of continuous, easily available, and comprehensive information for land-related resource management. The Natural Resources Conservation Service is developing a Computer-Assisted Management and Planning System (CAMPS). With local land information systems, CAMPS can provide maps, tabular data, and land-related records as a multipurpose, land-related information database.

Bazzani, M; Cecchi, G; Pantani, L; Tirelli, D; Alberotanza, L. 1995.
Venice Lagoon monitoring by a fluorescence lidar.
Proceedings, 1995 International Geoscience and Remote Sensing Symposium, Part 3, pp. 1735-1737.

The Venice Lagoon is a particular environment where a coastal lagoon hosts the Venice town, industries, and a large traffic harbor. Tidal movements provide the main water exchange between the lagoon and the open sea. In this situation, continuous monitoring of the water quality is necessary to control pollution phenomena, which sometimes reach dramatic levels, for example, sudden algae blooms. A fluorescence lidar was installed aboard a lagoon-boat, to perform remote fluorescence measurements together with traditional monitoring and in situ sampling all through the Venice Lagoon. In addition, continuous monitoring at a fixed station in the central part of the Venice town (Canal Grande) was carried out during a tidal phase. Water turbidity, dissolved organic matter, and pigment content were inferred from the lidar spectra. Turbidity was compared

with in situ measurements, showing a good agreement. The last part of the experiment deals with the airborne lidar monitoring of this particular site, during which significant results have been obtained.

Belton, W. 1995.
The mapping program at the U.S. Forest Service Geometronics Service Center.
Cartography and GIS 22(2):135–139.

In managing the national forests to support sustained, multiple-use activities, the U.S. Forest Service (USFS) must consider the often divergent needs of wildlife, fisheries, and outdoor recreation, as well as timber, mining, and grazing concerns. By emphasizing an ecosystem management approach, the USFS is planning to incorporate all uses of forest lands into the planning process, which will expand the area of interest to include adjacent federal, state, and private lands. Accurate, current maps and digital spatial data are essential for effective management. Land managers are now relying more on GISs to address these issues and to support their decisionmaking processes. There is an increased demand for digital data, primarily for base cartographic data to which thematic resource data can be registered. New environmental concerns, the emphasis on an ecosystem approach, and the introduction of GIS throughout the USFS will increase the need for quality digital and spatial data. The Geometronics Service Center (GSC) is responsible for producing the base maps to meet this requirement. The GSC will continue to develop modernized production processes to meet customer needs, maximize production, and reduce duplication.

Bergen, SD; Fridley, JL; Ganter, MA; Schiess, P. 1995.
Predicting the visual effects of forest operations.
J Forestry 93(2):33–37.

As a case study, the state of Washington Department of Natural Resources (DNR), performed a viewshed analysis on a tract of forested land scheduled for harvesting. The DNR used a GIS to identify areas at risk of visual degradation from harvest activities proposed in an actual management plan. ARC/INFO 6.1.1 was used with the Digital Terrain Model (DEM) to establish elevation and grid coordinates. Results of the study indicate that viewshed analysis is relatively easy to perform and uses reasonably available technology and data. Field verification is also encouraged.

Bevis, M; Bock, Y; Fang, P; Reilinger, R; Herring, T; Stowell, J; Smalley, Jr., R. 1997.
Blending old and new approaches to regional GPS geodesy.
EOS 78(6):61–66.

This article discusses the use of high precision global positioning system (GPS) geodesy, and, in particular, the Multimodal Occupation Strategy (MOST), to construct regional GPS networks by the continuous and campaign approaches.

Beyers, N; Gie, RP; Zietsman, HL; Kunneke, M; Hauman, J; Tatley, M; Donald, PR. 1996.
Epidemiology: the use of a geographical information system (GIS) to evaluate the distribution of tuberculosis in a high-incidence community.
TB Weekly, 11 March, ISSN: 1065–982X.

The article reported on the author's abstract for the study "Epidemiology: The Use of a Geographical Information System (GIS) to Evaluate the Distribution of Tuberculosis in a High-

Incidence Community." The study setting was two suburbs in the Western Cape portion of South Africa. The study mapped the incidence of tuberculosis down to individual residences using a GIS and the National Population Census for 1991, along with the health data. The conclusion states: "In a small area with a high incidence of tuberculosis, the cases are spread unevenly through the community and there are certain houses where tuberculosis occurs repeatedly. This information should be used to direct health services to concentrate on certain high-risk areas." This article was of interest because it gave an example in which GIS could be used to help establish an outreach strategy for targeting a population at risk.

Biagi, B; Pozzana, G. 1994.
A GIS-based information system for the assessment of the variations in the environment load, owed to changes in socio-economic factors.
European Geographic Information Sytem, Proceedings, EGIS '94, March, Paris, France. Utrecht, Netherlands:EGIS Foundation, pp. 642–651.

The concept for using a GIS to develop a decision support system is presented. This application would use mathematical models to identify changes in the quality and quantity of the flows of resources and pollution between the socioeconomic and environmental systems. Environmental loads could be located and compared with Italian laws.

Bian, L. 1997.
Multiscale nature of spatial data in scaling up environmental models.
In: Quattrochi, DA; Goodchild,, ME, eds. Scale in remote sensing and GIS. Boca Raton, FL:CRC Press, pp. 13–26.

This article looks at the effects of "scaling up" (data aggregation) on modeling and shows how semivariant fractal analysis can assist in forecasting the appropriate extent of scaling up appropriate to a particular model. Four connotations of scale are discussed: (a) *cartographic (or map) scale*–larger scale produces more detail; (b) *geographic scale (extent, domain)*–spatial extent of study area; (c) *resolution (grain; related concept: sampling intervals)*–size of the smallest distinguishable part of a spatial data set; smaller units are of finer scale, larger units of coarser scale; and (d) *operational scale*–scale at which a phenomenon operates, e.g., a forest operates at a larger scale than does a tree.

Bingner, RL. 1996.
Runoff simulated from Goodwin Creek Watershed using SWAT.
Trans Am Soc Agric Eng 39(1):85(6).

The GRASS GIS was used to develop input parameters in applying the deterministic Soil and Water Assessment Tool (SWAT) simulation model to the Goodwin Creek Watershed in northern Mississippi. Fourteen nested subbasins are simulated independently and daily, and annual runoff trends are predicted.

Blersch, D. 1997.
The national polar-orbiting operational environmental satellite system (NPOESS).
Earth Syst Monitor 7(3):5–16.

For the first time, the U.S. government is taking an integrated approach to identify and meet the operational satellite needs of both the civil and national security communities. Military and civil operational meteorological satellite systems will merge into a single national system. It is

expected to provide more than $450 million in savings through 2003. NOAA, DOD, and NASA created an Integrated Program Office to develop, manage, acquire, and operate the National Polar Orbiting Operational Environmental Satellite System (NPOESS). NPOESS will provide standard meteorological data and oceanographic, environmental, climatic, and environmental remote sensing information, as well as continue to provide surface data collection and search and rescue capability.

Bliss, NB; Reybold, WU. 1989.
Small-scale digital soil maps for interpreting natural resources.
J Soil Water Conserv 44:30–34.

This paper describes a pilot study (Chesapeake Bay watershed) that was conducted by the USGS and SCS to investigate how data can be used in a GIS and to explore potential mechanisms for archiving and distributing the data. The authors present a fairly detailed description of the process they used to link soil attributes to soil maps. This paper is useful to help design studies using GIS methods.

Bohard, E; Bohard, J. 1995.
Defining rural and resource lands in a rapidly urbanizing county.
Urban and Regional Information Systems Association, Proceedings, URISA 95, San Antonio, TX, July 16–20, 1:744–753.

This project used a GIS to identify and categorize land uses. This study of viable rural and resource lands arose from Washington's growth management legislation. It supports my conclusion from reading the following article that there are many opportunities for sharing GIS natural resources data.

Borstad, G. 1992.
Ecosystem surveillance and monitoring with a portable airborne imaging spectrometer system.
Proceedings, SPIE International Society of Optical Engineering 1930(2), pp. 883-892.

The paper describes a portable and extremely flexible airborne remote sensing system that allows rapid analysis in the field and ability to interact effectively with ecologists. Operating with local pilots and small unspecialized aircraft, the system fills the gap between satellite imagery and air photography. The central instrument of the system, a Compact Airborne Spectrographic Imager (CASI), can be used as a 288-band spectrometer for algorithm development, and as a multispectral imager to provide any 15 visible and near infrared spectral bands with spatial resolution down to 2 m or less. Other auxiliary sensors, such as thermal radiometers, can also be recorded simultaneously on an auxiliary 386 computer. GIS-compatible data are available within a few hours. The instrument package and processing facilities can be mobilized within 48 hours for use anywhere in the world. Because of its high spatial resolution and the ability to either fly under cloud or in weather-windows, the system has many uses in monitoring and mapping of coastal zones. Users can quickly reconfigure the spectral bands to optimize measurement and delineation of targets having different spectral signatures. In post-flight image processing, the analyst uses algebraic operators, color ratios, and multispectral classification to quantitatively map environmental parameters such as water quality (suspended sediments, phytoplankton chlorophyll-a, oil slicks, and effluent plumes), near-surface fish schools, and many types of vegetation in subtidal and intertidal areas, as well as in estuaries and wetlands.

Bostater, C. 1992.
Remote sensing methods using aircraft and ships for estimating optimal bands & coefficients related to ecosystem responses.
Proceedings, SPIE International Society of Optical Engineering 1930(2), pp. 1051-1062.

A solid state spectrograph has been used to obtain reflectance signatures for assessing ecosystem responses to changes in environmental quality. The methods use signatures to distinguish submerged aquatic vegetation (SAV), coral species and condition states (dead vs. live), and biochemical parameters such as chlorophyll-a and total suspended matter (seston). Examples are provided from various ecosystems and water types (CASE I ocean, CASE II coastal). Optimal bands for assessing seston are described in detail. The optimal region for seston appears to be centered where solar induced fluorescence (SIF) occurs based on SAV's, specific coral types, and high chlorophyll-a waters. Estimation of chlorophyll therefore necessitates normalizing the chlorophyll signal to the seston signal when this region is used to estimate chlorophyll-a when bands in the SIF region are used to estimate chlorophyll-a. Application of shipborne and airborne spectroscopy is a valuable tool for monitoring ecosystem changes related to global change issues and for calibration of algorithms from satellite data.

Bottcher, DB; Hiscock, JG. 1996.
GIS watershed assessment model for Suwannee River Basin.
Proceedings, Watersheds 96–-Moving Ahead Together: Technical Conference and Exposition, June 8–12, Baltimore, MD.

The overall objective of the GIS watershed assessment project is to identify and develop specific criteria and assessment algorithms that reflect the relative impacts of land use, soils, hydrography, and wetlands on the discharge water quality, wetlands value, and flooding impacts. Two methods were developed for this project. The first provides spatial assessment using impact indices, and the second utilizes hydrologic and contaminant transport modeling. The method used depends on the parameter of interest. The indexing approach is used for assessment parameters (BOD, coliform bacteria, and toxins) that are hard to quantify or are not directly associated with pollutant transport, while the modeling approach addresses the major pollutants of sediment and nutrients.

Bourgeois, PE; Robb, SC; Summers, JK; Macauley, JM. 1997.
EMAP's estuary program: interagency efforts to develop master database.
Geo Info Sys 7(2):14–18.

Through an interagency agreement between the U.S. EPA and U.S. National Biological Service, GIS technologies are used to support the Environmental Monitoring and Assessment Program (EMAP)–Estuaries program within the Louisiana Province. GIS technology is used to help illustrate the locations and sizes of estuaries, boundaries of the estuarine drainage areas, and locations of sampling stations during a 4-year period (1991–1994). USGS 1:100,000 digital line graph (DLG) hydrology data layer maps and NOAA coastal charts contributed to the estuary base map.

Bowen, WM; Salling, MJ; Kingsley, EH; Cyran, EJ. 1995.
Toward environmental justice: spatial equity in Ohio and Cleveland.
Ann Assoc Am Geographers 85(4):641–663.

The authors examine the spatial association between race, several measures of income,

and toxic emissions from TRI facilities in both Ohio and Cuyahoga County. For the Ohio analysis, the unit of analysis was the county. The census tract was the unit of analysis for Cuyahoga County, which was selected for study because it is Ohio's most industrial, urban, and populous county. They evaluate both the total poundage and an aggregated measure of the toxicity of TRI releases to various media and offsite. It is difficult to tell if they have used GIS in this analysis, because they do not specifically say they do. However, they discuss establishing the typology of TRI-site census tracts, and they provide several choropleth maps showing countywide TRI emissions as well as tract percentages of minorities overlaid with TRI release types (i.e., to air, land, water). They also provide choropleth maps showing total releases and toxicity of releases by census tract, overlaid with railroad tracks, in Cuyahoga County. (Well, if they didn't use GIS, they should have!) The authors concluded that their results provide little evidence of inequities based on TRI emissions and minority populations. When evaluating spatial associations at the state level, they found statistically significant correlations between minority densities and toxic release amounts, which they attribute to the confounding fact that industries, minority populations, and toxic releases tend to concentrate in urban areas. They caution that results at this level of aggregation (i.e., county level) could be misleading and therefore should not be used for environmental equity analyses. The part of the analysis that used census tract data for Cuyahoga County actually showed that minority density was inversely correlated to toxic chemical releases, and the TRI's were more likely to be located in poorer tracts than in minority-dominated tracts. The authors feel that use of census tracts is more appropriate for environmental equity analyses.

Brewer, CA; MacEachren, AM; Pickle, LW; Herrmann, D. 1997.
Mapping mortality: evaluating color schemes for choropleth maps.
Ann Assoc Am Geographers 87(3):411–438.

Criteria are described and evaluated for selecting colors for choropleth maps of mortality data. Results of this study indicate that emphasis on color in mapmaking is worth the effort, because it allows greater accuracy in map reading. The authors found that spectral schemes were effective if designed to include diverging lightness steps suited to the logical structure of the mapped data. The authors' goal was to develop a set of color schemes that would allow users with color-vision impairments to interpret maps accurately. (The color version of this article is more useful than the black-and-white.)

Brown, DG; Walsh, SJ. 1991.
Compatibility of non-synchronous in-situ water quality data and remotely-sensed spectral information for assessing lake turbidity levels in complex and inaccessible terrain.
GeoCarto Int 6(2):5-12.

Multiple regression modeling was used to estimate lake turbidity levels in Glacier National Park, Montana, USA, using LANDSAT Thematic Mapper digital data and nonsynchronous in situ turbidity data. Variations in model form and components were investigated to exploit spectral/biophysical relationships described in the literature and to accommodate local site and situation conditions. Because of limitations inherent in using nonsynchronous in situ and remote sensing data in GIS, the derived models explained lower levels of turbidity variance compared with models developed for other studies in other environments. Unique local conditions contributed to the model performance. Nonparametric tests of correlation and significance were

used because of these inherent limitations. Lake turbidity rankings secured through various GIS-linked models were relatively insensitive to changes in model form.

Brown, S; Schreier, H; Thompson, W; Vertinsky, I. 1994.
Linking multiple accounts with GIS as decision support system to resolve forestry/wildlife conflicts.
J Environ Manage 42(4):346–364.

This paper discusses the effectiveness of combining habitat suitability maps with operable forest maps of the zone between two national parks in British Columbia. The degree of wildlife/logging conflicts in the region is established through the use of GIS, combined with multiple accounts methods and resource databases, in assessing alternative management scenarios pertaining to forest resources. The sensitivity analysis in British Columbia helped to identify areas with rich timber resources, thereby helping to establish economic usefulness by comparing different harvesting scenarios with various wildlife constraints.

Brown, S; Schreier, H; Thompson, WA; Vertinsky, I. 1994.
Linking multiple accounts with GIS as decision support system to resolve forestry/wildlife conflicts.
J Environ Manage 42(4):349(16).

The Terrasoft GIS, with additionally incorporated topography, hydrology, forest inventory, and road network information, was used to evaluate wildlife suitability, model forest growth and yield, and model harvesting costs and values in the Tangier watershed in British Columbia. Timber production constraints resulting in maximal high-quality caribou habitat were identified.

Bui, EN; Smettem, KR; Moran, CJ; Williams, J. 1996.
Use of soil survey information to assess regional salinization risk using geographical information systems.
J Environ Qual 25:433–439.

This Australian study involved integration of hydrology, hydrogeology, and soil and land management in order to estimate risk of salinization after tree clearing in a river basin of the wet/dray tropics of Northern Queensland. The GIS themes included soil survey information, water resources data, and elevation data. The data related to soils included soil-landform relationships, parent material, soil thickness, depth to bedrock, and soil type. These factors were used to estimate drainage classes and permeability and to determine likely recharge or discharge areas. Cross-checking was accomplished through surveyed electrical conductivity measurements. The study determined that where total soluble salts are >0.25 percent and the water table was <6 m deep, a salinity hazard exists. The GIS was also used to calculate the amount of increased recharge likely to occur after tree clearing. The results also suggest that clearing may increase deep drainage by up to 10 times and that in areas of salinity risk, trees should not be cleared.
Bui, EN; Smettem, KRJ; Moran, CJ; William, J. 1996.
Use of soil survey information to assess regional salinization risk using geographical information systems.
J Environ Qual 25:433–439.

The authors use a GIS to identify areas at risk of salinization after tree clearing. Tree clearing alters water balances, increases deep drainage and increases phreatic water tables. Salt

stored in soil is remobilized and precipitated close to the ground surface if the new water table is less than 2 m deep. The objectives of this study were to identify potential ground water recharge areas and saline discharge areas, and to identify areas at particular risk. Watersheds with high salinity hazard are those with shallow ground water and saline soils. Conversely, areas with deep ground water and nonsaline soils have a low salinity hazard. Assessing risk requires an estimate of the likelihood and amount of recharge to ground water after tree clearing. This was done qualitatively based on a series of hydraulic equations. Potential recharge and discharge areas identified based on permeability and drainage classes were consistent with the spatial distribution of saline soils. Risk could only be assessed qualitatively. However, the system will be useful in evaluating tree-clearing permits.

Bullard, RD. 1994.
Overcoming racism in environmental decision making.
Environment 36(4):10–27.

The author is one of the prominent champions of the environmental justice movement. Although this article does not cite GIS specifically, the application of GIS has contributed to many of the points and conclusions concerning incidence of disease or citing of chemical plants and the demographic characteristics of an area. The article discusses "geographic equity," which refers to the location and spatial configuration of communities and their proximity to environmental hazards. One point the author makes is that "communities with hazardous waste incinerators generally have large minority populations, low incomes, and low property values." There are many clear examples of GIS applications in this article.

Burke, L. 1993.
Race and environmental equity: a geographic analysis in Los Angeles
Geo Info Sys 3(9):44–50.

The main purpose of the study was to determine whether race is a significant factor in the relationship with industrial facility locations when the effects of other important variables, such as income level and population density, have been controlled. The author used 1990 census data at the tract level for Los Angeles County, and locational data on more then 700 TRI's located in the county. The author selected the census tract as the unit of analysis based on the likely zone of effect surrounding TRI's and the fact that this unit is consistent with the spatial accuracy of the TRI data. GIS was used for data integration and exploration and for displaying results of statistical models. GIS was used for determining the number of TRI's and members of the different demographic groups in each census tract for subsequent statistical analyses. The results showed that race was a consistent and important variable in the relationship with TRI occurrence in a census tract. On average, there was a direct correlation between the number of TRI's in a census tract and the percentage of the minority population. There was an inverse relationship between the number of TRI's and both the population density and per capita income. Because race and income are both significant, and highly correlated, variables, this study could not conclude whether income or race was the more important explanatory variable in the relationship with TRI occurrence.

Burrough, PA. 1986.
Principles of GIS for land resources assessment.
Oxford University Press, New York, NY.

Chapter topics: Geographical information systems [reasons to use computers in cartography, cargography, components of a GIS]; Data structures for thematic maps [basic topological concepts, data base structure, raster and vector data structures]; Digital elevation models [models representing DEMs]; Data input, verification, storage, and output; Methods of data analysis and spatial modeling [a general approach to map overlay, advantages and disadvantages of cartographic modelling in land evaluation and planning].

Burrough, PA. 1986.
Data quality, errors, and natural variation.
Principles of GIS for land resources assessment, Chapter 6. Oxford University Press, New York, NY, pp. 103–121.

This chapter discusses the errors and variations that may arise from geographic information processing, from natural variation, or from original measurements, and other obvious sources. Obvious sources of errors include age of data, partial areal coverage, map scale, density of observations, relevance, format, accessibility, and cost. Errors resulting from natural variation or from original measurements include positional accuracy, accuracy of content, measurement error, laboratory error, field observer error or bias, and local spatial variation (impurities). Errors that arise through geographic information processing include numerical errors in storing and processing the data, topological map overlay, and classification and generalizations. Other errors may arise from rasterizing a vector map, overlaying spatial networks, and digitizing a map.

Burrough, PA. 1986.
Principles of GIS for land resources assessment.
Oxford University Press, New York, NY..

An excellent text that discusses in more detail than Aronoff=s book the theory of GIS and the associated information and analyses.

Burrough, PA. 1986.
Geographic information systems.
Principles of GIS for land resources assessment, Chapter 1. Oxford University Press, New York, NY, pp. 1–11.

The first chapter provides an introduction to maps and spatial information. It provides a history of the need for maps. Hand-drawn maps were expensive and resource intensive and developing GIS would help to improve mapmaking and spatial analysis. The chapter describes the history and progression that led to the development of GIS. Components of GIS include computer hardware (e.g., digitizer, plotter, central processing unit, disk drive, tape drive), application software modules (e.g., software for data input, storage, management, output, transformation), and organizational context (e.g., how it will be used, staff training, data gathering, management).

Carne, J; Allard, M. 1996.
Ireland rings in the changes: Irish utility re-engineers its network asset management.
Geo Info Sys, June, 6(6):24–32.

With deregulation looming, resulting in the need for a competitive advantage, Telecom Eireann is engineering a new way to manage its assets. By integrating computer-aided design (CAD) and GIS, the company has developed a system to maintain underground and overhead

telephone cable networks in hopes of improving its line maintenance, records management, and service to its 750,000 customers in rural Ireland. This "geo-engineering" system will make a single database of CAD and GIS data accessible to all personnel. The long-term future of Telecom Eireann's project is sparking much interest throughout the company for activities such as work-order scheduling, network planning, performance monitoring, and sales and plant maintenance. The geo-engineering system's simple database will make this information accessible to all, and give the company a competitive advantage.

Cary, T. 1994.
A world of possibilities: remote sensing data for your GIS.
Geo Inf oSys 4(8):38–42.

A recent study of the GIS and remote sensing markets identified data availability as the foremost issue affecting the use of remote sensing imagery. And, although many geographic databases could benefit from the use of satellite data, fewer than 20 percent of GIS users now take advantage of this resource. Many are hesitant to build a GIS with satellite imagery because they fear the data will not always be accessible. This article describes the volume of commercially available remotely sensed data, along with a variety of plans for future satellite systems, which are designed to keep the data coming. Current systems include LANDSAT, SPOT, ERS–1, JERS–1, IRS–1, Russian Reconnaissance photos, and MOMS. Future satellites include Lewis and Clark, RADARSAT, Worldview, Space Imaging, Eyeglass, and Seastar.

Chacon-Torres, A; Ross, LG; Beveridge, MCM; Watson, AI. 1992.
The application of SPOT multispectral imagery for the assessment of water quality in Lake Patzcuaro, Mexico.
Int J Remote Sensing 13(4):587-603.

A predictive model of water quality variables was developed for SPOT-1 imagery, and applied to Lake Patzcuaro, Mexico. With use of principal component analysis it was shown that, at most, two water quality variables, suspended solids and chlorophyll-a concentration, can be derived from the SPOT data. Having established the independent predictiveness of a set of empirical relations between the SPOT data and the water quality variables, the whole lake was analyzed using GIS to reveal the spatial distribution of suspended solids and chlorophyll-a. It was revealed that a very serious algal bloom had occurred. No bloom of such intensity has ever been observed before or suspected to have occurred in Lake Patzcuaro. The applicability of SPOT imagery to water quality monitoring was clearly demonstrated.

Chakraborty, J; Armstrong, MP. 1994.
Estimating the population characteristics of areas affected by hazardous materials accidents.
Proceedings, GIS/LIS, '94, October, Phoenix, AZ. pp. 154–163.

This article describes the application of GIS to identify intersections and neighborhoods most likely to be impacted by truck accidents in Des Moines, Iowa. The authors modeled the movements of chlorine gas from a truck accident in order to determine what areas might be affected. They identified the 50 intersections with the most truck accidents. They concluded that more minority and low-income households were likely to be impacted by such accidents than the city as a whole.

Chang, K; Verbyla, DL; Yeo, JJ. 1995.

Spatial analysis of habitat selection by Sitka black-tailed deer in southeast Alaska, USA. *Environ Manage 19(4):579–589.*

The authors used GIS to analyze Sitka deer habitat usage. The base map was based on aerial photographs. Soil types were related to plant communities using look-up tables. The predicted plant communities were verified using ground truthing. The locations of deer were determined based on telemetry. The vector-based GIS was used to (1) compute the proportion of each vegetation class within a polygon, (2) compute edge categories and distances, and (3) compute the distance of each deer relocation point to the old-growth/clear-cut edge. The authors compared the estimated values with either random values, or average values for the whole area. They concluded that (1) deer selected ranges having some clear-cut and some old growth, with a higher proportion of clear-cut area than the entire study area, and (2) deer tended to relocate within 400 m of the old-growth edge.

Chang, K-T; Verbyla, DL; Yeo, JJ; Li, Z-X. 1994.
GIS-based program aids wildlife habitat and timber management.
GIS World 7(1):40(4).

GIS technology was applied to the study of Sitka black-tailed deer in a logged forest of southeastern Alaska, thus aiding in the management of both habitat and timber resources. The vector-based GIS was used to manipulate spatial and attribute characteristics, and it was interfaced with peripheral programs for sampling, statistical analysis, and habitat analysis. Area, line, and point analysis of deer distributions within old- growth forests showed that deer preferred the borders between old growth and open clearcuts. Rapid growth in these clearcuts, however, quickly discourages deer habitation.

Chen, YD; McCutcheon, SC; Carsel, RF; Norton, DJ; Craig, JP. 1996.
Enhancement and application of HSPF for stream temperature simulation in the upper Grande Ronde watershed, Oregon.
Proceedings, Watershed '96, June 8–12, Baltimore, MD, pp. 312–315.

The authors describe a model to estimate the contribution of riparian vegetation buffers and topography to stream surface shade. Model inputs include incoming solar radiation, stream width, topographic shade angles in 12 directions, and location and nature of riparian vegetation (e.g., height and canopy density). Model outputs include solar radiation adjusted for riparian shading effects, and a shading factor, which is the ratio of total radiation and the radiation reaching the stream. The output is used in the Hydrologic Simulation Program-FORTRAN (HSPF) to predict stream temperature. ARC/INFO was used to divide the Grand Ronde watershed into relatively homogenous units so that the model could be applied and tested. Comparison with stream temperature monitoring verified that the model is accurate to 2.8° C. The model will be useful for identifying stream reaches for riparian restoration and preservation.

Cheng, MS. 1994.
User-friendly GIS aids in flood management. Prince George's County Department of Environmental Resources.
Water Environ Technol, April, 6(4).

Flood management and water quality study efficiency has been increased in Prince George’s County, Maryland, through the use of GIS-based models. Using TR-55, TR-20, and HEC-2, the county was able to analyze many "What ifs" scenarios to determine the best flood management alternative. GIS was also used to analyze water quality on a watershed basis.

Based on this information, 41 watersheds were prioritized for development and implemented within a watershed plan.

Cheng, Y. 1996.
The conformal space projection.
Cartography Geo Info Sys 23(1):37–50.

The author presents a new conformal space projection (CSP) for satellite imagery display. Compared with previous projections, it has these advantages: (1) it is a truly conformal projection, (2) the scale error is very small, (3) it can continuously display satellite imagery, (4) it is widely applicable to different satellite orbits, (5) it can easily integrate projection computation with orbital computation, (6) its computation is fairly straightforward, and (7) it provides a new concept in developing special space projections. The problem has traditionally been that as a satellite moves along its orbit, the Earth rotates too. The combination of tracking a satellite from the ground (which is also moving) is a very complicated curve, that, in general, cannot be expressed in an analytical formula. Theoretically, the oblique Mercator can only keep a fairly simple line, which is found by the intersection of the Earth's surface with a plane passing through the center of the Earth free from any distortion. The author argues that his new CSP is superior to past projections and supports his claims mathematically with a number of equations.

Chernin, PR. 1995.
Demonstrating watershed protection using GIS.
J North Eastern Water Works Assoc 109:132–139.

Relying on water treatment as the sole measure of protecting the water supply may not be sufficient. Exotic chemical and biological contaminants may not be treatable; high costs are associated with treating turbidity, nutrients, and organic compounds. Watershed management may provide another way to achieve quality water supplies. "GIS is so useful for watershed protection because of its ability to integrate, create, manage and map information that brings to life the natural and manmade characteristics of watershed and the relationships between them." Chernin discusses the utility of GIS in several areas: understanding watershed and water quality characteristics; mapping geographic areas to be protected; identifying buffers for wells, reservoirs, or tributaries; identifying and locating current and potential threats to water supplies; establishing clear legal authority for programs; public education; and implementation and enforcement.

Cherrill, A; Lane, M. 1994.
The survey and prediction of land cover using an environmental land classification.
Appl Geogr 15(1):69–85.

The objective of the study is to identify land-use research as the development of methods of assessing the implications of alternative economic policies and integrating the social, physical, and life sciences in a multidisciplinary approach. A field survey of the entire catchment was recognized as being prohibitively demanding of time and labor. The solution adopted was to record in the field the areas of NCC Phase 1 cover types within a stratified sample of grid squares and extrapolate from these data to predict the distribution of the cover types in unsurveyed areas. The 182 field survey maps were digitized using the ARC/INFO GIS. Results included land- cover estimates, lowlands, marginal uplands, and uplands. Comparison with independently obtained land-cover data has shown this approach to be capable of providing reliable estimates of the overall land-cover compositions of large geographical regions.

Chestnut, L. 1995.
Human health benefits assessment of the acid rain provisions of the 1990 Clean Air Act amendments of 1990.
Final Report, EPA Contract 68-D8-0005 of Work Assignment 2F-03 and 3F-12. November 10, 1995.

The assessment used atmospheric modeling results that were provided in an 80x80 km concentration grid. The modeling results were overlaid on census data using GIS (Mapinfo) to evaluate the exposure and make predictions of health effects. Chapter 3 focused on sulfate, and Section 3.3 describes the matching with population data in detail.

Choubey, VK. 1994.
Monitoring water quality in reservoirs with IRS-1A-LISS-I.
Water Resources Manage 8(2):121-136.

An attempt has been made to quantify the relationship between the variation in IRS-IA-LISS-I (Indian Remote Sensing Satellite-1A Linear Imaging Self-Scanning System) radiance data and field measured change in Secchi disc depth. Secchi disc depth was measured for 47 predetermined sampling locations on reservoir surface water. At extinction depth (Secchi depth [SD]), water samples were collected from all the sampling locations. Suspended sediments of eight locations representing various reaches of the reservoir were selected for mineralogical, particle size, and optical properties analysis. The LISS-I radiance value in band 1 (0.45-0.52 μm), band 2 (0-52-0.59 μm) and band 3 (0.62-0.68 μm) were used in a regression analysis. The absorption infrared band 4 (0.77-0.86 μm) was not included in the analysis. In these, the dependable variable was SD, and the LISS-I-radiance data were the estimator variable. Forty-seven data sets of 20 October 1988 from Tawa reservoir surface water were used to obtain an estimator equation for SD. The verification of the estimator equation was tested by applying it to a data set of 21 measurements of 28 September 1988 for this reservoir. The coefficient of correlation between observed and estimated values for the 28 September 1988 data set was r = 0.92 for SD, indicating that the equation could accurately predict the water clarity (SD) for this reservoir on new occasions from IRS-IA-LISS-I spectral data. It is shown that mineral composition and optical properties of suspended sediments influence the reflected radiance of water quality. It was concluded that IRS-IA-LISS-I data provide a useful means of mapping water quality in reservoirs.

Chuvieco, E; Salas, J. 1996.
Mapping the spatial distribution of forest fire danger using GIS.
Int J Geo Info Sys 10(3):333–345.

This paper presents a methodology for fire danger mapping using GIS. Our purpose was to map the spatial distribution of the different components used in this system, as well as to integrate them in a simple index. Chosen variables included topography, fuel types, and human activity. Refinements to previously developed methodologies: the inclusion of illumination, texture, weather data as variables. The study area is 150 km west of Madrid. Indexes used include the Weather Danger Index, Fuel Hazard Index, Fire Incidence Index, and Human Risk Index. All these variables were included in a raster GIS with a 30x30 m grid resolution. The methodology in this paper offers a simple approach to obtain fire danger maps, by considering the spatial distribution of factors affecting the start or spread of a fire. Actual implementation may be done in a few weeks, using low-cost software.

Civco, DL; Garcia, AR; Warner, GS. 1995.
Key steps to effective watershed characterization.
GIS World 8(11):62(5).

Watersheds are characterized to link physical characteristics to water quality indicators. The characterization process includes managing data on land management and cover, geology, soil, hydrology, and topography. These data are best managed and expressed using a geographic information system. Four basic steps compose the characterization process: the establishment of a primary objective, the search for and acquisition of general data, the selection of target watersheds using a multistep process, and the final characterization. Some of the parameters include geomorphology, stream network, geology, relief, soils, and climate.

Clark, Y; O'Bara, C; George, D. 1997.
Demonstrating a holistic approach to identifying and costing needs on a watershed basis: a national demonstration study. Cookeville, TN: Center for the Management, Utilization, and Protection of Water Resources. http://www.tntech.edu/www/acad/wrc/projects/wqi/index.html

An ARC/INFO GIS system used in conjunction with three models (AGNPS, MODFLOW, and HSPF) was used to provide a scientifically based tool for local citizens for watershed planning purposes. Watershed water quality was assessed using the above software along with comprehensive field validation. A watershed quality index was developed to assist in prioritizing subwatersheds for actions required. Based on the information derived from the analysis, cost were developed for work required for each watershed.

Clarke, KC, McLafferty, SL; Tempalski, BJ. 1996.
On epidemiology and geographic information systems: a review and discussion of future directions.
Emerg Infect Dis 2(2):85–92.

This article promotes use of GIS in epidemiology. The author cites the changes in software that make GIS now more accessible. He notes the long history that relates to mapping disease occurrence, such as relating cholera cases to water source, and brings the reader up to the present. The tasks GIS can contribute to are visualization, exploratory data analysis, and model building. Model building makes use of the multiple layers of data that GIS can now model to test hypotheses about causes of disease and transmission.

Clayton, DG; Bernardinelli, L; Montomoli, C. 1993.
Spatial correlation in ecological analysis.
Int J Epidemiol 22(6):1193–1202.

The term *ecological analysis* is used here from an epidemiological perspective–the analysis of environmental covariates of disease. The authors modeled spatial autocorrelation in terms of the pattern of adjacencies of areas. The objective was to develop an empirical model of disease. The dependent variable is the standardized mortality rate, which is the number of observed events (e.g., lung and lip cancers) divided by the expected number of events from reference rates. The explanatory variables include the degree of urbanization, determined from principal components analysis and the percentage of men employed in industry. The authors split the error term in two, one that varies spatially, and the other that is random. The spatial error was assumed to be distributed normally, with the mean given by the mean of the neighboring values. When the location variable was confounded with the explanatory variable, the regression

coefficient decreased. The authors concluded that this effect does not outweigh the advantages of including a spatial autocorrelation error term.

Clifford, PA; Barchers, DE; Ludwig, DF; Sielkens, RL; Klingensmith, JS; Graham, RV; Banton, MI. 1995.
An approach to quantify spatial components of exposure for ecological risk assessment.
Environ Toxicol Chem 14:895–906.

Estimating ecological risks from contaminants in the environment requires accurate characterization of the exposure of organisms to toxic materials. Since organisms integrate contaminate exposure over space and time, estimating exposure concentrations that correspond to actual exposure concentrations is difficult. GIS technology is used to quantify exposure. A map of the surficial concentrations of dieldrin was determined using Thiessen polygon procedures (ESRI) with a single sample location for each polygon. Polygons were also created using a triangular network (TIN) using all data points. Animal habitat ranges were identified and were characterized by exposure circles (specified area or radius) around each sample point. Thus risk was determined from the overlapping of the exposure circles and the soil concentrations. This paper is difficult to summarize in limited space. A time factor was also incorporated into this assessment. This paper provides good ideas on how to use different functions with a GIS package (ARC/INFO).

Connor, MS. 1992.
Remote sensing as a marine monitoring tool: the local perspective.
Proceedings, SPIE International Society of Optical Engineering 1930(1), pp. 281-291.

Marine water quality monitoring includes assessment of the public health status of beaches and shellfishing areas, validation of water quality models, assessment of the effectiveness of pollution abatement programs, and verification of the compliance of marine discharges with water quality standards. Marine monitoring programs in the United States have been estimated to cost between $100 and $200 million annually (1985 dollars). Federal agencies account for 43 percent of the total, state and local agencies 37 percent, and the private sector 18 percent. The challenge of designing environmental monitoring programs is to relate the basic concerns of the citizenry with environmental parameters that scientists can actually measure. Generally, the public's concerns can be grouped under four basic questions: Is it safe to swim? Is it safe to eat the fish and shellfish? Are the marine resources healthy? Has the aesthetic quality been preserved? For the most part, these four simple questions are not directly answerable by any specific measurement, but require a series of measures that point in the direction of an answer. The benefits of remote sensing for monitoring are similar to those of any new technology that has the potential to yield a basic understanding of a marine ecosystem. Recent critiques of various marine environmental monitoring programs indicate that too many of these programs collect extensive amounts of scientific data that are nearly impossible to interpret. The risk of remote sensing is that future monitoring programs will collect astronomic amounts of scientific data that are poorly related to the questions the public wants answered at a specific project. The promise of remote sensing will depend on its value in elucidating oceanic and estuarine processes that can be related statistically to the public's basic concerns.

Conry, T; Hushon, J; Goldberg, J; Kneeling, K. 1995.
Integrating operational and environmental data in an air force base-wide GIS.

Fed Facil Environ J 6(3):9–20.

A basewide GIS is being implemented at Vandenberg Air Force Base to merge planning, environmental, engineering, and operational functions. The GIS is intended to aid civil engineering and environmental personnel in coping with increasing legal mandates to manage, monitor, restore, and protect natural and cultural resources on the base, and to plan for and manage its built environment. Steps in GIS development for the military complex are detailed.

Conway, K. 1996.
Wolf recovery: GIS facilitates habitat mapping in the Great Lakes states.
GIS World 9(11):54–57.

GIS is being used by scientists in the Great Lakes region to aid wolf recovery planning. Gray wolf recovery projects face continued challenges locating favorable habitat and managing recovery programs. GIS was used to map previously unidentified areas of favorable wolf habitat in Michigan and Wisconsin. After digitizing locations and movements of 14 Wisconsin wolf packs, researchers generated "home range" polygons for each of the packs. They then analyzed current wolf habitat using land-use/land-cover datasets and developed a model to predict additional habitat. In the second phase, researchers estimated potential numbers of wolves that could occupy the identified habitat areas. They also overlaid areas of land management responsibilities for different agencies with the map of favorable habitat. The GIS allowed the Wisconsin Department of Natural Resources to integrate existing data, giving wildlife managers new information to apply toward wolf recovery efforts. The model is being applied in the northeastern United States.

Cook, D; Symanzik, J; Majure, JJ; Cressie, N. 1997.
Dynamic graphics and GIS: more examples using linked software.
Comput Geosci 23(4):371–385.

This fascinating article describes how ArcView 2.1 GIS software was linked to XGobi, software used for graphical analysis of multivariate to allow dynamic interaction between spatially displayed data in ArcView and graphically displayed data in XGobi. The user simply "brushes" subsets of the graphed data in XGobi and the corresponding data are highlighted on the linked ArcView map. The article gives five illustrative examples of possible types of analysis: (1) Scatter plots to map displays: This is illustrated on attribute data reflecting the residential desirability of 329 U.S. cities, where an XGobi scatterplot of climate vs. housing costs is linked to a map showing the corresponding locations of any U.S. cities whose scatter points are "brushed." (2) Spatial cumulation distribution functions linked to map: This is illustrated using a SCDF for forest damage, where the top 10 percent of the SCDF is brushed, causing the corresponding geographic locations to be highlighted on the ArcView map. (3) Variogram cloud linked to map: The variogram used in this example shows variation in precipitation values for a calendar quarter vs. distance separating the paired receptors. Brushing those points having high variation but close distance results in the ArcView map being highlighted at points surrounding a receptor on top of a mountain. (4) Lagged scatter dotplots from ArcView data are linked to XGobi scatter plots: A dotplot of distance between precipitation sampling points is linked to a scatter plot. Then three spatial lags (0, 20, and 40 km) are brushed on the dotplot and the scatter plots of third vs. fourth quarter precipitation are created to see if there is a correlation (or lack of correlation) dependent on lag distance. (5) Multivariate variogram cloud link: Angle between sampling sites from

ArcView is linked to XGobi multivariate variogram to detect asymmetries in scatter.

Corbley, K. 1996.
Utah finds biodiversity gaps using GIS.
Geo Info Sys 6(2):32–36.

In 1989, the U.S. Fish and Wildlife Service began an ambitious GIS development project–the Gap Analysis Program (GAP)–aimed at mapping the distribution of major vegetation cover types and terrestrial vertebrate animal species across the entire United States. The overall goal of the program is to protect ecosystems while the species that inhabit them are still common, which many conservationists consider a more economic and efficient approach than attempting to save species after they become endangered. In GAP, 40 states build statewide GIS databases that are combined in a central GIS, allowing ecosystems to be examined from a continental perspective. The Utah GAP information has been presented to state officials, who have drafted legislation for introduction in Congress to protect some federal lands in the state by giving them Wilderness Area status.

Corbley, KP. 1996.
One-meter satellites: practical applications by spatial data users. Part 3.
Geo Info Sys 6(7):39, Supplement..

One-meter satellite imagery will provide both a quality and quantity of geographic information currently unavailable from spaceborne remote sensing. GIS experts say that high-resolution images will expand their use of this information greatly. Users say that detecting and identifying small features in imagery becomes substantially more valuable in practical applications if the features can be located with a high degree of absolute and relative accuracy. For agricultural purposes, high spatial resolution and timely revisits are two capabilities that will make remote sensing an operation factor in precision farming. Accuracy has become an important issue in precision farming because variable rate technology (VRT) now allows farmers to apply precise doses of chemical or water to small grids in the field. Variations within a field must be identified by the farmer very quickly for the situation to be remedied with precision arming practices. In operational mode, the farmer would need the interpreted imagery available within 48 hours of acquisition by the satellite. Space Imaging is the only 1-meter system developer to announce a price. It plans to offer orthorectified images with 1.5 meter accuracy for $100 per square mile.

Corvaisier, P; Pignon, J. 1997.
Land and freedom.
GIS Europe 6(3):30–31.

This article recalls the basis of the districts in Paris, the commune, and discusses the process of developing an “urban information system” for the 10 communes of Paris. Great graphics in the article illustrate the complexity of the information being gathered. Each commune has its own GIS equipment to manage cadastral and land-use records. Other information is being added on utilities, pipelines, traffic, waste disposal, etc. Describes coordination among a variety of users to create a system that serves many needs.

Corwin, DL; Wagenet, RJ. 1996.
Applications of GIS to the modeling of nonpoint source pollutants in the Vadose Zone: a conference overview.

J Environ Qual 25(3):403–411.

This article provides an overview and review of nonpoint source pollutant modeling and briefly discusses some of the papers presented at the 1995 Bouyoucos Conference: Applications of GIS to the Modeling of NonPoint Source Pollutants in the Vadose Zone. An extensive bibliography is provided with this overview.

Cowan, DJ; Jensen, JR; Halls, J. 1991.
Maintenance of TIGER files using remotely sensed data.
GIS, Technical Papers, Vol. 4. ACSM–ASPRS Annual Convention, Bethesda, MD, pp. 31–40.

This article describes what the TIGER roads are like. TIGER images of a network of roads in suburbs northwest of Columbia, SC, are overlaid with four different sets of satellite imagery. Of these the 5x5 m resolution NASA CAMS helps more efficiently with better placement.

Cruz-Batres, C; Lovas, L. 1996.
InfoCAD–Geographical information systems for environmental management.
J Environ Manage Technol 1(2).

This article compares the use of InfoCAD, a GIS program by Digital Matrix, Inc., to programs like ArcView, but does not relate it to its use for environmental management. Many typographical errors were found in the article, but many good features were described that would improve the operation of ArcView.

Csillag, F. 1997.
Quadtrees: hierarchical multiresolution data structures for analysis of digital images.
In: Quattrochi, DA; Goodchild, ME, eds. Scale in remote sensing and GIS. Boca Raton, FL:CRC Press, pp. 247–271.

This article presents the following sequence of ideas: (1) Explains traditional quadtrees and gray-scale image quadtrees where each successive (parent) level is the average of the grayscale rating of the preceding (children) level; (2) Presents the concept of residual variability as a quality descriptor of quadtree representation. Residual variability is the variance in grayscale between the current partition and a finer resolution representation; (3) Describes the HQ-decomposition (Haar-Quadtree) procedure as a means of evaluating not just overall residual variability but also spatial distribution of variance. HQ-decomposition uses high-dimension vector representations (e.g., in R^{64} space) to capture the spatial distribution of grayscale; (4) Presents the nested analysis of variance way to analyze the Haar coefficients obtained in the HQ-decomposition in order to evaluate the "gain in explaining heterogeneity" resulting from the decomposition. The nested ANOVA can then be employed to guide the most advantageous routes along the quadtree to reduce heterogeneity inbetween levels of resolution. Aim: decrease the within-unit variance as fast as possible; (5) Proposes a sampling approach based on HQ-decomposition; (6) Compares results of sampling based on HQ-decomposition; and (7) Gives real-world examples.

Csillag, F; Kertez, M; Kummert, A. 1996.
Sampling and mapping of heterogeneous surfaces: multi-resolution tiling adjusted to spatial variability.
Int J Geo Info Sys 7:851–875.

This article describes a method for the approximation of two-dimensional surfaces by optimizing sample size, arrangement, and prediction accuracy simultaneously. A grid of ancillary data is approximated by a quadtree to determine a predefined number of homogeneous mapping units. The ancillary data are obtained from satellite images. Samples are taken from each mapping unit. The performance of this sampling was compared against other sampling strategies (regular and random). This was an interesting paper but difficult to follow. Keywords: GIS, kriging, Thiessen-polygonization, sampling strategies, sampling quadtrees, sampling efficiencies, noisy data, semivariograms.

Dangermond, J. 1996.
Geobusiness in the utility industry–it's time.
Geo Info Sys 7(7):7–9.

A recent surge in GIS-related technology development presents important new opportunities for using automated mapping/facilities management (AM/FM/GIS) tools, especially in the utilities business. The introduction of GIS technology into the utility industry began with the use of the technology chiefly for automated mapping functions. Over time, GIS has also been applied to engineering, and more recently to work-order workflow efforts. The growing business uses for GIS are now reaching the utility industry, including market analysis, environmental monitoring and analysis, long-term business planning, and regulatory compliance. Organizations that embrace this trend early will have a competitive advantage because the development of these systems will take time. Deregulation and the resulting need to be more competitive and efficient will be served by the further development of the AM/FM/GIS in the future.

Dangermond, J. 1997.
ARC/INFO: moving right along.
ARC News 18(4):1–3.

The president of ESRI, which makes ARC/INFO, wrote this very positive article about the ARC/INFO software. He states that ARC/INFO for Windows NT was an instant success and that they are now shipping version 7.1. This version includes "CAD-like" editing functions in the ARCEDIT feature. When ARC/INFO version 7.2 comes out, all the components and engines of version 7.1 will be exposed for use with standard permitting tools. This means the ARC/INFO can be completely embedded within a non-GIS application.

Daniels, RC. 1996.
An innovative method of model integration to forecast spatial patterns of shoreline change: A case study of Nags Head, NC.
Prof Geographer 48(2):195–209.

Many coastal erosion models are designed to be used at transects or discrete points, but produce valid results only for locations meeting a specific set of criteria. Results obtained from such models are thus difficult to generalize. This paper describes a GIS-based methodology to combine the results from different types of coastal erosion models to forecast possible responses of a coastline to several alternative sea-level rise scenarios. These forecasts are unique in that they integrate results from different models and allow alternative future shoreline projections. This model is important for coastline planners in that the forecasts can be used to assess possible impact on sea-level rise on a given region. Planners will be able to develop strategies to identify and mitigate many adverse impacts of coastal change combined with other factors such as

population, land use, and land cover in site selection analysis.

Danielson, T. 1997.
Top news stories reflect industry.
GIS World 10(8):34.

This article describes five trends in the GIS industry: market consolidation and curtailment, GIS interoperability, satellite technology expansion, data delivery diversification, and use of GIS in the Federal government. This article describes where the industry is headed in software development and applications that involve a variety of operating systems. In addition, there are descriptions of current GIS applications in military operations in Bosnia.

Davis, K; Miller, RL; von Zweck, O; Sprague Jr., VG; Kilroy, R; Sommers, J. 1995.
In-situ optics system for coastal ocean color monitoring.
Proceedings, 1995 IEEE/MTS Oceans Conference, San Diego, CA, October 9–12, Vol. 3, pp. 1787-1793, Piscataway, NJ:IEEE Publishers.

A recent transition of several naval operations to coastal environments has emphasized the need for regional- to basin-scale maps of water clarity. Data integrated from in situ and remotely sensing instruments were required to provide these maps. A specially designed vertical profiling system is the primary source of in-water optics data for the Naval Oceanographic Office. Optical measurements include radiance, irradiance, transmission, and absorption at multiple wavebands as well as light scattering at 880 nm. Select physical parameters such as temperature and salinity are also measured. A single controller manages both power and data transmission for all instruments. Data are transmitted to a PC GIS-based data acquisition/display system. The profiling system was recently modified to include the spectral wavelengths of the SeaWiFS ocean color instrument. The optics profiling system will collect sea-truth data for calibrating and validating ocean color instruments in coastal waters.

Decker, D; Seekins, R. 1997.
Creating a statewide digital base map: the Texas Orthoimagery Program.
Surveying Land Inf Sys 57(1):23–30.

This article describes the staged program initiated by the Texas GIS Planning Council to support the development of color infrared digital orthophoto quarter quadrangles (DOQQs) statewide as an up-to-date common base map for a wide array of GIS applications. The article defines a DOQQ as "an accurate digital image, with all distortion removed, from which spatial data (i.e., roads, hydrology, land cover) can be derived. In a DOQQ image, which is usually derived from aerial photography, the image is scanned and individual pixels are assigned to cell locations on a meter grid that corrects distortion due to elevation differences (this involves using digital elevation models [DEMs]) and ground control information is used to place the resulting image in its real-world location. The ground control is also used to remove distortion from the flight." The article presents the history of the project, which was set in motion when a "Base Map Development Resolution" was adopted by the GIS Planning Council. The article then explains the data required, funding and program participants, the vendor selection process, and the steps involved in producing a DOQQ. The latter is illustrated in a production flowchart. Products, data distribution, and future plans are then described.

Dekker, AG; Malthus, TJ; Hoogenbroom, HJ. 1995.

The remote sensing of inland water quality.
In: Danson, FM; Plummer, SE., eds. Advances environmental remote sensing. John Wiley, New York, NY.

For a short article (about 10 pages) this contains many fundamental ideas and numerous references. Discussion includes upwelling or downwelling irradiance, mixing zone pattern finding, and trying to sense constituents of the water column.

Dekker, AG; Malthus, TJ; Wijnen, MM; Seyhan, E. 1992.
Effect of spectral bandwidth and positioning on the spectral signature analysis of inland waters.
Remote Sensing Environ 41(2–3):211-225.

Airborne and satellite remote sensing systems (PMI/FLI, LANDSAT-Thematic Mapper, and SPOT-HRV) were used to assess their potential for inland water quality detection and monitoring. Airborne imaging spectrometry was acquired. Simultaneous (sub)surface spectroradiometric and laboratory-based spectrophotometric measurements allowed the description of the underwater lightfield through determination of the inherent and apparent optical properties. Spectral signature simulation of various systems increased understanding of the performances and led to development of the CAESAR Inland Water Mode spectral bandset. These results apply to the operational use of high-resolution airborne systems (CASI) and are relevant for future satellite systems such as MERIS, MODIS, and HIRIS, especially in the area of data reduction through selection of spectral bands and development of algorithms.

DeMers, MN. 1997.
The map as a model of geographic data: the language of spatial thinking.
Fundamentals of geographic information systems, Chapter 3. John Wiley, New York, NY, pp. 50–82.

This chapter focuses on maps and how they are used to represent entities (real-world objects) and their attributes. First, maps are models of real-world phenomena and therefore abstractions of reality. Characteristics of maps include scale (amount of reduction of spatial objects) and map legend (which unites entities with their attributes). The chapter discusses map projections (converting the three-dimensional Earth to a two-dimensional map), which can be broken down into four families: planar, cylindrical, conical, and azimuthal, and their distortions. To determine distance and direction, a grid system is used, such as the cartesian coordinate system or the universal transverse Mercator (UTM) system. The chapter also discusses the disadvantages of scale change and feature elimination, such as loss of detail and loss of data.

DeMers, MN. 1997.
Data storage and editing.
Fundamentals of geographic information systems, Chapter 6. John Wiley, New York, NY, pp. 154–176.

This chapter identifies types of errors and how to find and correct them. The three basic types of errors are entity error, attribute error, and entity-attribute agreement error. The latter two are more difficult to find than the former. The chapter describes entity errors, which include pseudo nodes (false nodes), dangling nodes (open polygon, overshoot and undershoot, missing labels or too many labels, sliver polygons, and weird polygons [polygons digitized in the wrong place or order]). These errors are among the easiest vector mistakes to find. Raster and vector can both have attribute error; types of attribute error include missing attributes and incorrect

attribute values. Incorrect attribute values are very difficult to find, more so in vector than raster. The most common source of attribute error is failure to keep track of the attributes as you type them in, thus causing the attributes to be misplaced and matched with the wrong entities. Other sources of error can be caused by edge matching and converting between Cartesian coordinates and real-world coordinates.

DeMers, MN. 1997.
Introduction to automated geography.
Fundamentals of geographic information systems, Chapter 1. John Wiley, New York, NY, pp. 3–18.

This chapter provides an overall background and introduction to geographic information systems. It describes the history of development of GIS and offers different definitions and names for GIS. The definition the authors choose "resembles the way GIS operates as a series of subsystems within a larger system." It also compares and contrasts computer assisted drafting (CAD), computer assisted cartography (CAC), and GIS.

DeMers, M. 1997.
Zoological maps.
Fundamentals of geographic information systems. John Wiley, New York, NY, pp. 75.

Mapping of animal locations and species ranges using GIS technology has been limited. Problems arise in defining point locations for estimated actual locations and for aggregating points to produce areas. Choosing an appropriate solution depends on knowing the subject animal's behavior.

DeMers, MN. 1997.
Cartographic and GIS data.
Fundamentals of geographic information systems, Chapter 4. John Wiley, New York, NY, pp. 83–121.

This chapter discusses types of data file and database structures and the advantages and disadvantages of each. Data file structures include simple lists, ordered sequential files, and indexed files (direct files or indirect files). With each successive structure, there is improvement in speed for conducting a search; however, there is increased complexity in organizing and planning for the files. Computer database structures include hierarchical, network, and relational. The two ways to graphically represent data are raster (grid) and vector (point data). Disadvantages of raster are reduced spatial accuracy and large storage capacity. Vector data allow for more detail and representation of data. The chapter also discusses how to compact raster and vector data to reduce storage space.

DeMers, MN. 1997.
GIS data input.
Fundamentals of geographic information systems, Chapter 5. John Wiley, New York, NY, pp. 125–153.

For vector data input, digitizers can be used; factors that determine the usefulness of a digitizer include stability, repeatability (precision), linearity, resolution, and skew. Scanners, another data input device, have two types: line-following and drum scanners. Transformations of GIS data coverages include translation, rotation, and scale change. The chapter provides

guidelines on how to digitize and how to avoid errors during digitizing. These guidelines are summarized as (1) define your purpose, (2) make sure the map addresses the purpose, (3) use the most accurate maps needed for the purpose, (4) keep your coverages small, (5) use the same map to obtain simple coverages to avoid georeferencing them, and (6) most importantly, think about your project before inputting the data. The chapter also discusses methods for raster input, such as presence/absence method, centroid-of-cell method, dominant type method, and percent occurrence, and the uses of remote sensing as raster data input.

DeMers, MN. 1997.
Spatial analysis: the foundation of modern geography.
Fundamentals of geographic information systems, Chapter 2. John Wiley, New York, NY, pp. 21–49.

This chapter helps the reader better understand spatial language and data. The types of spatial objects used are points, lines, areas, and surfaces. These can be presented spatially on a map, but some data that help to describe the spatial objects (name, age, etc) cannot be displayed spatially and are called attributes. Spatial data can be measured at different levels: nominal (name), ordinal (ranked), and interval/ratio (numbers). Spatial patterns or relationships can be characterized through a measure of proximity, spacing, orientations, and associations. The chapter also covers various methods for collecting data, such as direct sampling and probabilistic sampling.

Denning, J. 1993.
Small-government GIS.
Civil Eng 63(6):52–54.

The article presents three case studies discussing the multiple applications of GIS for a single (i.e., town, government) entity. The system has helped to streamline administrative and design aspects of the different services within the small government entity. Areas where GIS is used include design and road maintenance, providing information for planners and developers, developing stormwater management programs, and examining water main problems in terms of water pressure or firefighter capabilities. The biggest problem encountered is standardization of data.

Denning, R. 1996.
GIS and hydrologic modeling in watershed management.
Proceedings, Watersheds '96–Moving Ahead Together: Technical Conference and Exposition, June 8–12, Baltimore, MD.

A GIS was used to generate the necessary data layers and parameters used in models to examine the relationship between land-use changes in recent decades and the increased stormwater runoff associated with those changes. Aerial photography from 1963 and 1993 was used to interpret land-use/cover data. Zoning information was used to predict conditions in 2020. Using a GIS, the TR-55 Runoff Curve Number Method was applied to the watershed for the three target years. This project has shown that one of the most serious water quality problems is that of water quantity.

DePinto, JV; Atkinson, JF; Song, J; Cheng, C; Slawecki, T; Rodgers, PW. 1996.
Development and application of a coupled GIS-modeling system for watershed analysis.

Proceedings, Watersheds '96 , June 8–12, Baltimore, MD, pp. 896–899.

The authors describe the Geo-WAMS modeling support system, which was designed to develop and apply water quality models in Great Lakes watersheds. The model is demonstrated for quantifying the relationship between sources of BOD and the distribution of dissolved oxygen in the Buffalo River. It combines a watershed loading model (WLM) with WASP4/EUTRO4. The system was designed to ease the tedium associated with converting output from one model to appropriate format and spatial/temporal scale for use as input for the next model. ARC/INFO was used to store, generate, and retrieve input data; for calculating pollutant loads; and for displaying the resulting output. The authors also used the GIS linkage to display the output of the EUTRO4 model as a spatial animation. Geo-WAMS will be useful in making assessment about relative impact of different source management scenarios on oxygen in the river.

Deysher, LE. 1993.
Evaluation of remote sensing techniques for monitoring giant kelp populations.
Proceedings, Fourteenth International Seaweed Symposium. Hydrobiologia 260:307-312.

Photographs and maps of the floating canopy of the giant kelp provide an important data source to monitor nearshore water quality in southern California. Declines in water quality related to turbidity from coastal development, ocean discharges, and nonpoint source runoff have caused reductions in the areal extent of these kelp beds. Historically the kelp beds have been monitored by a variety of methods including small format infrared and color photography. New digital remote sensing instruments combined with GIS databases offer an efficient method for collecting and analyzing data on changes in kelp bed size and location. SPOT satellite imagery has been found to provide adequate resolution for mapping the larger beds of giant kelp along the California coast. Beds smaller than 10 ha are not resolved well with SPOT imagery and need to be mapped with a resolution greater than the 20 m pixel size provided by the SPOT multispectral imagery. Imagery from a prototype of the Positive Systems ADAR system, an airplane-mounted multispectral video sensor, provided a spatial resolution of 2.3 m in four spectral bands. ADAR imagery taken on 2 October 1991 of the San Onofre Kelp Bed in northern San Diego County showed 39 percent more kelp than did small-format color infrared photography made during the same time period.

Dierberg, F. 1991.
Feasibility of using remote sensing platforms as an aid to water quality monitoring in the Tennessee Valley. Capabilities and costs.
Publications of the Tennessee Valley Authority, TVA/WR/WQ-91/8.

Remote sensing devices, which include satellite- and airborne-mounted sensors (fluorosensors, imaging spectrometers, multispectral video, and scanners), were evaluated according to their availability and technical, operational, and economic features for water quality monitoring in Tennessee Valley Authority (TVA) reservoirs. Optical and electronic advances and lower capital costs have resulted in sensors that are more real-time oriented, user-interactive, flexible, portable, accessible, spectral/spatially resolved, and affordable than what had been available. Two airborne sensors, the Airborne Multispectral Measurement System (AMMS), manufactured by Xybion Electronic Systems Corp., and the Compact Airborne Spectrographic Imager (CASI), manufactured by Itres Research Limited and marketed by G.A. Borstad Associates Ltd., possess the cost and technical aspects to be seriously considered for acquisition by TVA. Either would add considerable capability to TVA's efforts of mapping turbidity,

transparency, chlorophyll, suspended solids, and aquatic macrophytes in reservoirs.

Dierberg, FE; Carriker, NE. 1994.
Field testing two instruments for remotely sensing water quality in the Tennessee Valley. *Environ Sci Technol 28(1):16-25*.

Two airborne remote sensing systems, the Compact Airborne Spectrographic Imager (CASI) and the Airborne Multispectral Measurement System (AMMS), were field-tested over reservoirs in the Tennessee River Valley during the summer of 1991 and the winter (AMMS only) of 1992. Univariate, linear regression analyses using ratioed wavelength bands and line height algorithms for radiance (CASI) or reflectance (AMMS) in the 625-725 nm wavelength range provided the best correlations to ground-truthed uncorrected chlorophyll-a (R^2 = 0.84-0.95) for both imaging systems during the summer when phytoplankton dominated the suspended solids composition. For the winter flight, using the AMMS system 3-4 days after a major rain event, reflectance in the 690-710 nm range was correlated to turbidity and suspended solids concentrations (R^2 = 0.79-0.85). High correlations between imaged data and chlorophyll in July-August and inorganic turbidity in February-March demonstrate the feasibility of using low-cost imaging spectrometers and multispectral video cameras from fixed-wing aircraft.

Dikshit, AK; Loucks, DP. 1995–96.
Estimating nonpoint pollutant loadings. I: A geographical-information-based non-point source simulation model.
J Environ Sys 24(4):395–408.

This article is the first in a two-article series. A geographical-information-based model, the Cornell Non-Point Sources simulation model (CNPS) has been developed to help planners identify, analyze and simulate the impacts of alternative land-use management policies and practices on nonpoint source pollutant loadings. It simulates hydrologic, erosion, and nonpoint processes using spatial data from GIS. The model can be used to (1) simulate erosion and runoff, sediment, and the pollutant loadings at the watershed outlet, (2) provide nonpoint water quality constituent loadings from a watershed to stream water quality model for comprehensive in-stream modeling, (3) analyze the runoff quantity and quality for different land-use management alternatives, and (4) study the relative changes in water quality of receiving water bodies associated with changes in land uses.

Dobson, AP; Rodriquez, JP; Roberts, WM; Wilcove, DS. 1997.
Geographic distribution of endangered species in the United States.
Science 275(5299):550–553.

Biodiversity is a term currently used to describe the variety of living things and their relationships to each other and interactions with the environments. Geographic distribution data for endangered plants, bird, fish, and mollusc species in the United States were used to locate hot spots of threatened biodiversity.

Dohner, E; Donahoe, S; Solomon, P. 1996.
An integrated approach to ecological restoration using GIS.
Proceedings, Watersheds '96–Moving Ahead Together: Technical Conference and Exposition, June 8–12, Baltimore, MD.

GIS can be a useful tool for developing cost-effective and ecologically comprehensive

restoration strategies. Long-term success relies on integration of watershed characteristics such as percentage of impervious surfaces, erosion rates, sediment yield, condition of riparian habitat, nutrient loadings, PS discharge, and potential effects of current or future development. Databases accessed to support the investigation include stream classifications, habitat assessment scores, biological community assessment scores, cross-sectional streambed profiles, and water quality data. Correlation analyses can be used to relate physiographic parameters to parameters that reflect the condition of biological communities.

Drummond, WJ. 1995.
Extending the revolution: teaching land use planning in a GIS environment.
J Plan Educ Res 14(4):280–291.

Use of GIS in professional planning applications has increased at an explosive rate over the past decade, resulting in what some have termed a "quiet revolution." The real value of this GIS revolution will not be evaluated based on the number of GIS courses offered by planning educators, but by the acceptance of the technology by the profession. At present, use of GIS technologies for land-use planning is still relatively new. A general, modular strategy for incorporating GIS technology into land-use planning coursework is described that utilizes a combination of GIS, database, and spreadsheet software. Several examples are included to illustrate the benefits of this approach.

Dutton, G. 1997.
Encoding and handling geospatial data with hierarchical triangular meshes.
In: Kraak, M; Molenaar, M; Fendel, E., eds. Advances in GIS research. Proceedings, Seventh International Symposium on Spatial Data Handling. London: Taylor & Francis, pp. 505–518.

This article is by one of the originators of an octahedral Quaternary Triangular Mesh (O-QTM) approach for digitizing the global surface. The paper begins with a survey of the history (going as far back as the 15th century) of attempts to model the Earth as a polyhedron. It then compares and quantifies the advantages and disadvantages of using different polyhedral shapes (e.g., tetrahedron, octahedron, icosahedron, and truncated icosahedron) to develop a triangular mesh on a sphere. The remainder of the article looks at the author's work using the O-QTM to handle and visualize data in a hierarchical triangulated domain. It presents computational procedures and properties associated with accessing geographical data organized in the O-QTM hierarchically structure. The article concludes with an illustration of a recent preliminary application in which O-QTM was used to produce multi-resolution cartographic representations from a single hierarchical geospatial database.

Dwyer, AM, Bolton, RA. 1994.
NOAA's satellite active archive goes online.
Earth Sys Monitor 4(4):1–16.

Users around the world are now able to access data easily from NOAA's polar-orbiting satellites via NOAA's new Satellite Active Archive (SAA). The SAA system enables users on the internet to quickly search, browse, order, and receive satellite data. Development and management of the SAA are being led by the Office of Satellite Data Processing and Distribution (OSDPD) within the NOAA National Environmental Satellite, Data, and Information Service (NESDIS). NESDIS is also working with the respective organizations on national climate data, geophysical data, oceanography data, and NASA's EOSDIS program. Partners in the U.S.

Global Change Research Program are also participating in the Earth Observing System (EOS) program. SAA provides a DIRECTORY with high-level information, a GUIDE giving detailed information about each data set, an INVENTORY to specify search criteria, an ORDER that allows users to flag items, NEWS to display current information about SAS, and REMOTE which links remote computer systems.

Eggen-McIntosh, S; Lannom, KB; Jacobs, DM. 1994.
Mapping forest distributions of Central America and Mexico.
Proceedings, GIS/LIS '94, October, Phoenix, AZ, pp. 273–281.

North and Central American forestry agencies are cooperating to apply the methodology of the recently completed U.S. forest cover map to mapping forest distributions in Mexico and Central America. This project takes advantage of the recent availability of a full calendar year of time-series Advanced Very High Resolution Radiometer (AVHRR) imagery for the entire area. Forest areas will be identified, quantified, and then classified based on rainfall and elevation data. As a result, the degree of forest fragmentation and other resource considerations could be analyzed.

Elliott, B. 1997.
Bermont moves forward on E-911 rural addressing.
GIS World 10(6):42–44.

This article describes how Bermont used a GIS system to enhance the state's 911 system. This is a good example of a practical use of GIS and is explained well in this article.

Enache, M. 1994.
GIS-ready decision support system.
Proceedings, URISA94, (1):206–218.

A decision support system concerning health risk awareness and comparative risk assessment in the Philippines was developed for the World Bank. It is intended to be used as a rapid assessment tool for strategic planning, policy discussions, and resource allocations. Interfaces were designed for analysts, computer operators, and decisionmakers. The current package aims to combine Windows, Visual Basic, Microsoft Access, and Atlas GIS for Windows.

Engman, ET. 1995.
The use of remote sensing data in watershed research.
J Soil Water Conserv 50(5):438–440.

This brief review points out that the most unique contribution of remote sensing to this discipline is that all other hydrologic data are from point measurements, whereas remote sensing provides area data. Spatially continuous data complement point measurements. As such it has some potential to help address the major problem of aggregating the dynamic behavior of hydrologic processes at various space and time scales despite their great heterogeneity. In addition, remote sensing offers some kinds of data that, either by area of coverage or parameter measured, have not been available through other means. Some of the basic opportunities include measuring land cover/use, vegetation indices, drainage patterns, topography, surface temperature, radiation balance, sensible heat flux, soil moisture, and snow properties. These parameters may be valued directly or in many cases through their indirect association with still more hydrologic or biological properties of interest. Further research should combine designs using instrumented

watersheds and remote sensing tools.

Environmental Systems Research Institute, Inc. (ESRI). 1994.
GIS continues growth in real estate.
Available from: ESRI, 380 New York St., Redlands, CA.
ARC News Reprint, Spring, pp. 16.

This article describes how a private consulting firm uses GIS in the real estate market for doing market analysis and expanding GIS in nontraditional areas. Larry Daniel, VP of research and information systems at Castillo Company, Inc., of Phoenix, AZ, stated, "Considering data in a thorough, timely manner necessitates using a GIS. Geography is a natural in real estate."

Environmental Systems Research Institute, Inc. (ESRI). 1994.
ARC/INFO map book 1993.
Available from: ESRI, 380 New York St., Redlands, CA.

An extensive demonstration of GIS applications by ARC/INFO users in 1993 resulting from the annual ESRI competition.

Environmental Systems Research Institute, Inc. (ESRI). 1994.
ARC/INFO revision 7, geographic information system analysis and data management.
Available from: ESRI, 380 New York St., Redlands, CA.

Short informational brochure on Revision 7 of ARC/INFO discussing better data entry (ARCEDIT, ArcScan), extended data model, sophisticated analysis (ARC/INFO GRID, ARC/INFO NETWORK), powerful data management (ArcStorm), client server GIS (Inter-Applications–IAC), enhanced cartographic output (ARCPLOT), and ArcTools (ARC Macro Language–AML).

Environmental Systems Research Institute, Inc. (ESRI). 1994.
ArcView version 2, GIS for everyone.
Available from: ESRI, 380 New York St., Redlands, CA.

Short informational brochure on Version 2 of ArcView presenting the features to link tabular data, access spatial data, customize analyses, use geographical aspects of data, conduct GIS analyses, and develop quality outputs.

Environmental Systems Research Institute, Inc. (ESRI). 1994.
ArcView: The geographic information system for everyone; introducing ArcView.
Available from: ESRI, 380 New York St., Redlands, CA.

A short introduction to ArcView discussing all the features presented in the course on Introduction to ArcView (but without the class exercises). Topics covered: managing your work, displaying and querying spatial data, attributes of spatial data, visualizing and querying data, producing maps, and automating and customizing your work.

Environmental Systems Research Institute, Inc. (ESRI). 1995.
Getting to know desktop GIS.
Available from: ESRI, 380 New York St., Redlands, CA.

A short introduction to desktop GIS using ArcView to demonstrate the principles of GIS in a colorful, descriptive, and visual format. This document explains the terms with lots of

pictures and examples. Topics covered: Desktop GIS: what it is and what it does; This is how it works; Asking questions; Getting answers; Making information presentable; What you need to know about data; and Using desktop GIS.

Environmental Systems Research Institute, Inc. (ESRI) Educational Services. 1995.
Introduction to ArcView.
Available from: ESRI, 380 New York St., Redlands, CA.

This is an extensive textbook and workbook with examples for the person who wants to learn how to use ArcView. Topics covered: ArcView basics; creating views, themes, and image themes; working with themes and charts; the power of tables; spatial query and analysis; creating a map layout; and addresses and other events.

Environmental Systems Research Institute, Inc. (ESRI). 1996.
ARC/INFO version 7.1, many important new features!
Available from: ESRI, 380 New York St., Redlands, CA.

Informational brochure on enhancements of ARC/INFO 7.1, including new graphical editing tools, a new vector geoprocessing tool (AREAQUERY), new ARC GRID functions, a new ARC TIN command, etc.

Environmental Systems Research Institute, Inc. (ESRI). 1996.
ESRI map book volume eleven: geography connects our world.
Available from: ESRI, 380 New York St., Redlands, CA.

The maps contained in this volume showcase users' innovative and important GIS applications and projects. These are the "finest" maps created in 1995 by the more than 100,000 worldwide users. The maps are beautiful and show many of the ways in which geographic information is being used throughout the world. One of the most colorful and interesting from the ground-water arena is entitled "Protective Function of Groundwater Covering" from the Bavarian Geological Survey, Munich, Germany.

Environmental Systems Research Institute, Inc. (ESRI). 1997.
ArcView GIS: The geographic information system for everyone.
Available from: ESRI, 380 New York St., Redlands, CA.

A descriptive brochure on ArcView discussing features for visualization, quality mapping, spatial analysis, data integration, application development, extensible architecture, and user support.

Ernst, MR; Frossard, W; Andrews, DW. 1994.
Comparison of nonpoint pollutant loadings from geographic information system modeling and wet weather stream flow monitoring.
Lake Reservoir Manage 9(1):79-84.

Traditional water quality sampling to ascertain nonpoint loadings to southern reservoirs focuses on sampling from events when tributaries are carrying significant amounts of runoff. Many southern reservoirs receive the majority of their runoff from one or two storm events each year, making sampling of these events critical in assessing the nonpoint load. The four Texas water supply reservoirs discussed in this paper have at least 75 percent of their nutrient load and

95 percent of their sediment load coming from nonpoint sources. Efforts to quantify nonpoint loads are challenged by the large size of the watersheds, unpredictability of rainfall and tributary reaction and difficulties in sampling rain-swollen tributaries. GIS modeling techniques using remote sensing, published nutrient export coefficients, and the Universal Soil Loss Equation (USLE) offer the reservoir manager a quick assessment of average nonpoint loadings from large areas. GIS nonpoint assessments are purported to provide estimates within a factor of two for nutrient loads and give a relative ranking highlighting the "critical" subwatersheds impacting a given reservoir. The Tarrant County Water Control and Improvement District Number One (the District) has conducted storm event tributary sampling on four major water supply reservoirs in north central Texas since 1989. The District has also contracted for GIS assessments of each reservoir's watershed. This paper discusses a comparison of observed traditional sampling results and GIS modeling results.

Ertep, SA; Lee, GW. 1994.
Use of GRASS to facilitate red-cockaded woodpecker management at Fort Benning Military Reservation.
URISA, p. 628–633.

The Geographic Resources Analysis Support System (GRASS) was applied within 129,000 acres of manageable forest land near Columbus, Georgia, to try to automate the foraging analysis for the red-cockaded woodpecker (RCW). As an endangered species, a foraging habitat has been defined for the RCW in terms of stand age, density, and distance from the center of a colony. The only new data needed were to define the center of the colonies, which have overlapping habitats. GRASS determined the suitable foraging areas geographically, produced maps, and generated reports for import into Lotus 1-2-3 for identifying colonies with stand attributes and stand acreage. The main time savings is the computer’s calculation of acreage in less than 1/10th the time.

Evans, BM; Myers, WL. 1990.
A GIS-based approach to evaluating regional groundwater pollution potential with DRASTIC.
J Soil Water Conserv 45(2):242–246.

The study consisted of two components, one the development of a GIS database for the Indian River Inlet area of Delaware and the other the predictive modeling that yielded a ground-water pollution risk and hazard assessment and map series for the area. Drinking water protection was among the most important uses to protect. Impact-related information collected for the GIS included elevation of the aquifer base and water table, soil permeability, elevation, land cover, sewer service areas, and transmissivity. The predictive modeling using DRASTIC involved manipulating the data to qualitatively assess the potential for negative impacts to ground-water in any of the cells of the database. The most important factors for making these judgements were depth to water table, net recharge, aquifer media, soil media, slope, impact of the vadose zone, and hydraulic conductivity of the aquifer. Factors could be weighted as desired. Model outputs generally reflected pollution potential.

Evans, BJ; Gordan, JV; Mavros, WV; Perry, EM. 1994.
The use of geographic information systems technology for salmon habitat analysis.
ASPRS/ACSM, pp. 200–208.

Using the Lower Granite Reservoir as a pilot study area, this project demonstrated that

GIS technology could be used for aquatic environmental studies. The eventual aim was to use GIS technology to evaluate the impact of lowering the reservoirs of the Snake River in Idaho, Oregon, and Washington. This mitigation method is expected to improve the survival of threatened and endangered salmon. The impacts of related changes in the physical environment on the surrounding terrestrial wildlife also were considered. The researchers concluded that (1) as GIS technology moves toward three-dimensional modeling and analysis, it will have fewer limitations for aquatic applications, and (2) reproducible results are one of the greatest benefits of using a GIS.

Fayer, M; Gee, G; Rockhold, M; Freshley, M; Walters, T. 1996.
Estimating recharge rates for a groundwater model using a GIS.
J Environ Qual 25:510.

There has been concern about the transport of contaminants from defense wastes as a result of natural recharge. The authors' objective was to estimate the distribution of natural recharge to use in a ground-water flow and transport model. The authors used a GIS to identify all combinations of soil type and vegetation in the area. They then used the GIS to assign estimates of recharge rates using field data or simulation if field data were unavailable. The GIS estimated the annual recharge volume for each soil-vegetation combination. The GIS map could later be used to determine the impact of changes in vegetation and to estimate the recharge volume before farms and the defense site were located in the area.

Fedra, K, Pemberton, R; Elgy, J; Mannis, A. 1996.
Air quality management: an effect-based approach (development of a sophisticated environmental management technique based upon the integration of air quality modelling withing a GIS/DSS framework).
Proceedings, International Conference on Development and Application of Computer Techniques in Environmental Studies, Como, Italy, Sept. pp. 637–648. In: Development and application of computer techniques to environmental studies–Envirosoft 96. Computational Mecanics, Inc., Billerica, MA.

This project combined GIS and DSS to formulate an effects-based and cost-effective air quality management strategy. The goal was to provide policy makers with a tool for maximizing air quality improvements while minimizing any economic disadvantages.

Fischl, P. 1996.
Predicting areas of future public water supply problems–Floridan aquifer, Northeast Florida.
AWRA Symposium on GIS and Water Resources, September 22–26, Ft. Lauderdale, FL.

This study is part of an assessment of water supply needs and sources in which the St. Johns River Water Management District (SJRWMD) has been required to identify areas expected to have inadequate water resources to meet the future water supply demand in the year 2010. The plan was to use regional ground-water flow models and local analytical ground water flow models to evaluate the effect of increased pumping on the ground-water flow system. A GIS methodology was developed (SUN Sparcstation II using SunOS 4.1.3 (UNIX), running ARC/INFO 6.1.1) using an overlay procedure with gridded surfaces to identify areas that have a high potential for (1) vegetative impacts, (2) salt water intrusion, and/or (3) an increase in public water supply demand. Data surfaces used included (1) long-term decline in the potentiometric surface of the Floridan aquifer, (2) short-term decline in the potentiometric surface of the Floridan

aquifer, (3) confining unit thickness over the Floridan aquifer, (4) vertical head difference between the Floridan aquifer and the surficial aquifer, (5) percentage of fresh water in the aquifer, (6) horizontal distance to areas of no potable water in the aquifer, (7) wetland locations, and (8) projected 2010 population density. Results showed a high potential for water problems (i.e., high scores). The Atlantic coastal areas show high scores, as do the Gainesville and Ocala areas due to several compounding factors. Along the coast, factors include the presence of poor-quality water, distance to poor-quality water, changes in elevation of the potentiometric surface of the Floridan aquifer, and large population projections. High inland scores are due to large population increases and changes in the elevation of the potentiometric surface of the aquifer, as well as a thin confining unit in the Ocala area.

Fisher, PF. 1989.
Knowledge-based approaches to determining and correcting areas of unreliability in geographic databases.
In: Goodchild, M; Gopal, S., eds. Accuracy of spatial databases. New York: Taylor & Francis, pp. 45–54.

Fisher, RF. 1991.
Modeling soil map unit inclusions by Monte Carlo simulation.
Int J Geo Info Sys 5:193–208.

Fitzgerald, RW; Lees, BG. 1994.
Assessing the classification accuracy of multisource remote sensing data.
Remote Sensing Environ 47:362–368.

The authors claim that traditional assessment of errors in the classification of remote sensing and GIS data is inadequate**.** The Kappa test statistic technique is recommended and used in this article. The Kappa test statistic and non-site-specific accuracy assessments were applied to floristic classification errors that were generated by a neural network and decision tree classification of a subscene area of Kioloa, Australia. Authors and results suggest that the Kappa statistic tool is the preferred tool for testing classification accuracy based on error matrices.

Florence, J; Hormsby, K; Egenhofer, MJ. 1997.
The GIS wallboard: iterations with spatial information on large scale displays.
In: Kraak, M; Molenaar, M; Fendel, E., eds. Advances in GIS research. Proceedings, Seventh International Symposium on Spatial Data Handling. London: Taylor & Francis, pp. 449–463.

This article explores the concept of a GIS wall display device (which the authors call "GIS WallBoard") and the possible advantages it might offer over current computer GIS displays. The article begins with a discussion of the important role of WallBoard in collaborative spatial decisionmaking (e.g., a group of planners working together on a proposed development). It describes the general features of WallBoard. The heart of the article contains discussions of (1) interactions the GIS Wallboard could support (e.g., both touch-based and empty-handed gestures, eye contact, voice interaction, computer input, multi-modal inputs) and (2) the broader range of "interaction spaces" (arm's length, spitting distance, and within-sight) that would be possible with the WallBoard but not with current computer desktop displays. The article also describes some basic GIS manipulation capabilities (selection, zoom, pan, rotation, and navigation) at the "arm's length" interaction level.

Fola, SE. 1989.
Patterns of stream channel response to urbanization in the humid tropics and their implications for urban land use planning: a case study from southwestern Nigeria.
Appl Geogr 9:273–286.

Examines the extent to which urban channels in a humid tropical environment are in equilibrium with the varying urban hydrological states. The degree and location of urbanization in the watersheds appear to be the main determinants of the nature of stream channel response to urbanization. This is another useful paper to investigate the impact of urbanization on surface water bodies.

Foster, MA; Robillard, PD; Lehning, D; Masson, D. 1996.
Expert GIS and model based guidance for protection and enhancement of water quality in agricultural watersheds.
Proceedings, Watershed '96, June, No. 2:1127, Baltimore, MD. http://www2.deasy.psu.edu/erri/

This article focuses on two knowledge-based software applications for nonpoint source pollution control: STEWARD and XGSTEWARD. Expert rules are based on lessons learned through the Rural Clean Water Program and are based on site characteristic and the contaminant of concern. XGSTEWARD is a GRASS GIS and calculates quantitative indices for leaching potential and nutrient loading, then applies the same expert rules as STEWARD. Both applications were undergoing user evaluation, and new versions were anticipated in 1996.

Frank, SM; Goodchild, MF; Onsrud, HJ; Pinto, JK. 1995.
A survey on user requirements for framework GIS data.
Proceedings, Vol 1, URISA 95, San Antonio, TX, July 16-20, pp. 637-651.

This article reports on a National Center of Geographic Information and Analytic survey that targets users of existing GISs or GIS products. The users were asked about data needs. The returned information was analyzed across sectors of government, private industry, and academia, by geographic region, and by professional area of application. The goal was to determine the criteria that could help in the selection of current digital geographic data sets that best meet the National Spatial Data Infrastructure. One conclusion is that many current GIS users apparently lack technical knowledge about GIS. The differences in user requirements appear to be related to application needs.

Fraser, RH; Warren, MV; Barten, PK. 1995.
Comparative evaluation of land cover data sources for erosion prediction.
Water Resources Bull 31(6):991–1000.

The authors compared LANDSAT MSS and TM with aerial photography in terms of their ability to predict erosion using MUSCLE. In MUSCLE, land cover is used to estimate VM–the vegetation management parameter. The authors investigated whether the land-cover classification would change with the different sources, and whether the resulting soil loss prediction will change. As a first step, they used a nearest neighbor function to convert coverages to UTM. They compared unsupervised, supervised, and a hybrid approach to classification. A 5x5 filter was used after classification. Of the classification errors, 92 percent occurred in the forest cover types. The causes for the errors included the rectification process and the analyst's classification of mixed forest. Fortunately, soil loss predictions were insensitive to these minor discrepancies in the land-cover classification. The TM, hybrid-classification map explained 90 percent of the

variation in the aerial photo-derived map.

Freeman, W; Fox, J. 1995.
ALAWAT: a spatially allocated watershed model for approximating stream, sediment, and pollutant flows.
Environ Manage 19(4):567-577.

The authors used GIS plus a model to look at (1) hydrology in an undisturbed watershed, (2) calculated suspended sediment contributions from urban areas, and (3) simulated effects of street sweeping. They used the normal ratio methods to approximate rainfall for grid cells lacking data. Conclusion: Street sweeping would have to be increased from once every 14 days to once every 2 days to reduce suspended sediment loads by one-half.

Frye, E; Denning, R. 1995.
Michigan township uses watershed-based decision support system.
Geo Info Sys 5(9):55–57.

This article evaluates stormwater runoff impact on watershed with a model that included rainfall, land use (derived from aerial photography), and soil group. It provides information to township officials to help them make better informed land-use decisions. It describes an excellent application of GIS to ecological risk assessment.

Galagan, C. 1997.
Geographic information systems and ASA.
Marine Environ Modell, January 11(1).

ASA is a leader in the integration of numerical models and GIS technology. Innovations in GIS customization tools, data availability, and internet applications are enabling exciting new product development and expanding the way individuals use GIS technology. The model systems are being expanded to fully integrate with popular GIS applications such as ArcView. In addition, model applications will become web-enabled so that data, GIS, and model functionality will be available to their clients via the internet. For example, GIS layers of critical habitats in Tampa Bay or real-time wind speed and direction data from an offshore buoy can be used directly in the integrated hydrodynamics and water quality model system. These models have also been modified to incorporate raster charts and remotely sensed imagery and have been extended to enterprise databases.

Galloway, B. 1997.
Schools of thought: putting GIS on the curriculum.
Mapping Awareness 11(3):32–34.

ESRI's ArcView is being promoted in Northern Ireland. GIS has become part of the geography curriculum (in high school?). This article describes the teacher and student training tools (using CD ROM) that were developed to introduce GIS into the curriculum.

Geschwind, SA; Stolwijk, JA; Bracken, M; Fitzgerald, E; Stark, A; Olsen, C; Melius, J. 1992.
Risk of congenital malformations associated with proximity to hazardous waste sites.
Am J Epidemiol. 135(11):1197–1207.

The authors linked two existing databases of the New York State Department of Health to evaluate the relationship between congenital malformations and maternal residential proximity to

hazardous waste sites in New York State. A secondary purpose of the study was to test the feasibility of linking environmental and health databases and using geographic mapping methods for delineating environmental exposures. They used a four-tier approach: (1) test whether residential proximity to a waste site during pregnancy increased the risk of congenital defects; (2) test whether defects of specific organ systems were more likely to be correlated with proximity to a toxic waste site; (3) test whether specific features of a waste site (i.e., off-site migration of chemicals) increased the site's potential health risk; and (4) evaluate the risk of particular organ system defects known to be associated with specific chemical exposures. They assigned lat/long coordinates to 590 waste sites in 20 New York counties. They used 12,442 individual congenital malformations representing 9,313 cases taken from the New York Congenital Malformations Registry in 1983 to 1984. They used 17,802 control births from New York State for the same time period. Addresses for cases and controls were assigned lat/long coordinates. Each waste site was assigned a composite hazard ranking score based on several factors, such as the likelihood of human exposure to residences within a 1-mile radius of the site, and toxicities of identified chemicals. An "exposure risk index" was calculated for each respondent, incorporating the distance from the site and the site's hazard ranking score for each site within a 1-mile radius of the birth residence. They used a coordinate matching program to match all case and control coordinates to the waste site coordinates. This program calculates the distance and direction of each birth residence from hazardous waste sites within a 1-mile radius. Individuals living within 1 mile of a site were considered potentially exposed. The results of the study showed a small, but statistically significant, additional risk for birth defects associated with maternal proximity to toxic waste sites.

Gi-Chul, Y; Risley, D; Koneff, M; Davis, C. 1994.
Development of Ohio's GIS-based wetlands inventory.
J Water Soil Conserv 49(1):23–28.

The Ohio Division of Wildlife has adopted state-of-the-art GIS to replace the national wetland inventory maps, which it uses for natural resource management. The GIS is composed of sophisticated computer hardware and software configurations that are designed to handle, interpret, and manage large spatially referenced databases. If properly used, the GIS will give the state the capability of periodically monitoring its wetland resources in a consistent and efficient manner.

Gi-Chul, Y; Risley, D; Koneff, M; Davis, C. 1994.
Development of Ohio's GIS-based wetlands inventory.
J Water Soil Conserv 49(1):23–28.

This is a discussion of the Ohio Division of Wildlife GIS to replace the national wetland inventory maps, which it uses for natural resource management. The system is composed of sophisticated computer hardware and software configurations that are designed to handle, interpret, and manage large spatially referenced databases.

Gillespie, MK; Howard, DC; Ness, MJ; Fuller, RM. 1996.
Linking satellite and field survey data, through the use of GIS, as implemented in Great Britain in the Countryside Survey 1990 Project Morna K. Gillespie, Institute of Terrestrial Ecology, Grange-over-Sands, UK.
Environ Monitor Assess 39(1-3):385.

In 1990, the Institute of Terrestrial Ecology undertook a major project to record land cover in the United Kingdom, which was called the Countryside Survey 1990. A number of different technologies were employed, including satellite image analysis and field surveys. Data from the two sources were analyzed using a GIS, and efforts to integrate the data are described. Experience has shown that the combined surveys provide localized and more detailed estimates than either data set alone.

Gilliland, MW; Baxter-Potter, W. 1987.
A geographic information system to predict non-point source pollution potential.
Lake Reservoir Manage 3(2):23-29.

Bacterial densities (total coliform, fecal coliform, and fecal streptococci) and suspended solids in runoff from a feedlot, pasture, and cornfield were measured. Densities of fecal coliform were highest from the feedlot but were 1000 to 10,000 times greater than the water quality standard for swimmable waters from all three land uses. Densities of fecal streptococci were highest from the corn field, which suggests that wildlife are the source of bacteria. Fecal coliform/fecal streptococci ratios distinguished cattle from wildlife as the source of bacterial pollution both among land uses and among seasons of the year. Suspended solids concentrations in runoff ranged from 423 to 925 mg/L and were highest from the cornfield. A GIS was developed to include algorithms associated with nonpoint source pollution. The system accepts digitally mapped information on soil type, topography, and land use. It calculates characteristics such as slope and slope length, and relates these characteristics to soils and land-use parameters in order to produce three-dimensional maps of runoff potential, sediment pollution potential, and bacterial pollution potential. It offers the advantages of retaining the geographic character of pollution potential information and of conveying in three-dimensional graphical terms the effects of topography, soil type, land use, and land management practices.

Gitelson, A; Garbuzov, G; Szilagyi, F; Mittenzwey, KH; Karnieli, A; Kaiser, A. 1993.
Quantitative remote sensing methods for real-time monitoring of inland waters quality.
Int J Remote Sensing 14(7):1269-1295.

Spaceborne remote sensing of inland water quality is based on the assumption that the relationship between the reflectance and the concentration of relevant water quality constituents is known a priori. Simultaneous measurements of the upwelling and downwelling irradiances, along with phytoplankton chlorophyll-a, suspended matter, and dissolved organic matter concentration at over 20 water bodies throughout former USSR, Hungary, Germany, and Bulgaria, are reported in this article. The measurements cover different trophic states of water bodies, from oligotrophic to hypertrophic, and different climatic conditions. The range of chlorophyll-a is 0 multiplied by 1 to 350 mg/m^{-3}, suspended matter is 0 multiplied by 1 to 66 mg/L^{-1}, and dissolved organic matter absorption at the wavelength 380 nm is 0 multiplied by 1 to 12 m^{-1}. All radiometric measurements are performed with a single radiometer in the 400-750 nm range with spectral resolution better than 1 nm. Factor and signature analysis, as well as multispectral statistical modeling of water quality parameters versus simulated spectral band ratios, makes possible the determination of appropriate functions of reflectance for estimating phytoplankton chlorophyll-a, suspended matter, and dissolved organic matter concentrations. One set of measurements is used to develop empirical relationships among the spectral reflectance and the above-mentioned water quality parameters. The other sets of measurements are used to test these relationships. The maximum error of estimation are: 3 mg/m^{-3} for chlorophyll-a, 4 mg/L^{-1} for suspended matter, and 0

multiplied by 065 mg Cm^{-3} (mg of carbon per m^3) for dissolved organic matter. The results are used to develop an appropriate methodology for monitoring of the eutrophication process in inland waters and to test concepts of inland water quality monitoring from space.

Gitelson, A; Szilagyi, F; Mittenzwey, KH. 1993.
Improving quantitative remote sensing for monitoring of inland water quality.
Water Resources Res 27(7):1185-1194.

Simultaneous measurements of the upwelling and downwelling irradiances, along with phytoplankton chlorophyll-a, suspended matter, and dissolved organic matter concentration at over 20 water bodies throughout the CIS, Hungary, Germany, and Bulgaria, are reported in this paper. The measurements cover different trophic states of water bodies, from oligotrophic to hypertrophic, and different climatic conditions. The range of chlorophyll-a is 0.1-350 mg/m^{-3}, suspended matter is 0.1-66 mg/L^{-1} and dissolved organic matter absorption, at a wavelength of 380 nm, is 0.1-12 m^{-1}. All radiometric measurements were performed with a single radiometer in the 400-750 nm range with spectral resolution better than 1 nm. Factor and signature analysis, as well as multispectral statistical modeling of water quality parameters versus simulated spectral band ratios, made possible the determination of appropriate functions of reflectance for estimating phytoplankton chlorophyll-a, suspended matter, and dissolved organic matter concentrations. One set of measurements was used to develop empirical relationships between the spectral reflectance and the above-mentioned water quality parameters. The other sets of measurements were used to test these relationships. The maximum errors of estimation are: 3 mg/m^{-3} for chlorophyll-a, 4 mg/L^{-1} for suspended matter, and 0.065 mg Cm^{-3} for dissolved organic matter. The results are used to develop an appropriate methodology for monitoring of eutrophication processes in inland waters.

Glickman, TS. 1994.
Measuring environmental equity with geographic information systems.
Resources, summer 1994, pp. 2–6.

The author discusses his methods and preliminary results of a GIS study examining environmental equity with respect to the risks from industrial hazards in Allegheny County, PA. He has combined risk assessment techniques with GIS software in order to look at both residential proximity to hazards and the health and safety risks associated with these hazards. He has classified Allegheny County's industrial facilities into those that may pose a risk of chronic hazards (TRI facilities) and those that may pose a risk of acute hazards (EHS facilities). The TRI facilities are considered to pose chronic hazards because they have continual, routine chemical releases. The EHS facilities are considered to pose acute hazards because they store large quantities of "extremely hazardous substances" that could be released during an accident. The author drew concentric circles of 0.5-, 1.0- and 2.0-mile radii around each facility and designated the combined areas within the circles as the "close-proximity region," where people live in close proximity to the facilities. Using GIS, he calculated the proportion of nonwhite residents and poor residents both inside and outside the close-proximity region for both the TRI and EHS facilities. For both kinds of facilities, he found that both demographic groups made up a larger percentage of the population inside the close-proximity region compared with their percentage of the population in the remainder of the county. These types of findings are similar to those of other studies. The paper then discusses the results of combining these proximity-based measures with the risk-based measures for the EHS facilities. The risk-based measures include such things

as probability of accidental chemical release from a facility, size and location of area affected by such a release, toxicity of chemical released, and day versus night-time accidental releases. Combining both the proximity- and risk-based measures, he assumed that equity for nonwhites (or the poor) exists if their percentage of the total risk is the same as that of the nonwhites (or poor) among the entire county population. He found that the percentage of nonwhites and poor at risk from accidental chemical releases from the EHS facilities was lower (9 percent and 8 percent, respectively) than the percentage of nonwhite and poor people living in the whole county (13 percent and 12 percent, respectively). He felt this outcome resulted from the fact that nonpoor whites are often at greater risk from hazards that affect a large area, such as major accidental chemical releases, than from hazards that affect only a small area. The radius of the area affected by a major chemical release accident often exceeds 1 mile, and nonwhites and poor people tend to live closer to EHS facilities than do white and nonpoor people.

Glickman, TS; Golding, D; Hersh, R. 1995.
GIS-based environmental equity analysis, a case study of TRI facilities in the Pittsburgh area.
In: Beroggi, GEG; Wallace, WA., eds. Computer supported risk management. Dordrecht, Boston: Kluwer Academic Publishers, pp. 95–114.

The authors wanted to investigate the effect that areal unit of analysis has on the evaluation of environmental equity. Using GIS technology, they examined the demographics of populations associated with all TRI facilities in Pittsburgh and surrounding Allegheny County, Pennsylvania. They identified all census block groups, tracts, and municipalities and classified them as being TRI (i.e., containing at least one TRI) or non-TRI (i.e., containing no TRI's) communities. They also drew half-mile and 1-mile radius circles around each of the 88 TRIs, and dissolved the boundaries of the overlapping circles to produce two single layers representing all the TRI communities within both a half-mile and 1 mile of a TRI. The area of Allegheny County lying outside the union of the circles was designated as the non-TRI community. They looked at several demographic measures of race, poverty, and potentially at-risk populations, including the percentage of the black population, median household income, and percentage of population less than 5 years of age. When comparing the demographic measures for the various TRI and non-TRI communities, they found significant differences associated with the unit of analysis. They also found that although the same kinds of inequities were seen in the half-mile and 1-mile circles, the absolute magnitude of the differences was greater in the 1-mile circles. Based on their findings, the authors caution that the spatial unit of analysis in environmental equity studies needs to be selected carefully and tailored to evaluating the problem at hand (i.e., health risk evaluation versus proximity evaluation). They also suggest that several units of analysis should be used and sensitivity analyses conducted to examine the impact of the spatial unit on the study results. They felt that for proximity analyses, use of the circles around the TRIs was the most appropriate unit of analysis.

Goodchild, MF; Quattrochi, DA. 1997.
Scale, multiscaling, remote sensing, and GIS.
Scale in remote sensing and GIS. Boca Raton, FL: CRC Press, pp. 1–11.

The subject of the collection, "geographic scaling," is an overworked and yet ambiguous concept. It is used to refer to both the "magnitude" of a study (its geographic extent) and also the degree of detail (its level of geographic resolution). GIS has opened up the possibility of (a) multiscale representation of geographical space and (b) approaching scale as a generic issue,

aspects of scale considered as a generic issue, observations of the Earth, data volume, and the term “scale.” The remainder of the article describes the order and summarizes the other essays that appear in the volume.

Goodchild, MF; Parks, BO; Steyaert, LT, eds. 1993.
Environmental modeling with GIS.
New York: Oxford University Press.

This book is a followup from a conference held in Boulder, Colorado, in September 1991, but it is not a conference proceedings. It is fairly readable and well produced.

Goodchild, MF; Steyaert, LT; Parks, BO; Johnston, C; Maidment, D; Crane, M; Glendinning, S. 1996.
GIS and environmental modeling: progress and research issues.
GIS World Books, Ft. Collins, CO, 486 p.

Gorokhovich, Y. 1996.
The NYC water quality division GIS and its applications for the watershed management.
Proceedings, Watersheds 96–Moving Ahead Together: Technical Conference and Exposition, June 8–12, Baltimore, MD.

The main use of GIS is integration of different layers of information for model input: layers include stream locations, land use, soil, geology, climate, and water quality. Estimates of the total annual mass of phosphorus (P) entering a reservoir or lake are obtained by identifying land use, applying export coefficients, and then summing the annual P contribution for each nonpoint source and point source within the watershed. By changing the assumptions on land use and export coefficients, it is possible to evaluate the effects of future land-use changes on nutrient loadings, and subsequently water quality. The GIS system allows automatic processing of the area delineation. To accomplish this, elevation data were converted into the Digital Elevation Model (DEM). Then the DEM file was converted into the raster grid containing information about the flow direction of water along the surface of the land. Another GIS application was created to calculate reservoir volumes, which are necessary for reservoir modeling.

Gorres, J; Gold, AJ. 1996.
Incorporating spatial variability into GIS to estimate nitrate leaching at the aquifer scale.
J Environ Qual 25:491–498.

This study analyzed the effect of spatial variability of soil properties and management practices on ground-water quality. The analyses were carried out at different spatial scales from point level to the entire recharge basin. GIS and stratified sampling were used together to characterize soils and assess variability in potential NO_3 leaching. The authors developed cumulative distribution functions of several properties of soil for input to the root zone model. The analyses were of markedly lower variability basinwide than at the point scale, suggesting that GIS at common mapping scales may be appropriate for use by water quality managers to protect large production wells.

Gorres, J; Gold, AJ. 1996.
Incorporating spatial variability into GIS to estimate nitrate leaching at the aquifer scale.
J Environ Qual, 25(3):491–498.

The Rhode Island GIS soils database was used to generate six broad soil strata for use in a root-zone nitrogen fate model to predict nitrate-nitrogen concentrations at a production scale well. Monte Carlo analyses with the model were used to assess uncertainty associated with predicting NO3-N leaching for different soil/land management strata.

Gosinski, T. 1995.
Implementing a regional traffic data management system.
Proceedings, Vol. 1, URISA 95, San Antonio, TX, July 16–20, pp. 735–743.

The Intermodal Surface Transportation Efficiency Act (ISTEA) and the Clean Air Act Amendments shift transportation decisionmaking toward the local level in such areas as air quality control and employer trip reduction. In response, the Houston-Galveston Area Council developed a Traffic Data Management System to efficiently store, display, query, analyze, and disseminate information. The data can be accessed by other planning agencies.

Gould, MD; Tatham, JA; Savitsky, B. 1988.
Applying spatial search techniques to chemical emergency management.
Proceedings, GIS/LIS '88 Third International Conference, Nov. 30–Dec. 2, San Antonio, TX, pp. 843–851.

The authors discuss the use of AM/FM, spatial searching, air dispersions modeling, and population overlays in a comprehensive facility system to deal with chemical emergencies. They describe different hardware and software options for building such a system. They also discuss how to integrate the products of an air dispersion model with the chemical and health hazard characteristics of a chemical plume resulting from an accident. This plume information can then be used in conjunction with mapped population data to determine who is at risk and what emergency actions should be taken. They also suggest queries that can be made to determine the number and kinds of people who may live in the path of the plume.

Graham, LA. 1997.
Land, sea, air GPS/GIS field mapping solutions for terrestrial, aquatic and aerial settings.
GIS World 10(1):40–46.

The author contends that feature positioning systems such as GPS now allow users to build GIS databases while out in the field. The author evaluated several systems in the field and concluded that real-time computer mapping software is a valuable tool in collecting accurate GIS data and attributes in the field. This software is particularly useful when interfaced with real-time differential GPS. The optimal combination of software, devices, and methodologies varies depending on whether the user is in a terrestrial, aquatic, or aerial setting.

Graham, LA. 1997.
Land, sea, air GPS/GIS field mapping solutions for terrestrial, aquatic and aerial settings.
GIS World 10 (1):40–46.

This article describes the types of equipment that can be used in the field to accomplish "real-time feature mapping." The article covers laser mapping devices, digital still cameras, and video integration that can be operated in conjunction with GPS and real-time mapping software. This is a good article because it notes some down-to-earth problems, such as trees around a pond interfering with GPS or radio signals.

Graham, LA. 1997.
Land, sea, air GPS/GIS field mapping solutions for terrestrial, aquatic and aerial settings.
GIS World 10(1):40–46.

The author evaluated a variety of field data collection devices to determine performance in terrestrial, aquatic, and aerial environments. Devices included laser mapping devices, digital still cameras, and single- or multiple-camera video data integration. Combinations of software and field data collection devices and methods were also evaluated. Comparison tables are presented summarizing device performance.

Graham, LA. 1997.
Modern-day magic options abound from raster-to-vector conversion.
GIS World 10(7):32–38.

Raster to vector conversion is possible using six software products. Not all maps are good candidates for conversion, but the software available to make this conversion is quite good.

Graham, SJ. 1997.
Products liability in GIS: present complexions and future directions.
GIS Law 4(1).

This article discusses liability problems that are likely to arise as more people use GIS and GIS software packages become more mass-produced. The author believes that strict product liability concerns could rise from hardware, software, data, and the personnel required to operate the system. The author implies that data quality is particularly at risk because problems can occur with positional accuracy, attribute accuracy, logical consistency, resolution accuracy, completeness, and temporal changes. Such errors could lead to personal injury or death. The author believes that the GIS profession should police itself and its quality or the law will, and should, accomplish that task for it.

Grant, RE. 1997.
Integrating network models: CAD versus GIS.
Water Eng Manage 144(4):29.

The author discusses the thought process engineers and GIS managers should consider when integrating CAD with GIS. Although both systems have different applications, both can process information using the same database. The author points out that users may be interested in some common data attributes, but for different applications. Attributes of the same data also may not be interchangeable between the different applications. The author concludes that vendors are creating tools for seamless integration of data, but users of the tools should be mindful of their needs and the limitations of these integrating tools.

Grant, R; Shah, N. 1996.
Data conversion for a small-town GIS.
Geo Info Sys 6(4):38–41.

The town of Stonington, Connecticut (population 17,000), began to consider implementing a GIS to keep pace with the town's rapid growth over the past 7–10 years, mostly as a tourist destination and retirement community. Because of the town's limited budget, it needed to consider carefully all options before choosing a data conversion method. The goal of the GIS is to increase the efficiency of town staff in working with geographically related

information and data, primarily by improving geographic data sharing between departments. This program would centralize maps in the town office to avoid duplication of efforts and reduce expenses. Although the data conversion is still under way, the benefits of GIS have already been realized: the director of emergency management foresees using GIS for planning evacuation in emergency situations; the local fire departments want to use GIS to study response times and locate district boundaries; and the planning department is using the data to find variances in zoning and re-evaluating existing zones. Town officials hope that they will soon be able to offer GIS maps to developers for a fee.

Green, K; Cosentino, B. 1996.
Using satellite imagery to detect and monitor forest change.
Geo Info Sys 6(2):22–30.

During the past decade, many types of pests have ravaged the forests of eastern Oregon and Washington and the Sierras of California. Massive tree mortality and damage have resulted, rapidly changing wildlife habitat and expanding the potential for forest fires fueled by excessive dead, woody materials throughout the forests. The rapidly changing forest landscape presents substantial challenges for forest mapping, inventory, and planning for forest managers. Working under a NASA Earth Observation Commercialization Program (EOCAP) contract, Pacific Meridian Resources investigated the use of multitemporal satellite imagery to detect and measure land-use and land-cover change. Different techniques for monitoring change were investigated, addressed, and compared; the results of the assessments were then employed to develop easy-to-use change-detection software. The utility of multitemporal satellite imagery in detecting and measuring forest damage caused by pest outbreaks was examined. The results of this comparative analysis showed that using image differencing of ratios of the near- to mid-infrared bands provided the highest accuracy in measuring forest crown cover change.

Green, K; Finney, M; Campbell, J; Weinstein, D; Landrum,V. 1995.
FIRE: using GIS to predict fire behavior.
J Forestry 93(5):21–25.

The paper discusses the application of GIS to spatially represent fire behavior, including various assumptions of fuel type, weather conditions, and topography. FIRE! is a GIS-based model that was developed for Camp Lejeune for predicting fire behavior across both time and space. It also allows for decisions to be sensitively analyzed for managers fighting fires. Future versions of the model will include economic costs and benefits.

Groves, M. 1997.
The cutting edge; ground control; a crop of satellites and computers is helping farmers manage fields more efficiently.
Los Angeles Times, Business Section, March 10.

This article discusses the future of precision farming in California. The lead in precision farming has been in the midwest, where fewer crops are grown on larger pieces of land. In California, more crops are grown on smaller parcels using irrigation. This makes it more difficult to use systems like GIS and GPS because of higher cost to produce the data needed. Recently, ESRI came out with software that enables growers to assess field conditions and how those relate to yield. Within the next year, two Colorado companies plan to launch the first high-resolution private-sector satellites. EarthWatch in Longmont, Colorado, plans to launch a satellite that will

feature 30-meter resolution. Next January, Space Imaging Eosat in Thornton, Colorado, plans to be the first company to offer 1-meter resolution on a commercial basis. This sharpening of resolution will make it easier for farmers to manage smaller areas precisely.

Gruber, U; Haefner, H. 1995.
Avalanche hazard mapping with satellite data and a digital elevation model.
Appl Geogr 15(2):99–113.

The objective of the study is to evaluate the potential of high resolution satellite imagery (LANDSAT-TM, SPOT-XS) for avalanche hazard mapping and to develop an appropriate method for mapping vast, remote mountain areas. DEM raster format was used to derive elevation zone, slope angle, and aspect. Two sites were chosen for study: Beckenreid and Davos in the Swiss Alps. LANDSAT-TM satellite data were used for the forest classification. Classification results were verified by scanning 1:25,000 topo maps. A Salm-Voellmy model was used to calculate hazard and to establish an avalanche hazard map. Results showed advantages and disadvantages of using satellite imagery.

Guan, W. 1997.
Evaluating ARC-to-Oracle linkages.
Geo Info Sys 7(2):38–44.

The article discusses criteria for evaluating technical approaches in ARC-Oracle interfaces. The evaluation criteria include update frequency, query speed, interaction level, and user friendliness. The seven approaches include connection, conversion, manipulation, integration, native mode query, harsh tables, and third party script.

Gumbricht, T. 1996.
Application of GIS in training for environmental management.
J Environ Manage 46:17.

The need for integrated GISs, using different sources of data, different types of models, error handling, and artificial intelligence, is increasing. For students, the course the author was testing was too ambitious and initially tedious. Once students master GIS, however, inferring domain-specific knowledge is relatively efficient. The author concluded that education needs to be focused more on problem solving.

Gurnell, AM; Angold, PG; Edwards, PJ. 1996.
Extracting information from river corridor surveys.
Appl Geogr 16(1):1–19.

All maps are subject to some degree of locational error, but the spatial accuracy of maps of natural environmental features may present particular problems as a result of the frequently fuzzy boundaries of such features. This paper develops and tests a method for extracting quantitative information from river corridor survey maps, which are used throughout England and Wales by the National Rivers Authority for recording ecological and geomorphological features. The study was done on the Coal Burn river, which was selected because it contains varied features within a relatively short, unbranched length of river. Information was extracted independently from the same river corridor survey by three different operators to assess the degree and nature of operator variance. The analyses presented in this paper illustrate the success with which computer-compatible information can be extracted from river corridor survey maps.

Guthe, WG; Tucker, RK; Murphy, EA; England, R; Stevenson, E; Luckhardt, JC. 1992. Reassessment of lead exposure in New Jersey using GIS technology. *Environ Res 59:318–325.*

This paper summarizes the results of a pilot study conducted in Newark, East Orange, and Irvington, New Jersey, in which GIS (ARC/INFO) technology is used to overlay several data layers in order to identify areas where children may be at high risk for lead exposure. This area contains a large number of children with elevated blood lead levels and industrial, residential, and vehicular sources of lead contamination. Data layers include census tract boundaries and demographic data, blood lead screening record of children, locations of industrial sites emitting lead, locations of hazardous waste sites contaminated with lead, and road locations with their associated traffic volume estimates. The interim results provide a visual sense of the patterns of reported blood lead relative to the potential sources of exposure and the population at risk. The paper provides a series of thematic maps of the area, and a final map in which these different themes are overlaid. The final map shows some areas with a good correlation among children's elevated blood lead levels, location of sensitive populations, and sources of lead exposure. This map also shows several areas with reported high blood lead levels that were not predicted based on the overlay of data on potential risk factors. The authors believed this meant that additional parameters not currently included in the analysis may be significant predictors of elevated blood lead. These parameters may include lead levels in drinking water, distance of the census tract from a blood screening center, economic and social factors not currently considered, location of abandoned industrial sites, and illegal smelting activities. The authors stated that this pilot project was successful and they plan to continue adding relevant data layers. All of this information will be used to build a community educational needs profile and help design appropriate intervention strategies.

Guthe, WG; Tucker, RK; Murphy, EA; England, R; Stevenson, E; Luckhardt, JC. 1992. Reassessment of lead exposure in New Jersey using GIS technology. *Environ Res 59:318–325*.

This article describes the collection of data and use of GIS to develop maps that will relate elevated blood lead levels in children to location. Using ARC/INFO ADDRESSMATCH to locate where children lived and the lead exposure, maps were created that showed areas of elevated lead exposure. The next step is to identify probable sources of lead and areas where soil samples should be taken. Community outreach is planned to prevent lead poisoning.

Hagar, WG; Miniutti, PG; Stallsmith, BW. 1992. Remote monitoring of oxygen levels in Savin Hill cove of Boston harbor. *Proceedings, SPIE International Society of Optical Engineering 1930(1), pp. 547-556.*

Seasonal oxygen levels of Savin Hill Cove of Boston Harbor were monitored using an interactive remote sensing device. A combination oxygen and temperature meter with RS232 linkage was used to process and send data to a portable computer. The sensing probes for the meter were suspended 1.5 meters from the water surface on a floating platform that rose and fell with the tide. Stored data were retrieved either onsite by transfer computer or by telemetry using a modified cellular telephone connection to the remote sensor computer. There was wide variation in seasonal oxygen values during the year. Spring and winter values showed lower temperatures with higher and more constant oxygen values than the summer and fall data. Summer and fall measurements showed a great deal of daily biotic input with oxygen levels ranging from 3 to 8 mg

per liter of water. Fast Fourier transforms of the data exhibited seasonal diel and tidal influences.

Hall, RK; Ota, AY; Hashimoto, JY; Maher, NM. 1995.
Geographical information systems (GIS) to manage oceanographic data for site designation and site monitoring.
Mar Geodesy, EPA, Jul.–Sep., San Francisco, CA, 18(3):161(11).

GISs can be used as a tool within the technical evaluation process to show spatial and temporal relationships between different data types. GIS data were used to determine the disposal site for dredged material from San Francisco Bay, CA, which is necessary to maintain navigational channels for vessel traffic. The site-designation process is described, including the preliminary screening, the use of existing and newly acquired
data, and the determination of the preferred site. The use of GIS technology as a site management and monitoring tool is outlined.

Hallett, SH; Jones, RJA; Keay, CA. 1996.
Environmental information systems developments for planning sustainable land use.
Int J Geo Info Sys 10(1):47–64.

The Soil Survey and Land Research Centre (SSLRC) is responsible for classification and mapping of soils in England and Wales. To store the large amounts of data collected and to interpret and make them more readily available to users, development of national Land Information Systems (LandIS) was begun in 1979. Since the launch of LandIS, emphasis has shifted from agricultural production to environmental issues, and therefore a range of satellite computerized environmental information systems have been developed as powerful tools for spatial analysis, manipulation, and visualization of soil and land data. These include: national soil map, national soil inventory, national catalog of soils, agroclimate database, and catchment information system. LandIS applications include determination of crop suitability, nitrate pollution, heavy metal contamination, acidification, and farm waste disposal.

Hallmark, S; O'Neill, W. 1995.
Integrating air quality analysis and GIS-T.
Proceedings, Eighth Annual Symposium on Geographic Information Systems for Transportation (GIS-T), pp. 418–434.

A GIS was linked with air quality models, CALINE3 and CAL3QHC, to measure and analyze the impact of transportation-related air pollution. The GIS generates air pollution concentration contours using a Triangulated Irregular Network. Of particular interest to the authors were drive-through facilities, which were found to tend to cluster spatially and to often contribute at least as much to local air pollution as did signalized intersections in the vicinity.

Hallmark, S; O'Neill, W. 1996.
Integrating geographic information systems for transportation and air quality models for microscale analysis.
Transportation Res Rec 1551:133–140.

Building on their earlier research, the authors found that output from air quality models in the form of pollution concentrations at specified receptor locations can be input to a GIS for hot-spot identification, estimation of contributions of off-road mobile sources, and impact analysis. TRANSCAD, a transportation-based GIS, was used to demonstrate contour generation,

classification, and point-in-polygon analysis. The authors noted GIS/air quality model incompatibilities in their coordinate systems and in how street segments are represented and that additional data collection might be needed for signal analysis.

Hamlett, JM; Miller, DA; Day, RL; Peterson, GW; Baumer, GM; Russo, J. 1992. Statewide GIS-based ranking of watersheds for agricultural pollution prevention. *J Soil Water Conserv 47(5):399–404.*

Results are presented from a Pennsylvania study that used a GIS in combination with modeling capabilities to rank critical nonpoint-pollution potential of 104 watersheds. The data layers in the GIS database included watershed boundaries, land cover, animal population density, topography, soil data, precipitation data, and a rainfall-runoff factor. The watersheds were ranked by the Agricultural Pollution Potential Index, which comprises four separate components: runoff index, chemical use index, sediment production index, and animal loading index. The relative pollution hazard for each watershed was then calculated using the GIS data layers, the ranking model, and GIS software. Recommendations for improvements in the ranking system are proposed.

Hamlett, JM; Miller, DA; Day, RL; Peterson, GW; Baumer, GM; Russo, J. 1992. Statewide GIS-based ranking of watersheds for agricultural pollution prevention. *J Soil Water Conserv 47(5):399–404*

A GIS-based model was used to rank the pollution potential of 104 watersheds in Pennsylvania. The objectives were to select important processes and parameters of watersheds that contribute to water quality degradation, to develop a ranking model, and to apply that model to the watersheds. Parameters used for ranking included watershed boundaries, land cover, animal density, topography, soil, precipitation, and rainfall-runoff factors. For the initial model, potential pollution production for each cell was summed, and no ground-water component was used. The ranking index combined values for runoff, chemical use, sediment production, and animal loading. Weightings were applied to each factor to reflect relative importance. The model is sensitive to the land-cover and elevation data because each component uses these data layers in calculations. The output of the exercise is a map of Pennsylvania watersheds with relative rankings for NPS pollution potential. The article ends by discussing several opportunities for improving the ranking system.

Hamlett, JM; Miller, DA; Day, RL; Peterson, GW; Baumer, GM; Russo, J. 1992. Statewide GIS-based ranking of watersheds for agricultural pollution prevention. *J Soil Water Conserv 47(5):399–404.*

GIS combined with a pollutant generation and transport model was seen by these authors as the appropriate basis for GIS-based agricultural pollution prevention. The study covered 104 watersheds composing the full extent of the state of Pennsylvania. The model was a screening level model that was entirely GIS-based. The main purpose of the model was to rank the pollution potential of each watershed from agriculture. The ranking index developed for the project included four areas: a runoff index, sediment production index, animal loading index, and chemical use index. These data were commonly available. Statewide data used in the ranking also included watershed boundaries, land cover, animal density, topography, soils, precipitation, and rainfall-runoff factors. Cost constraints had to be considered in deciding which data to use and in limiting the complexity of the model. Results allowed the authors to identify critical nonpoint

pollutant contributing watersheds to be identified and targeted for further investigations and control programs.

Hammel, DJ; Wyly, EK. 1996.
Variations in housing price depreciation: the 'Taste for Newness' across heterogeneous submarkets.
Urban Geogr 17:248–268.

This article is important not because of what it said, but because of what it did not say. With an academic interest in urban planning, this student expected the authors would discuss how they used a GIS in their research. Essentially, the authors' study was designed to develop a computer model that would use tract-level census statistics to identify gentrified urban areas. Given that the research was conducted so recently (presumably within a few years of the article's publication), it seemed entirely probable and appropriate that GIS would be used to conduct the research. That was not the case. The enlightening aspect of the article was that the study could have been done much more easily if GIS had been used. One might have assumed that the technology would be available and familiar to the authors and within their budgets.

Han, L; Rundquist, DC; Liu, LL; Fraser, RN; Schalles, JF. 1994.
The spectral responses of algal chlorophyll in water with varying levels of suspended sediment.
Int J Remote Sensing 15(18):3707-3718.

The purpose of this paper was to investigate the spectral responses of algal chlorophyll and water, under natural sunlight with varying suspended sediment concentrations (SSC). Twenty levels of SSC with each of two sediment types were generated, ranging from 50 to 1000 mg/L, in 7510 L of water containing chlorophyll-a concentrations of 718 µg/L and 295 µg/L. Results indicate that suspended sediments do not eliminate the prominent spectral patterns of algal chlorophyll, even as SSC reached 1000 mg/L. Between 400 and 900 nm, the relation between reflectance and SSC satisfies the expression: $d^2 R(\text{lambda})/dS^2 < 0$. The effects of varying SSC on the positions and magnitudes of pronounced chlorophyll features were investigated. The ratio between the NIR and red wavelengths was totally independent of SSC. Thus, the findings support using it as an index for measuring chlorophyll in natural surface water containing suspended sediments.

Han, S; Evans, RG; Hodges, T; Rawlins, SL. 1995.
Linking a geographic information system with a potato simulation model for site-specific crop management.
J Environ Qual 24:772–777.

This paper presented the development of an interface between PC ARC/INFO with SIMPOTATO (a potato growth simulation model). The SIMPOTATO model predicted potato yield and nitrogen leaching distributions. The most important model input parameters were irrigation water, soil texture, and initial soil nitrogen (N). Soil properties were collected from a 61 x 61 m grid. Soil samples were converted to raster format, with a 12.2 x 12.2 m grid size, by a nonparametric blocking algorithm (Han et al., 1993). The raster data were converted to ARC/INFO data map layers. Altogether, seven data layers were used to create seven map layers: (1) irrigation water with nitrogen fertilizer, (2) soil texture–0 to 30 cm, (3) soil texture–30 to 60 cm, (4) initial soil N–0 to 30 cm, (5) initial soil N–30 to 60 cm, (6) potato yield, and (7) N leaching. The paper also discusses types of linkages that have been used to interface GIS and

simulation models (two types of linkages: direct simulation with GIS and GIS interfacing with simulation models). In this interesting paper, the authors conclude that improvements in SIMPOTATO can improve the accuracy of the proposed system (GIS with simulation model). They further suggest that the interfacing of GIS and the GIS-ARC/INFO can be useful for site-specific crop management.

Han, S; Evans, R; Hodges, T; Rawlins, S. 1995.
Linking a geographic information system with a potato simulation model for site-specific crop management.
J Environ Qual 24:772–777.

The authors used a GIS for developing potato crop management practices. Using the GIS, they studied potato yield and nitrogen leaching distributions. They determined that the most important factors were irrigated water/nitrogen, soil texture, and initial soil nitrogen. The GIS helped them identify the overwatered areas, and they found that uniformly irrigating the fields increased potato yield and reduced nitrogen leaching. However, a significant limitation of the study was that field verification of the model's estimated potato yields and nitrogen leaching was not possible due to budget constraints. The authors noted that all inputs to the model were based on measured data, so they believe that the results of the model should be relatively accurate.

Hansen, HS. 1997.
Interactive analysis of spatial data.
In: Kraak, MJ; Molenaar, M; Fendel, EM, eds. Advances in GIS research. Proceedings, Seventh International Symposium on Spatial Data Handling. London: Taylor & Francis, pp. 895–904.

This article describes how interactive spatial statistical analysis tools can be built into a vector desktop GIS (specifically ArcView 2.0) to perform exploratory data analysis. The article begins by describing five analytical methods (Moran's I, Geary's c, G_i-statistic, G_i*-statistic, and Moran Scattergram) that are used to analyze spatial autocorrelation (association) in geographical data. It then describes the code that was written in ESRI's Avenue object-oriented programming language to implement these analytic methods. Illustrations are provided to show how the resulting enhancements to ArcView allow ordinary users to perform spatial autocorrelation analysis in an interactive easy-to-use desktop environment. An example application is provided involving analysis of the regional distribution of root crops on the Danish island of Funen.

Hardin, D. 1995.
Computer tools simplify sewer planning, management.
Water Environ Technol 7:34–35.

Software and a GIS system helped Garland, Texas, rehabilitate and manage its wastewater infrastructure. Using GIS, 30 relief sewer options were developed and evaluated for more capacity. The recommended options were then incorporated into the citywide capital improvement plan. Daily maintenance activities were streamlined and tracked by way of the GIS.

Hardzinksi, C. 1994.
Buffering impacts on forest resources: Nett Lake Reservation, Minnesota.
Proceedings, GIS/LIS '94, October, Phoenix, AZ, pp. 434–437.

The advent of GIS technology has enabled tribal managers to integrate the planning of

natural resources, including determining the trade-offs between various land management options or activity levels. For this project, timber harvesting buffers were placed around selected lakes, streams, roads, and community areas on Nett Lake Reservation. This resulted in a 12 percent reduction in the forest acreage available for management. The map product now is used to help locate desired cover types for harvesting and access routes.

Hardzinski, C; Meyer, C; Besougloff, J. 1996.
GIS in Indian country: federal GIS activities.
GIS/LIS News, Summer, 13:1.

The Bureau of Indian Affairs (BIA) within the Department of the Interior is the primary federal agency responsible for management of trust resources on Indian reservations in Minnesota. In the past, the relationship between federal and tribal governments has been one of manager-trustee, raising criticism over a lack of tribal input and control with managing these activities. Significant legislation, however, has been passed over the last 15–20 years, which allows tribal governments to contract with the BIA to perform services on reservations and assume program management administered at the federal level. Necessary components of expanding the tribal role include delegation of authority, transfer of funding, and development of management tools. In these respects, the use of GIS within the BIA has gone through several progressions to transfer the technology to tribal governments, resulting in GIS capability becoming commonplace at tribal offices. GIS capability supports activities such as locational information of animal habitat for use during annual population surveys, analysis of wetlands, maintaining current forest cover type databases in support of forest management, and addressing environmental and cultural impacts of economic development projects. GIS has become an integral part of management activities throughout Indian Country and is contributing to effective management of Native American resources.

Harrington, Jr., JA; Schiebe, FR; Nix, JF. 1992.
Remote sensing of Lake Chicot, Arkansas: monitoring suspended sediments, turbidity, and Secchi depth with LANDSAT MSS data.
Remote Sensing of Environ 39(1):15-27.

This research used water quality data from Lake Chicot, Arkansas, and a corresponding set of LANDSAT MSS data to compare the ability of satellite-based sensor systems to monitor suspended sediment concentration, Secchi disk depth, and nephelometric turbidity. Lake Chicot was selected, in part, because of the availability of a wide range of water quality conditions. Secchi disk depth and nephelometric turbidity are both optical measures of water quality and differ from suspended sediment concentration, which is a measure of the weight of inorganic particulates suspended in the water column. Four different models for these relationships between satellite data and water quality data were tested. Two different solar spectral irradiance curves and an orbital eccentricity correction factor were tested using the exponential model. Results suggest that (1) remote sensing from space-based platforms can provide meaningful information on water quality variability; (2) an exponential model best characterizes the relationship between the satellite data and the water quality measures investigated; (3) slight differences result from using the solar curve proposed by the World Radiation Center (as opposed to the NASA standard); and (4) predictions based on optical measures of water quality, rather than measures of the weight of particles in the water column, are slightly better when using LANDSAT MSS data.

Harris, S. 1997.
Evaluating possible human exposure pathways to populations relative to hazardous materials sites.
Proceedings, ESRI International User Conference, July 8–11, San Diego, CA. (www.esri.com)

Public health personnel in Georgia are using ArcView GIS 3.0 to map sources of hazardous chemicals and the variety of pathways by which such chemicals may be transported to an exposure point, such as drinking water, food, or home. Sources they have mapped include landfills and hazardous waste sites. Transport information includes highways, topographic information, flood extent coverage, and hydrologic information. These data layers, of sources and transport media, were then mapped to indicate possible exposure points, such as wells or showers, where people might come into contact with hazardous chemicals through air or water transport. GIS was used to map potential exposure pathways.

Harris, R; Hopkinson, P; McCaffrey, S; Huntsinger, L. 1997.
Comparison of a geographical information system versus manual techniques for land cover analysis in a riparian restoration project.
J Soil Water Conser 52:112.

The authors are concerned that few studies have attempted to determine the benefits and costs of GIS versus manual cartographic analysis. Thus, they set out to compare the cost involved in calculating land-cover areas with a GIS and manual calculations using a planimeter and dot-grid. The authors also conducted simple modeling of riparian forest restoration potential to determine the value of the GIS for restoration planning. The authors found that both the GIS and manual methods arrived at similar results, but the cost of using the GIS was many times greater. However, the authors do point out that an advantage of GIS is that the data are permanently stored and may be easily retrieved. For an untrained person, the authors found that developing a simple modeling procedure was difficult and time-consuming. The results, while useful, required validation. The authors recommend that decisionmakers consider the long-term benefits and costs before developing a GIS for riparian restoration planning.

Hastings, D. 1992.
Geographic information systems: more than just mapping.
Earth Syst Monitor 4(1):9–12.

This article describes the lessons learned at the National Geophysical Data Center (NGDC) about GIS. The article first describes what a GIS is, followed by the various applications at the NOAA's NGDC in Boulder, Colorado. NGDC uses modern scientific GIS to integrate individual global environmental data sets into a coordinated Global Change Data Base. In addition, they investigate the ability of existing data sets to characterize the global environment. Preliminary work with statistical techniques shows that incongruous relationships often occur between environmental data in existing data sets. Several examples are described. The articles also suggests several GIS systems for those who are getting started with GIS, including GRASS (Geographic Resources Analysis Support System) and IDRISI.

Haubner, SM; Joeres, EF. 1996.
Using a GIS for estimating input parameters in urban stormwater quality modeling.
Water Resources Bull 32(6):1341(11).

A GIS was used for estimating water-quality model-input parameters. The model parameters describe watershed characteristics such as land use and cover, building density, soil characteristics, and hydrology. The GIS was used in an urban watershed (Parkers Lake, MN) for the Source Loading and Management Model.

Hay, LE; Battaglin, WA. 1996.
A visual/interactive method for examining the national stream quality accounting network (NASQAN) data.
Proceedings, Watersheds 96–-Moving Ahead Together: Technical Conference and Exposition, June 8–12, Baltimore, MD.

The USGS developed NASQAN in 1973 to describe the water quality of the nation's streams and rivers on a systematic basis and to identify temporal trends in the concentrations of measured constituents. A Scientific Visualization System (SVS) was used to represent visually a three-dimensional model output of the data over time. SVS permits manipulation and display of data that have three spatial dimensions and are time variant. Incorporating SVS techniques into a geographic problem-solving environment can greatly enhance data interpretation because both spatial and temporal dimensions can be explored, large complex data sets can be viewed interactively, and multiple data images can be presented to accommodate a variety of scientific and management perspectives.

Heitgerd, JL; Burg, JR; Strickland, HG. 1995.
A geographic information system approach to estimating and assessing national priorities list site demographics: racial and hispanic origin composition.
Int J Occup Med Tox 4(3):343–363.

The authors used GIS in a proximity analysis of the racial and Hispanic composition of populations living within 1 mile of 1200 National Priorities List (NPL) sites located across the United States. They used ARC/INFO to develop coverages consisting of the site boundaries of these facilities as listed by EPA in 1992. These boundaries define the approximate geographic location and extent of the hazardous substance release as delineated by EPA. The authors also used ARC/INFO to develop 1-mile buffer zones around each facility boundary and determine the size of the population living within this buffer. The potentially impacted "community area" was defined as the area within the NPL site boundary plus the 1-mile buffer zone. The population site values were derived by summing all the census blocks within the impacted areas for each county. This shifted the focus of the analysis from the NPL sites to the counties within 1 mile of those sites, while retaining the block level observational data. Across the United States 670 counties had a part of their total area located within 1 mile of the 1200 NPL sites. The comparison population was defined spatially as those living in one of the 670 impacted counties but more than one mile from the site. They used a cross-sectional design to estimate the total population, including breakdowns by race and Hispanic origin, at the census block level for areas within 1 mile of these sites. The results indicate that about 11 million people live within the impacted areas and that racial and Hispanic origin distributions around the sites generally are consistent with regional population differences. The results of the ANOVA indicate significant differences in the mean percentage for each racial and Hispanic origin group between those living within the impacted area and those living within the comparison area. No statistically significant difference was found for the percentage of whites living in the impacted versus the comparison areas.

Hemenway, Jr., DF. 1996.
Best of the net 1996.
GIS World. January. http://www.geoplace.com/print/gw/1996/0196/0196feat.html.

The article provides the best links (the most useful sites) for GIS, including the best database site, corporate GIS site, and so on.

Henry, MS; London, JB; Brooks, KR; Singletary, LA. 1991.
GIS: a new tool for local economic development.
In: Clouser, R, ed. Rural infrastructure and economic issues: information systems, transportation and education. Proceedings, Regional Workshop, Southern Region Information Exchange Group-53, 3–4 October 1990, Atlanta, GA SRIEG-53 Publication No. 1, SRDC Publication No. 146, April, pp. 35–41.

The article presents background information on how GIS can be used in land-use planning. Several examples illustrate how GIS has been applied for this purpose throughout the country. One conclusion in the article relates to how GIS may fit into the field of public health or urban planning: "If GIS can help to bridge the gap between research results that show up in scientific journals and the willingness of policy makers to make decisions based on the best evidence available, the cost of buying into GIS may be small relative to the benefits of more effective public infrastructure investment policy." This conclusion is something to ponder.

Hession, WC; Shanholtz, VO. 1988.
A geographic information system for targeting nonpoint source pollution.
J Soil Water Conserv 43(3):263–266.

The project was designed to use a GIS in estimating potential sediment loadings to streams from agricultural lands, mainly for the purpose of Chesapeake Bay water resources management in Virginia. The approach incorporated use of the universal soil loss equation (USLE) and a delivery ratio to make the estimates. Three levels of analysis were built. The first level incorporated all the Virginia portion of the Bay drainage and dealt with analyses of terrain across the entire area. The second level was more focused on critical agricultural areas, where the greatest improvements could be made. The third level was the individual farm level. Performance of the database was yet to be evaluated at the time of the paper, but the products appeared useful on all three intended levels of service.

Heuvelink, GB; Burroughs, PA. 1993.
Error propagation in cartographic modelling using Boolean logic and continuous classification.
Int J Geo Info Sys 7:231–246.

These authors indicate that soil and ground-water attributes are manipulated by logical cartographic modeling; however, these results are often assumed to be exact. In reality the results will be in error because the values of input attributes cannot be determined exactly. Also the effect may not be definable by a simple rule. For example, if erosion hazard for each polygon or pixel is determined from a set of rules based on soil texture, percent slope, and vegetative cover, the erosion hazard may be still be a problem even if all three rules are not exceeded. Thus the process may be much more complicated than the simple rules are able include. This paper analyzes how errors in such values propagate through Boolean and continuous modeling involving the intersection of several maps. The error analysis was conducted using Monte Carlo methods on data interpolated by block kriging to a regular grid, which yields predictions and

prediction stand deviations of attribute values for each pixel. The results suggest that Boolean methods of SIEVE (overlaying different maps) mapping are much more prone to error propagation than the continuous equivalents. Thus continuous classifications may be one way to deal with the problem of discrete boundaries or breaks between classes or groups. This is a good paper, although somewhat technical and difficult to abstract without a lot of detail. Several useful concepts are presented. Keywords: error, GIS, SIEVE, pixels, Booleans, fuzzy sets.

Hewitt, M. 1994.
Crossing the ARC/Oracle Bridge
Geo Info Sys 4(8):26–27.

This article describes the learning process of EPA's EMSL research laboratory in connecting ARC/INFO to the Oracle RDBMS instead of the RDBI as the database integrator (DBI) for their EMAP program. The purpose of the DBI is to increase the information functionality of ARC by allowing direct interface with very powerful and robust relational data base systems such as Oracle. Their objective was to enhance the existing functions of the EGI and DBI by providing a user-managed bridge, in a product called ABE. The Windows Motiff interface allows the following functions: connect, import, join, and query. Although the bridge was successful, the group suggested that complicated queries should use SQL queries. However, EMAP decided to employ Oracle as their backbone RDBMS.

Hodgson, ME; Gaile, GL. 1996.
Characteristic mean and dispersion in surface orientations for a zone.
Int J Geo Info Sys 10:817–830.

Statistical methods to describe surface orientation (slope and aspect) in an area or zone are described and discussed. Aspect statistics are problematic because of the circular scale used to measure aspect and the hemispherical scale for both slope and aspect. Two techniques are presented for computing the mean and dispersion measures of aspect and a bidirectional surface orientation. The relevant directional statistics and calculations are discussed with appropriate examples (circular mean aspect and dispersion for zone and hemispherical mean aspect and dispersion for zone).

Hunsaker, CT; Schwartz, PM; Jackson, BL. 1996.
Landscape characterization for watershed management.
Proceedings, Watersheds 96–-Moving Ahead Together: Technical Conference and Exposition, June 8–12, Baltimore, MD.

Many studies have shown that the proportion of different land uses within a watershed can account for some of the variability in surface water quality. This paper outlines the application of landscape pattern metrics for monitoring and assessing regional water quality. Land-use and -cover data came from the Advanced Very High Resolution Radiometry (AVHRR) satellite imagery. Landscape pattern was characterized by proportion of seven land-use types and several integrative metrics-dominance, contagion (shape complexity). Disturbed land covers like agriculture, barren, and rangeland have positive associations with water-quality parameters. Contagion and proportion of forest were found to be negatively correlated with water quality parameters. Thus, an area that has contiguous land covers or that is dominated by forests tends to have better water quality.

Hyde, A. 1997.
Regulated facilities that pose a threat to sensitive habitat.
Proceedings, ESRI International User Conference, San Diego, CA July 8–11. (www.esri.com).

This paper describes work in Indiana using GIS to determine what industrial facilities are located near sensitive habitats that contain endangered species. This is a good example for EPA because the author describes all the EPA data from the various programs (toxics, air, and water) that were collected for a given facility. Needless to say, data integration is ongoing. They identified which facilities to look at based on the location of the sensitive habitat mapped with a quarter-mile "buffer zone." Facilities had to fall in three or more buffer zones to be identified for analysis.

Inskeep, WP; Wraith, JM; Snyder, RD. 1996.
Soil and climate data input.
J Environ Qual 3:445(9).

Four readily available data sets of soil and climate inputs were used in the Chemical Movement through Layered Soils (CMLS) model to estimate the depth of picloram movement at the end of a growing season in Teton County, Montana. The ARC/INFO GIS was used to generate and organize the input data for the model runs and to prepare maps showing different predicted picloram leaching depths. The four databases are described. The two CMLS model runs that used the USDA-NRCS County Soil Survey Geographic database soil inputs in place of the USDA-NRCS State Soil Geographic data base soil inputs identified numerous small areas where the predicted depth of the picloram solute front exceeded 100 cm. The overall results indicated that CMLS model predictions can vary with the choice of climate and soil inputs.

Iredale, H. 1995.
NOAA's coastal change analysis program (C-CAP) monitors critical marine habitats.
Earth Syst Monitor 5(3):1–8.

The Coastal Change Analysis Program (C-CAP), a component of NOAA's Coastal Ocean program, has begun coordinated studies to monitor the alterations of coastal areas of the United States. C-CAP is working with EPA's Environmental Monitoring and Assessment Program, the F&G National Wetlands Inventory, and other federal agencies. Their purpose is to enhance protocol, conduct regional change analysis using remotely sensed data, and establish data management infrastructure. C-CAP employs satellite images and aerial photography to cover large coastal areas of interest in order to monitor functional stats and changes in critical habitats. LANDSAT satellite Thematic Mapper sensor scenes will be used when feasible. C-CAP will use the data to determine land cover and changes between years. Submerged aquatic vegetation is also monitored. Data are available for distribution.

Jacobs, A. 1996.
All roads lead to the 'net (web-based geographic information systems).
Computerworld 30(28):45(1).

Users have easy access to spatial-analysis information now that GIS has become available on the web. Currently, only MapInfo is offering its ProServer web-based program, but other GIS vendors are likely to follow, according to market research. Industry experts indicate that GIS market revenue expanded 18.3 percent in 1995 to $548 million. Part of the growth in GIS comes from customers using information generated from maps to assist in managing businesses.

Observers also suggest that use of the internet and corporate intranets will make it more cost-effective and easier to introduce GIS projects. One of the main benefits of ProServer is that MapInfo charges for licenses based on the number of people who need to access data rather than the number of desktop systems in a company.

Jacobs, A. 1996.
Mapping software finds the 'net (ESRI Inc to introduce ArcView 3.0 geographic information system, Internet-based mapping software).
Computerworld 30(32):44(1).

ESRI Inc. is readying ArcView 3.0, a new version of its flagship GIS, along with a new internet-based GIS due later in 1996. ArcView 3.0 includes a new plug-in architecture with modules that simplify specific tasks such as spatial analysis and determining the best travel routes between two points. The web-based MapObjects mapping tool will let users create mapping and GIS applications that reside on a web server and access dynamic maps and other data via a browser on an intranet or the internet. Some users are wary of doing mapping over the internet, citing high costs and security concerns.

Jaquet, JM; Schanz, F; Bossard, P; Hanselmann, K; Gendre, F. 1994.
Measurements and significance of bio-optical parameters for remote sensing in two subalpine lakes of different trophic state.
Aquat Sci 56(3):263-274.

Bio-optical measurements were carried out on eutrophic Lake Zug and oligotrophic Lake Lucerne, to provide data and models for the in situ calibration of multispectral imagery collected in 1991 during an AVIRIS flight over Central Switzerland. The results indicate that Secchi depth, chlorophyll and total suspended solid concentrations, vertical extinction coefficient, absorption coefficient, and irradiance reflectance in the PAR region can be used to discriminate between the two lakes. Dissolved organics concentration, scattering and total attenuation coefficients estimates, as well as backscattering probability, are less acceptable because of instrumental limitations. Relationships between optical and water quality parameters were investigated and found to behave according to accepted theoretical frameworks. Both lakes exhibited vertical and horizontal heterogeneities in chlorophyll and turbidity, and had contrasting mean bio-optical characteristics: although suspended solid concentrations were similar, transparency was lower in Lake Zug, but reflectance was substantially higher in Lake Lucerne. Water color determined by chromaticity analysis was blue-green in Lake Lucerne and green in Lake Zug. Reflectance spectra simulated through a three-component optochemical model did not completely match those derived from in situ measurements, because of lack of site-specific optical cross-sections for suspended minerals and dissolved organics. The monitoring of water quality in subalpine lakes by remote sensing, both with present and future technology, is discussed and considered as possible, provided that their optical behavior is known, and preferably expressed by a valid optochemical model.

Jensen, JR; Narumalani, S; Weatherbee, O; Morris KS; Mackey, HE. 1992.
Predictive modeling of cattail and waterlily distribution in a South Carolina reservoir using GIS.
Photogrammetric Eng Remote Sensing 58(11):1561–1568.

The authors developed a model to predict the spatial distribution of cattails and waterlilies using spatially distributed biophysical information and a GIS. The GIS was used to store data,

query the database, and employ Boolean logic to predict macrophyte distribution. The model was built using the concept of "environmental constraint criteria"; that is, macrophytes would be present in a given pixel if all of the environmental criteria were met. The criteria were developed using Par Lake and included water depth, slope, fetch, soil type, and temperature. The same criteria were measured in L Lake and boolean logic was applied to predict where the macrophytes would occur. Monitoring of L Lake qualitatively verified the model's predictions.

Ji, W; Johnston, J. 1994.
A GIS-based decision support system for wetland permit analysis.
GIS/LIS, pp. 471–476.

The National Biological Survey developed a permit database in Alabama as a pilot for coastal wetland permit analysis. This was a test of the Multifunctional Coastal Ecosystem Decision Support GIS, which encompasses wetland restoration planning, biodiversity modeling, and spill damage and contaminant risk assessment. Such decision support systems help resource managers to organize and analyze huge volumes of environmental data for decisionmaking.

Johansen, ME, Tommervik, H; Guneriussen, T; Pedersen, JP. 1994.
Using a geographic information system (ARC/INFO) as a tool for integration of remote sensed and in-situ-data in an analysis of the air pollution effects on terrestrial ecosystems in Varanger (Norway) and Nickel-Pechenga (Russia).
Proceedings, International Geoscience and Remote Sensing Symposium (IGARSS '94), August, Pasadena, CA., Vol. 2, pp. 1213 Published by IEEE.

This paper demonstrates the damage to vegetative cover due to transboundary air pollution from industrial sources. Air pollution and contamination data were combined with vegetation cover maps. This use of ARC/INFO as a remote sensing tool has broader applications, particularly the methods of verifying and correlating the remote sensing based maps with the air pollution data.

Johnson, BE; Smith, RH; Anderson, JL. 1995.
Comparison of distributive vs. lumped rainfall-runoff models on Goodwin Creek Watershed.
Integrated water resources plan for the 21st century. Proceedings, 22nd Annual Conference, American Society of Civil Engineers/et al. May 7–11,Cambridge, MA, pp. 1065(4).

A GIS was incorporated in a two-dimensional distributive hydrology model (CASC2D) to simulate rainfall/runoff in the Goodwin Creek Watershed. CASC2D's ability to simulate streamflow runoff hydrograph shape, rate of rise, and volume is unmatched by the lumped model approach when accurate watershed spatial data are available, and without the subbasin stream gauge data on which the lumped models rely.

Johnson, G; Myers, W; Patil, GP; Walrath, D. 1996.
Multiscale analysis of the spatial distribution of breeding bird species richness using the echelon approach.
Center for Statistical Ecology and Environmental Statistics. Pennsylvania State University. Technical Report No. 96-0601.

The authors apply the echelon method for characterizing spatial distribution of species richness (see related paper under Myers et al., 1996, below). The analysis may aid in objectively identifying areas for particular protection. The objective was to examine changes in pattern at different scales to see whether the conclusions of the analysis would alter. Echelon objects of the

first order are identified by moving outward and downward until saddles between peaks are identified. All polygons between the saddles then become members of that echelon. The process is conducted iteratively. The authors used Pennsylvania Breeding Bird Atlas data to demonstrate the method. Species/polygon pairs were codified according to the degree of subjective probability that a given species occurred within that polygon. EMAP hexagons were used to illustrate the large degree of aggregation; breeding bird blocks were used to illustrate a smaller degree of aggregation scale. The comparison between the two scales was investigated by examining "globally high/locally moderate" and "globally moderate/locally high" combinations, using cumulative species-area curves. Globally moderate/locally high polygons exhibited jagged curves, indicating a fragmented landscape with local pockets of high diversity.

Jones, J. 1997.
Federal GIS projects decentralize
GIS World 10(8):46–51.

In the past, the federal government instigated GIS technology. Now the government is leaning more toward using commercial products. The author cites examples: FEMA is using ARC/INFO for disaster modeling and mitigation. The Agency is also developing a new management software package. At EPA, GIS operations are being decentralized, mostly because use of GIS has become so widespread. In the past, ARC/INFO was standardized but is now more open to other vehicles. The Bureau of the Census relies on an array of commercially available GIS packages, but also has developed proprietary GIS software. The Department of Transportation is another major GIS user, as are the Department of Defense and the National Imagery and Mapping Agency.

Jungert, E. 1997.
A qualitative approach to recognition of man-made objects in laser-radar images.
In: Kraak, MJ; Molenaar, M; Fendel, E., eds. Advances in GIS research. Proceedings, Seventh International Symposium on Spatial Data Handling. London: Taylor & Francis, pp. 943–954.

This article describes a qualitative method for matching the three-dimensional images provided by aircraft-based laser-radar sensors to previously stored model objects. The aim is to identify manmade objects. The matching process is based on generating qualitative slope descriptors (QSDs) for the images and the stored objects and then seeing if the two match. QSDs contain angle and quadrant information about the line segments that compose an object. The article begins by describing the characteristics of laser-radar images. Then, the process of generating QSDs is presented. Next, the article describes how the QSDs are used to perform object matching. The article concludes with a discussion of how image distortions are handled and identifies problems that require further investigation.

Juracek, KE. 1994.
Interactive query of state water-appropriations and water-use information.
Geo Info Sys 4(11):44–48.

GIS technology was used to develop a user-support tool to summarize water-appropriations and water-use information by geographic area, source of water, and type of water use. The tool is referred to as the Water Information Management and Analysis System (WIMAS). WIMAS can be used to perform ground-water level analysis by yielding spatial

averages, and trends; provide surface water information, stream flow data; monitor ecologically sensitive areas; and assist in regulating water structures.

Juracek, K. 1994.
Interactive query of state water-appropriations and water-use information.
Geo Info Sys 4(11):44–48.

Managing and analyzing data-intensive water resources is a challenging task. In Kansas, a primary source of hydrologic information is the Kansas State Board of Agriculture's Division of Water Resources, which maintains extensive digital databases containing information about water appropriations and water use by point of diversion. To date, use of the databases by the Division of Water Resources and other agencies has been inhibited by lack of an effective means to access, analyze, and display the information. To remedy this situation, the division, in cooperation with USGS, used GIS technology to develop a user-support tool referred to as the Water Information Management and Analysis System (WIMAS), to summarize water-appropriations and water-use information by user-defined geographic area, source of water, and type of water use. The systems capabilities and applications of WIMAS are described. One such example was the recent study to assess the effect of saline river water on ground-water quality, where WIMAS generated data files for input to a ground-water flow model.

Juras, AA. 1995.
Application of remote sensing in studies of water quality in the Amazon Region.
Lakes Reservoirs Resource Manage 1(2):141-145.

This paper deals with basic matters concerning use of remote sensing and GIS techniques related to limnological/water quality surveys in the Amazon Region. The main conclusions are: (1) it is important to use these techniques for detecting problems before the construction of new projects involving water resources in the Amazon Region and (2) remote sensing focused on water quality should be seriously considered in planning Brazil's space program as a means of providing data for more effective water basin management.

Kang, YT; Kahniser, TE; Wolfson, LG; Bartholic, JF. 1994.
WIMS: a prototype wetlands information management system for facilitating wetland decision making.
Proceedings, American Congress on Surveying and Mapping/American Society of Photogrammetry and Remote Sensing (ACSM/ASPRS), April, Reno, NV. Vol. 1, pp. 290–300.

Like the above project, this project produced a tool for evaluating wetlands. It is narrower in scope in that there is less surrounding the GIS component. It also has a GRASS version as well as an ARCH/INFO version.

Kao, J-J; Lin, H-Y; Chen, W-Y. 1997.
Network geographic information system for landfill siting.
Waste Manage Res 15(3):239–253.

A prototype network GIS was developed to (1) improve a complex municipal solid waste landfill siting procedure in Taiwan, (2) provide siting information to the general public, (3) assist local environmental protection agencies with maintenance of their GIS, and (4) facilitate managing, instructing, and evaluating local landfill siting in Taiwan. A multimedia network interface provided continuous local or remote access to the system via the internet.

Kay, D; Stoner, J. 1988.
The effects of catchment land use on stream water quality in an acid-susceptible region of West Wales: the implications for compliance with EC drinking water and fishery directives.
Appl Geogr 8:191–205.

This paper examines the effects of catchment land use on water quality. Each of the three broad land-use groups (afforestation, moorland, and improved agriculture) present different problems with respect to noncompliance with drinking water criteria. Useful to reference the impact of these types of land use on water quality.

Kellogg, RL; Maizel, MS; Goss, DW. 1992.
Agricultural chemical use and ground water quality: where are the potential problem areas?
U.S. Department of Agriculture, Soil Conservation Service, Economic Research Service, Cooperative State Research Service, National Center for Resource Innovations. NAL TD427 A35K45. Washington, DC: USDA.

This is a good document that utilizes GIS technology to evaluate the potential of pesticides to contaminate ground water. Databases used include soils databases (NRI and SOI-5), pesticide use databases, crop data, etc. The leach class of different soil map units was determined from soils data (attributes). By overlaying different layers, the areas with high potential to contaminate ground water with pesticides and nitrate-nitrogen were identified. This is a good summary paper. The available data were discussed and integrated into a national assessment using GIS technology. Keywords: ARC/INFO, NRI, SOI-5, MLRA, hydrologic units, pesticide leaching potential.

Kellogg, RL; Maizel, MS; Goss, DW. 1994.
The potential for leaching of agrichemicals used in crop production: a national perspective.
J Soil Water Cons 49:294–298.

This study was designed to help define areas of the country with the highest priority for study and program implementation, and to develop leaching vulnerability indices for pesticides and nitrates. Pesticide and nitrate leaching indices were developed and maps showing distribution were prepared. This is a good, useful paper that presents a practical use for GIS to help manage ground-water contamination.

Kessler, B. 1995.
PC based GIS grows on foresters.
J Forestry 93(5):28–29.

The author discusses successes and difficulties encountered by foresters transitioning from traditional, centralized computer management to PC-based GIS forest management. One of the biggest problems was making data readably accessible to field personnel. Working with PC ARC/INFO ESRI developed a system linking directly the main office with foresters in field offices. This system allowed for data to be quickly exchanged and used in GIS-based analysis at the main office.

Kester, D. 1992.
Global ocean observing system.
Proceedings, Ocean Climate Data Workshop, February 18–21, Greenbelt, MD. Published by NASA/Goddard Space Flight Center, Greenbelt, MD. Abstract printed in Aquatic Sciences &

Fisheries Abstract (ASFA) #3, p. 95.

A Global Ocean Observing System (GOOS) should be established now with international coordination (1) to address issues of global change, (2) to implement operational ENSO forecasts, (3) to provide the data required to apply global ocean circulation models, and (4) to extract the greatest value from the $1 billion investment over the next 10 years in ocean remote sensing by the world's space agencies. The objectives of GOOS will focus on climatic and oceanic predictions, on assessing coastal pollution, and on determining the sustainability of living marine resources and ecosystems. GOOS will be a complete system, including satellite observations, in situ observations, numerical modeling of ocean processes, and data exchange and management. A series of practical and economic benefits will be derived from the information generated by GOOS. In addition to the marine science community, the energy industries of the world and the world's fisheries will benefit. The basic oceanic variables required to meet oceanic and predictability objectives of GOOS include wind velocity over the ocean, sea surface temperature and salinity, surface current, sea level, extent and thickness of sea ice, partial pressure of CO_2 in surface waters, and chlorophyll concentration of surface waters. Ocean circulation models and coupled ocean-atmosphere models can be used to evaluate observing system design, to assimilate diverse data sets from in situ and remotely sensed observations, and ultimately to predict future states of the system. The volume of ocean data will increase enormously over the next decade as new satellite systems are launched and as complementary in situ measuring systems are deployed. These data must be transmitted, quality controlled, exchanged, analyzed, and archived with the best state-of-the-art computational methods.

Khakural, BR; Robert, PC. 1993.
Soil nitrate leaching potential indices: using a simulation model as a screening system.
J Environ Qual 22:839–845.

The authors describe how results from different screening models (LEACHM-N and NLEAP) using soil survey information (attributes) were used to compare simulated NO_3-N lost to measured NO_3-N lost. These leaching losses were then broken into six nitrate leaching potentials classes that were assigned to different map units based upon their soil properties. Thus the leaching potentials were assigned, using GIS, to a soil map (soil map units) to produce a leaching potential map for a county.

Khorram, S; Cheshire, H; Geraci, AL; La Rosa, G. 1991.
Water quality mapping of Augusta Bay, Italy from LANDSAT-TM data.
Int J Remote Sensing 12(4):803-808.

LANDSAT Thematic Mapper (TM) digital data were used to map the distributions and concentrations of selected water quality indicators in and around Augusta Bay, Sicily. The general approach involved near-simultaneous acquisition of TM data and water quality samples from 42 sites; laboratory analysis of samples; extraction of sample site digital numbers from the TM data; development and validation of regression models based on sample data, application of models to the entire study area; and generation of color-coded output maps. Results were good for modeling temperature, turbidity, Secchi disc depth, and chlorophyll-a, and indicate that remotely sensed data as part of GIS may be applicable to monitoring water quality in this geographic area.

Kihn, E; Kroehl, H. 1994.
The global inventory of biomass burning (GIBB) project.

Earth Syst Monitor 5(2):8–10.

The National Geophysical Data Center (NGDC) has undertaken the Global Inventory of Biomass Burning (GIBB) project to produce the first systematic, global inventory of fires and to compute the resulting greenhouse gas emissions, including CO, CO_2, CH_4, O_3, NO_2, hydrogen, methylchloride, and particulates. The GIBB project will construct daily maps of fire locations and estimate the quantity of greenhouse gases emitted by these fires. Global fires are clearly seen in nighttime images recorded by Defense Meteorological Satellite Program instruments at visible and near infrared wavelengths during each orbit. For example, forest fires during the summer's tragic fire season in the western United States provided an opportunity to develop, test, and evaluate our fire detection algorithms. Another example showed smoke from fires in Borneo hanging over Singapore.

King, GQ. 1991.
Geography and GIS technology.
J Geogr 90:66–72.

The author discusses GIS and presents a case for inclusion of GIS in a geography program curriculum.

Klemas, V; Weatherbee, OP. 1995.
Remote sensing of biomass and stress in coastal wetlands.
Proceedings, 2nd Annual Marine and Estuarine Shallow Water Science and Management Conference, Atlantic City, NJ, April 3–7. Published by U.S. EPA, Philadelphia, PA. pp. 221–228.

Remote sensing represents a synoptic, cost-effective methodology for analyzing land cover and many other attributes of coastal watersheds. For estuarine studies, land-use change represents a key layer in GIS-type databases. For instance, changes in land-use patterns affect nonpoint source pollutant runoff and may alter wetlands health and estuarine water quality. The goal of this effort was to improve coastal management on a regional and national scale by utilizing remotely sensed data in a GIS framework to integrate and evaluate land-use change and condition indicators that are important for monitoring and managing wetland/estuarine health. Condition indicators are characteristic of the environment that elicits a change in the condition of an ecological resource. They include both natural and human-induced stressors. Selected stressor indicators are particularly useful when a relationship between specific condition and stressor indicator can be established. For instance, for the past 7 years researchers at the Center for Remote Sensing have developed remote sensing techniques to map the biomass of large Spartina marshes. The spectral reflectance signature variations can be related to changes in Spartina biomass induced by stress. The stress may be caused by salinity variations, changes in local hydrology, or runoff from undesirable land uses. As a result, the Wetlands Subcommittee of the Federal Geographic Data Committee has endorsed biomass as a convenient indicator of wetland health, which can be measured over large areas by carefully executed remote sensing techniques. Instead of attempting to measure all biological/chemical/physical properties, however, we are optimizing the procedure by determining key condition/stress indicators that can be obtained cost-effectively by remote sensing. When indicators change beyond prescribed threshold values and "sound the alarm," the GIS approach will help users relate these changes to land-use change and ecological properties and aid in formulating the appropriate response. This approach optimizes data acquisition and processing for effective decisionmaking; i.e., only those

stress/condition indicators will be measured and processed that are required to solve specific problems or make management decisions.

Knapp, P, Bishop, K; Lancaster, J; Taylor, R. 1993.
Use of GIS in optimizing timber thinning strategies in the Eastern Sierra Nevada.
Prof Geographer 45(3):323–331.

This paper demonstrates the use of GIS to develop timber-thinning strategies on the Kyburz Planning Area of the Tahoe National Forest in northeastern California. The primary criteria used in the assessment of selective thinning potential were forest health and fire hazard ratings. By eliminating environmentally sensitive, economically unfeasible, or low fire hazard areas from consideration, use of GIS reduced the area that was considered appropriate for thinning by approximately 58 percent. GIS offers considerable potential for improving resource management strategies. The major benefit of using a GIS to develop timber-thinning strategies is that it allows the Sierraville Ranger District (SRD) to view a variety of different scenarios before implementing a management program. The project was developed to assess the feasibility of using GIS to develop new resource management strategies in the Tahoe National Forest. Feedback from SRD personnel about the results has been favorable.

Kondratyev, KY; Pozdniakov, DV. 1992.
Development of optical remote-sensing techniques for studying the quality of inland waters.
Environ Conserv 19(4):354.

Problems of nature conservation and management are becoming more and more urgent. One problem that has acquired critical significance in many countries is water quality (and, first of all, drinking-water quality). Regular monitoring of water quality is a necessary condition for conservation and management of rivers, lakes, and water-storage reservoirs, which are the basic sources of drinking water. A very efficient way of monitoring such waterbodies is through application of remote-sensing techniques to obtain data on water-quality parameters. This paper presents results of studies on the subject that were conducted in St. Petersburg, Russia. The techniques mentioned were used to determine the concentrations of chlorophyll-a (CHL) in phytoplankton and dissolved organic matter (DOM). Two complementary approaches have been developed: (1) passive and active optical remote-sensing, which are based on the effects of specific absorption of natural light by the CHL and DOM molecules, respectively, and (2) the effect of forced fluorescence of the same matter under the influence of laser radiation having a certain wavelength.

Laiderman, J. 1997.
Site selection.
Business Geogr 5(2):20–23.

Using data to identify customers, screen markets, choose sites, and analyze a trade area involves collecting data, sampling, and use of models.

Lais, S. 1997.
Groups clash over mapping agency's role.
Gov Comput News 16(19):1–80.

When users and producers of federal mapping data met recently, sharp disagreements arose over how information technology can best meet national policy demands. Defense and

civilian agencies viewed the creation of the National Imagery and Mapping Agency (NIMA), which combined defense and intelligence mapping organizations into a single group, with some trepidation. Though NIMA's outreach efforts have somewhat alleviated anxiety, tough talk on Capitol Hill about NIMA budgets is generating new fears that Congress will underfund the agency. NIMA needs a new strategy to ensure that customers are receiving and understanding their products. Different agencies often want the same information, but presented differently.

Landry, R; Fournier, RA; Ahern, FJ; Lang, RH. 1997.
Tree vectorization: a methodology to characterize fine tree architecture in support of remote sensing models.
Can J Remote Sensing 23(2):91–107.

A tree vectorization methodology was developed to characterize architectural parameters in individual jack pine trees. The objective of the study was to implement a method to generate a realistic geometric description of a complete forest tree. The method had to preserve a realistic spatial distribution of all wood and foliage elements as a function of height and radial distance to the trunk. Species-specific branch curvature and branch and foliage clumping also had to be considered. The study site was in the boreal forest of central Saskatchewan, Canada.

Lathrop, Jr., RG; Van de Castle, JD; Brass, JA. 1994.
Monitoring changes in Greater Yellowstone lake water quality following the 1988 wildfires.
GeoCarto Int 9(3):49-57.

The fires that burned in the Greater Yellowstone Area (GYA) during the summer of 1988 were the largest ever recorded for the region. Wildfire can have profound indirect effects on associated aquatic ecosystems by increased nutrient loading, sediment erosion, and runoff. Satellite remote sensing and water quality sampling were used through GIS to compare pre- versus post-fire conditions in the GYA's large oligotrophic (high transparency, low productivity) lakes. Inputs of suspended sediment to Jackson Lake appear to have increased. Yellowstone Lake has not shown any discernable shift in water quality. The insights gained separately from the LANDSAT Thematic and NOAA AVHRR remote sensing systems, along with conventional in-situ sampling, can be combined into a useful water quality monitoring tool.

Leavesley, GH; Markstrom, SL; Brewer, MS; Viger, RJ. 1996.
The modular modeling system (MMS)–the physical process modeling component of a database-centered decision support system for water and power management.
Water Air Soil Pollut 90(1–2):303(9).

A GIS interface component is being added to the Modular Modeling System (MMS). MMS consists of three components–preprocess, model, and postprocess; it allows the coupling of physical process models with water and power resource-management models. The GIS interface will permit the testing of a variety of objective characterization and parameterization techniques for MMS.

Lee, JK; Park, RA; Mausel, PW. 1992.
Application of geoprocessing and simulation modeling to estimate impacts of sea level rise on the northeast coast of Florida.
Photogrammetric Eng Remote Sensing 58(11):1579–1586.

The objective of the paper is to demonstrate how geoprocessing techniques can be applied

to simulate responses of coastal wetlands to sea-level rise. The model used, SLAMM, simulates the effects of sea-level rise on a cell-by-cell basis. A decision tree is used to govern transfers among coastal classes. Input variables include elevation, sedimentation, and accretion rates; proximity of the marsh to the coast; and presence of dikes. The model computes changes in wind and wave action and beach erosion rates. The model was applied to an area near Jacksonville, FL. ERDAS and PC ARC/INFO were used along with SPOT imagery. Supervised classification was used to classify coastal areas into 22 landcovers. Under reasonable scenarios, the simulation predicted a significant loss of coastal marshes. This is partially because it was assumed that dry lands would be protected by engineering solutions and would not be converted to marsh. The authors noted that the input and output of data were a significant factor in efficient integration of digital data and GIS software. In addition, attention to the appropriate scale was essential in choosing the structural details of modeling. When remotely sensed data are used, the spatial scale used in data input and manipulation must be appropriate to the process resolutions of the model.

Leopold, G. 1996.
DOD details digital-mapping initiative.
Electron Eng Times, June, 905:142.

This article describes an initiative to develop geospatial information systems for battlefield data. Description of an attempt to combine intelligence data and digital imagery, distributed in real-time, routed through GIS to assist U.S. troops in battle.

Leung, Y; Leung, KS. 1993.
An intelligent expert system shell for knowledge-based geographical information systems. 1. The tools.
Int J Geo Info Sys 3:189–199.

This paper presents a tool to enable better use of GIS data. Current GISs typically use Boolean logic, a rigid mathematical system that gives no allowance for imprecision in information, human cognition, perception, and thought process. The authors suggest that Boolean logic sometimes leads to fundamental problems in representing the information and decision analysis. They present some fuzzy logic and expert systems technology as a means of enhancing intelligence in GIS. ("Fuzzy logic is a non-standard logic within which an inference is a deduction of imprecise conclusions from a set of imprecise premises.") Some potential applications are presented. Keywords: Expert systems, GIS, fuzzy logic, FLESS (fuzzy-logic-based expert system shell).

Leung, Y; Leung, KS. 1993.
An intelligent expert system shell for knowledge-based geographical information systems: 2. Some applications.
Int J Geo Info Sys 3:201–213.

Some fairly detailed examples (specific rules) are presented concerning the use of fuzzy logic with respect to GIS (land type, climate, etc.). This is an interesting series of papers, but it is not clear how the system could be used within GIS (in ArcView). It may be useful in pre-GIS preparation of input data. This type of information is useful for work involving imprecise (i.e., fuzzy) data.

Liao, H-H; Tim, US. 1994.
Interactive water quality modeling within a GIS environment.
Comput Environ Urban Syst 18(5):343(21).

The availability of GIS offers tools to spatially structure and manage water quality data for modeling exercises. An interactive water quality modeling scheme derived within a GIS environment is described. Pollutant export and soil erosion models are combined with ARC/INFO software, which describes geographic information about spatial elements, and a graphic user interface. The system also permits cost-effective use of simplified water quality models for assessment of nonpoint source pollution in watersheds. The interactive modeling technique represents a spatial decision support tool to target critical areas of water quality problems.

Limp, FW. 1997.
Weave maps across the web.
GIS World 10(9):46–55.

This article reviews four web-based mapping products: Autodesk MapGuide 2.5, ESRI MapObjects Internet Map Server for ARC/INFO, Intergraph GeoMedia Web Map 1.0, and MapInfo ProServer. This reviewer logged on to ESRI's MapObjects Internet Map Server and used their demo, which applies Toxic Release Inventory System data by zip code. This product was impressive.

Limp, FW. 1997.
Weave maps across the web.
GIS World 10(9):46–55.

This article compares four web-based mapping products: MapGuide, Internet MapServer for Map Objects and for ArcView, GeoMedia Web Map and ProServer. Much of the information about these packages is quite technical. However, this may become a good resource for learning about (1) the differences in use of image graphics vs. graphic objects, (2) using map prepublishing vs. direct data access, (3) client-level requirements, (4) amount of geographical analysis accessible from the Web, and (5) data and platform restrictions. The article appears to conclude that the "best" product depends on how the product is to be used. The authors sum up the article by saying that if one's data are already in a certain format and cannot be transferred to another system, then one's decision is made. If data restrictions do not exist, one should decide which product to use based on, for example, whether one wants to do spatial queries, address matching, detailed geographical entities, or extensive interaction with live relational databases.

Lindell, L; Steinvall, O; Johnson, M; Claesson, TH. 1985.
Mapping of coastal water turbidity using LANDSAT imagery.
Int J Remote Sensing 6(5):629–642.

LANDSAT data along with Secchi disk depth was used to determine relative nutrient and solids loading situations around the Swedish coast and as a basis for the applicability of laser bathymetry for water depth surroundings.

Liu, G; Coleman, TL; Gooding, E. 1995.
Windows-based GIS in demographic analyses.
Proceedings, GIS/LIS '95, Volume II, Annual Conference and Exposition, November, Nashville, TN, pp. 646–658.

The authors present a framework for using Windows-based GIS software to create a base map and thematic map for demographic analyses. They also provide information comparing some of the features of different GIS systems, such as Atlas GIS, ArcView, and ARC/INFO. They discuss some basic characteristics of the TIGER Line Files and indicate the steps needed to convert these data files into a base map of census tract boundaries. They also discuss the need for obtaining population attribute data to create appropriate demographic theme maps using the tract base maps. They discuss some of the features of the Census Summary Tape files and how one can use these for the attribute tables and map products.

Lo, KFA. 1995.
Erosion assessment of large watersheds in Taiwan.
J Soil Water Conserv 50(2):180(4).

GIS technology supplemented the application of the Agricultural Nonpoint Source Pollution (AGNPS) Model in quantifying erosion problems at the Bajun River Basin and the Tsengwen Reservoir Watershed in Taiwan. Hydrology, erosion, and sediment and chemical transport were simulated to estimate sediment yield per hectare and total watershed yields and to assist in prescribing watershed soil conservation practices.

Logan, B. 1996.
Fishing for a river solution.
Comput Canada 22(22):52.

GIS was used to deal with problems caused by sudden temperature increase in the Fraser River system in British Columbia, which adversely affected salmon migration patterns. Salmon migration patterns and spawning data were combined with other data such as water level, water temperature, air temperature, and snow melting patterns for the Department of Fisheries and Oceans Fraser system DBMS. The data were combined with an existing digital mapping system to provide timely data analysis and prevent future problems.

Loibl, W. 1997.
Modeling tropospheric ozone distribution considering the spatio-temporal dependencies with complex terrain.
In: Kraak, M; Molenaar, M; Fendel, E, eds. Advances in GIS research. Proceedings, Seventh International Symposium on Spatial Data Handling. London: Taylor & Francis, pp. 667–677.

This article describes the digital elevation model that was developed to reflect the elevation and diurnal variations in ozone concentrations throughout Austria based on data from a national network of ozone monitoring stations. First, using regression analysis, standard ozone/elevation/daytime functions were derived where the standard ozone concentration was described as a function of the (1) relative elevation from the local valley bottom and (2) time of day. The standard function produces ozone values reflecting of a typical summer day. To reflect seasonal, day-specific, and local influences, a deviation curve was added to the model. It was calculated in terms of the deviations in day-specific hourly measurements from those produced by the standard function at three elevation ranges. The result was a day-specific ozone/elevation curve that was then used to calculate a cell-by-cell ozone concentration for insertion in the digital elevation model. A complete ozone concentration surface was produced for each specific hour of a specific day. The resulting DEM needed to be further modified to reflect local geographical influences on ozone concentration. Interpolation needed to be used to reflect the influence of

local deviations as a function of the distance from a given monitoring site. However, traditional spatial interpolation could not be used to produce the deviation surface because the local deviation in ozone concentration is dependent on altitude, i.e., the lower the relative elevation, the higher the deviations in ozone concentration. To reflect this, an elevation-dependent weighting function was derived and then interpolation was performed by inverse distance weighting. Using the interpolation, a cell-by-cell deviation surface was created for the DEM. Day-hour-specific ozone concentration maps for Austria were then produced by simple cell-by-cell addition of values from the (1) day-specific DEM ozone concentration surface and (2) final DEM deviation surface. The resulting daily maps have been continuously disseminated since 1996 by the Federal Environmental Agency of Austria on the internet.

Lopez, XR. 1996.
Stimulating GIS innovation through the dissemination of geographic information.
J Urban Reg Inf Syst Assoc 8(2)24–37.

This article discusses access and commercialization of spatial databases and three alternative models for information dissemination (cost-recovery, proprietary partnerships, and open-access).

Lopez, XR. 1996.
Stimulating GIS innovation through the dissemination of geographic information.
J Urban Reg Inf Syst Assoc 8(2):24–37.

This article suggests that government agencies, because they are using systems such as GIS that are providing better ways to keep public information, are at a cross-road for deciding how they should disseminate the information. The author proposes three alternatives: (1) cost recovery (i.e., anyone who wants the data can have it but they must help pay the cost of maintaining system), (2) proprietary partnerships (i.e., government contracts with companies who will disseminate information for profit), and (3) open-access (i.e., make data available at marginal cost to anyone and private sector can market the data if they wish). The author believes the third alternative provides the greatest benefit.

Lotz, T. 1996.
A landmark in Lima, Ohio: The legacy of West Ohio Gas continues as GIS charts the utility's second century course.
Geo Info Sys 6(3):16–21.

As part of the company's reorganization for growth, West Ohio Gas Company (Lima, OH) has integrated a GIS, known as the Asset Information Management System (AIMS), one year ahead of schedule and 10 percent under budget. The company's overall goal is to grow in the increasingly competitive energy market by being more competitive and by focusing more intently on new products and services to meet customer needs. GIS, as well as related automated mapping/facilities management systems (AM/FM), has gained widespread use among natural gas and other utilities in recent years. GIS technology is being used as a tool to manage spatial information about facilities; their relationship to customers, products, or services these facilities offer; and the land environments in which they operate. AIMS' functions will benefit the entire company and will include linkage to the company's accounting function to assist with property records management, as well as integration with customer information services to help personnel answering service calls to provide quick answers to customer calls.

Lougeay, R; Stol, MJ; Brazel, A. 1994.
Surface emissivity calibration of LANDSAT thermal data: creating an urban surface temperature map of Phoenix, Arizona.
Geogr Bull 36(2):74–82.

An analysis of surface temperature, extracted from LANDSAT thermal remotely sensed imagery, was compared with current land use in regions of rapidly expanding urban landscapes, near and including Phoenix. Digital values of the LANDSAT Thematic Mapper thermal spectral band can be transformed to observed ground surface temperatures by first calculating the spectral radiance, then calculating the "at satellite" temperature of each pixel. Image maps of surface temperature have been compared with land-use maps. In the rapidly developing area of the Phoenix metropolitan region, one can observe the influence of changing land use upon changing urban climate.

Lovejoy, S. 1997.
Watershed management for water quality protection: are GIS and simulation models THE answer?
J Soil Water Conserv 52:103.

The author argues that using a GIS to predict the exact sources of pollution and the changes in land use necessary to meet water quality objectives may be too costly. He prefers the use of simulation models that allow "micro-targeting" of conservation efforts. He suggests that local decisionmakers first use their limited funds for simple watershed management ideas such as riparian buffers. Then, when the potential for these simple ideas has been exhausted and as more funds become available, the decisionmakers can invest in more hi-tech approaches.

Lowell, K. 1993.
Predictive model development and evaluation with unknown spatial units.
Photogrammetric Eng Remote Sensing 59:1509–1515.

The author worked with a simple model of plant succession: Open-->Cedars-->Forest. The objective was to predict the cover type at a given year by the 1939 cover type, topographic aspect, soil, and distance from a seed source (i.e., forest). To estimate the cover type for a given cell, the author used discriminant functions using values of the independent variables for that cell. A reduced model, based on 1939 cover types and the number of years since 1939, performed even better than the full model. The author concluded that the full model contained variables that were significant because of spatial correlation only, and so had little predictive value. She concluded that in cases where the units that are spatially independent are not known, an analysis of the spatial autocorrelation of the residuals should be conducted.

Lowry, JH; Miller, HJ; Hepner, GF. 1995.
A GIS-based sensitivity analysis of community vulnerability to hazardous contaminants on the Mexico/U.S. border.
Photogrammetric Eng Remote Sensing 61(11):1347–1359.

The authors provide a detailed description of how they used GIS technology to estimate and determine community vulnerability to hazardous material releases in the Mexico/U.S. border community of Nogales, Sonora/Arizona. They used composite mapping analysis (CMA) to model community vulnerability using information on the location of potential hazard material generation sites relative to the locations of sensitive populations (i.e., children under 18 years old, adults over

65 years old) and institutions (i.e., schools, hospitals, clinics). The authors show how GIS enhances the CMA approach to vulnerability analysis and allows development and exploration of a well-structured set of vulnerability scenarios based on different weighting of the input variables. They developed eight spatial data layers reflecting variables that can be meaningfully partitioned into two major components: hazard-related and human-related factors. The hazard-related data layers included location of industrial facilities and two modes of hazardous material transmission (surface and sewer transmission). The human-related data included layers representing the two sensitive age groups, population density, and sensitive institutions. They describe in detail how they generated 18 different vulnerability scenarios from these data layers and performed a sensitivity analysis to determine the key variables and robustness of the model. They provide maps to show how the location and ranking of vulnerable areas change as the assumptions and weighting factors change for the different scenarios. They conclude that this GIS-based community vulnerability model is robust in predicting estimates of high and very high vulnerability, but is less robust in predicting very low, low, and medium vulnerability. They believe this is good, since the zones of highest vulnerability are the most important for evacuation planning. They also summarize data access and quality issues and the differences between U.S. and Mexican data.

Luettich, Jr., RA; Kirby-Smith, WW; Hunnings, W. 1993.
PSWIMS, a profiling instrument system for remote physical and chemical measurements in shallow water.
Estuaries 16(2):190-197.

PSWIMS (Profiling Shallow Water Instrument Mounting System) is a relatively simple instrumentation system developed to remotely collect vertical profiles of physical and chemical parameters in shallow water that is subject to significant changes in depth. The system is designed for observations that cannot practically be made with moored sensors (due to the high cost of multiple sensors, the physical size of sensors, or the inability of moored instruments to accommodate changes in water depth) or with hand-held sensors (due to the need for frequent observations over extended periods of time). Results are presented from two field deployments that demonstrate the utility of PSWIMS for measuring horizontal flux and for monitoring water quality parameters in shallow water.

Lull, KJ; Tindall, JA; Potts, DF. 1995.
Assessing nonpoint source pollution risk.
J Forestry 93(1): 35–40.

In accordance with the 1987 Renewal of the Clean Water Act, Section 319, states have to assess, identify, and define water quality problem areas and their causes. The state of Montana developed an erosion-impact matrix and implemented a risk analysis using GIS on two pilot study areas. Results from the two studies indicated that resulting information was good for relative comparisons. However, detailed analysis of the watershed required extensive field monitoring and verification.

Lynch, J, Bowersox, VC; Geimm, J. 1996.
Trends in precipitation chemistry in the U.S. 1983–94. An analysis of the effects in 1995 of phase I of the clean air act amendments, Title IV.
U.S. Geological Survey, distributed by USGS, Information Services, open file report 96B0346

June 1996.

This is an evaluation of NADP/NTN (National Acid Deposition Program / National Trends Network) data for anion, cation, and precipitation amount. GIS is applied to create contour plots of concentration and percent changes in compounds of interest. The kriging technique is used for visualization.

Mack, C; Marsh, SE; Hutchinson, CF. 1995.
Application of aerial photography and GIS techniques in the development of a historical perspective of environmental hazards at the rural-urban fringe.
Photogrammetric Eng Remote Sensing 61(8):1015–1020.

The authors use GIS technology to study how land use/land cover changed between 1954 and 1985 in a 155 sq km area of western rural-urban fringe in Phoenix, AZ, and to evaluate the relationship between land use and environmental hazards. The study was designed to gain historical perspective on changing land use within the urban-rural fringe in order to provide significant insight into the nature of environmental hazards (past and future) in these dynamic areas. The study was undertaken as a result of a reported high incidence of childhood leukemia concentrated in a residential neighborhood of Phoenix. The authors summarize how they developed land-use/land-cover maps from interpretation of historical aerial photographs and layered this over USGS topo base maps. They also performed a topological comparison of the known and possible waste disposal classes in 1976 with digital soil maps. The authors graphically show how several key land-use/land-cover categories have changed during this 32- year period. The results also show that significant areas of historical dumping may currently, or sometime in the future, expose residents to environmental hazards, because the majority of these landfills and dump sites have been located along the Salt River in soils unsuited for waste disposal. (The Salt River flows along the southern border of the study area.) A large percentage of the abandoned waste disposal sites have been converted to public, urban undeveloped, and industrial land uses. The authors concluded that historical land-use information could be coupled with information on waste disposal using GIS technology to gain a unique perspective on environmental risk.

Malthus, TJ; Dekker, AG. 1994.
First derivative indices for the remote sensing of inland water quality using high spectral resolution reflectance.
Proceedings, Inland and Coastal Water Quality '93–Measurement and Modelling, J Env International 21(2):221-232.

Remote sensing is a technique with potential for monitoring the surface water quality of lakes and rivers. However, new technologies are required in order to overcome the poor spatial and spectral resolutions of conventional satellite sensors. This paper presents the results of novel derivative analyses applied to both high spectral resolution subsurface reflectance and similar data obtained at 450 m above lakes in the Netherlands. Several first derivatives, at 670, 722, and 840 nm wavelengths, showed good potential for the prediction of surface suspended matter concentrations. These were similar in strength to correlations found between reflectance in a single band and suspended sediment. First derivatives of reflectance, at 620, 638, and 661 nm in particular, showed higher correlations with chlorophyll-a concentrations than did individual reflectance wavebands. The results suggest that derivatives of reflectance, calculated using high spectral resolution reflectance, may be used as the basis for indices for detection of inland water quality and warrant further study.

Mandrak, NE. 1995.
Biogeographic patterns of fish species richness in Ontario lakes in relation to historical and environmental factors.
Can J Fish Aquat Sci 52:1462–1474.

This is a very nice paper. Spatial autocorrelation may result from spatially structured historical and environmental variables affecting species distributions, or may be the result of extraneous variables not included in the study. It is a confounding factor that may produce spurious correlations between pattern and process variables. The objectives of this study were to (1) identify patterns of fish-species richness in Ontario Lakes; (2) look for relationships between richness and historical and environmental factors, controlling for scale and autocorrelation; and (3) postulate processes that influence observed patterns of regional lake species. A quadrate sampling scheme was used. The spatial structure was examined by plotting Moran's I coefficient against the distance between quadrat centers. The dependent variable was species richness. Explanatory variables included distance from dispersal corridors, the time since the last glacier, climate, elevation, lake chemistry, and morphometry. Spatial autocorrelation was partialled out of the data set using the partial Mantel test (Smouse et al., 1986). Principal coordinates analysis was conducted only on the corrected set. Each matrix exhibited spatial correlation. After adjustment, only climate and postglacial dispersal explained a significant amount of the variation in species richness. Greater species richness was found in quadrats close to entry locations of dispersal corridors and covered by glacial lakes for the longest periods of time.

Mangold, G. 1996.
Farming with precision.
Successful Farming, December.

Precision farming is also known as site-specific management (SSM). It involves collecting and controlling information to accurately manage parts of fields for actual needs instead of whole fields for the average need. SSM uses a variety of computer-related information including GIS, GPS, remote sensing, direct sensor technology, and variable rate technology (VRT). One main point of the article is that information age farming is about information, and not about "contraptions," as the author refers to computers.

Mann, WW. 1995.
Land use/transportation impact model-LUTRIM.
Proceedings, 33rd Annual Conference of the Urban and Regional Information System Associates (URISA). July, San Antonio, TX. Journal of the URISA, Vol. 1:710–722.

LUTRIM combines urban land-use and urban transportation models to determine transportation impacts on land uses. Factors include real estate values, crime, air quality, school ratings, and traffic congestion. The program can be used as a land-use model, a travel forecasting model, or both, to measure impacts of transportation improvements on land-use forecasts.

Marr, P; Schoolmaster, FA. 1988.
An application of GIS to monitoring site changes in gasoline service stations and underground storage tank locations
Proceedings, GIS/LIS '88, Third International Conference, Nov. 30–Dec. 2, San Antonio, TX, pp. 852–860.

The authors demonstrate the use of GIS (ARC/INFO) to inventory and monitor underground storage tank locations and ownership regardless of changes in surface land. The study was conducted in Denton, Texas. The authors identified 136 former and current gasoline stations in Denton based on field work, zoning records, and interviews with long-time residents of the town. They provide maps showing the town's streets and locations of all gas stations and reused and abandoned underground storage tanks. They also provide a table listing the 11 data layers they developed and their attributes. They also indicate that a water quality monitoring program of public and private wells and streams was needed so that data layer could be added to provide updates to the ground-water flow models and facilitate detection of leaked materials. The authors list four applications resulting from development and implementation of such a GIS-based monitoring system, such as the improved capability for proactive (routine monitoring and checking) and reactive (emergency response) leak detection.

Masuoka, P; Foresman, T; Fifer, S; Acevedo, W; Clark, S; Crawford, J; Buchanan, J. 1995.
Visualization techniques for the analysis of Baltimore regional GIS data.
Proceedings, GIS/LIS '95, Volume II, Annual Conference and Exposition, November, Nashville, TN, pp. 704–712.

The authors are involved in a joint research project to assemble a GIS consisting of maps, census data, and satellite images of the Baltimore, MD, area from the 1700's to the present. The GIS will eventually be expanded to include a 2-degree by 2-degree region that encompasses the Baltimore-Washington corridor. When completed, this system will allow researchers to study historical changes in urban and rural patterns, population density, and land cover. The authors very briefly discuss preliminary work being done to test various ways to visualize the data in preparation for the completed GIS. Data sources include 1:100,000 and 1:250,000 scale DEMs, vector data of roads and urban land cover, and LANDSAT TM imagery. The authors very briefly summarize some of the major pros and cons of the different images tested as backgrounds for displaying the GIS data. They briefly discuss original DEM images, contour maps, shaded relief maps, color-encoded shaded relief maps, and Thematic Mapper images as possible backgrounds. They selected TM images and the original DEM since they were thought to provide the best backgrounds for displaying Baltimore urban growth and transportation data.

Mathews, KB; MacDonald, A; Aspinall, RJ; Hudson, G; Law, AN; Paterson, E. 1994.
Climatic soil moisture deficit–climate and soil data integration in a GIS.
Clim Change, 28(3):273(15).

Many researchers predict that significant global warming will occur over the coming decades due to the buildup of greenhouse gases. This warming will likely have profound impacts on both climate and agricultural practices around the globe. The design and development of a GIS-based technique for predicting potential effects of climate change on the susceptibility of soils in Scotland to drought are described. The primary focus of this research was the generation of a technique for mapping available water capacity in soils. A sample assessment of the soil drought susceptibility of Scotland in the year 2030 is presented to illustrate the effectiveness of the methodology. The scenario is examined with maps and derived statistics.

Mattikalli, NM. 1995.
Integration of remotely-sensed data with a vector-based geographical information system for land-use change detection.

Remote Sensing 16(15):2813–2828.

Remotely sensed images are increasingly being used to derive land-use data. Methods have not been developed to analyze vector formatted data for land-use change. The data derived from satellite images will be in raster format. To integrate raster data with large volumes of vector data already available in a GIS, an effective data integration technique is needed. This paper presents a methodology for integrating remotely sensed raster data with vector data.

Mattikalli, NM; Richards, KS. 1996.
Estimation of surface water quality changes in response to land-use changes: Application of the export coefficient model using remote sensing and geographical information system.
J Environ Manage, 48(3):263(20).

The authors developed a strategy to determine hindcast water quality changes (nitrogen and phosphorus concentrations) utilizing remote sensing data, geographic information system techniques, and historical land-use data to describe increased agricultural intensification and heavy reliance on chemical fertilizers. They applied this export coefficient model to an eastern England watershed.

May, JW. 1994.
Automated mapping and GIS in Florida local planning agencies.
URISA, pp. 755–770.

Local comprehensive planning has been mandatory in Florida since 1989 due to the pressures of rapid population growth. In 1993, the 459 local government units were surveyed about their use of computers in this effort. A followup survey was sent to 96 local planning agencies that had a planning agency and planning staff, that used computers in their planning work, and that used an automated mapping system. Eight percent of all city planning agencies in Florida and 43 percent of all county planning agencies in Florida use a GIS. A profile of these planning agencies was developed. The agencies use GIS for a variety of purposes, including land-use and natural resources inventories. The biggest institutional issues faced by these agencies were general budget constraints, base map preparation, and inconsistent management/political support. Most agencies believe GIS was worth the investment and is meeting some or all of their expectations. The author predicts increasing GIS inroads at local planning agencies to improve their analytical capability and decisionmaking. This experience provides guidance to other organizations planning to work with GIS, as well as to GIS natural resources data seekers that it is widely available.

McCann, AJ; Joubert, L; Gold, AJ; LaBash, C; August, PV; Puffer, RH. 1994.
Training municipal decision-makers in the use of geographic information systems for water resource protection.
Proceedings, Annual Symposium of American Water Resources Association (AWRA), Jackson Hole, WY, Jun 26-29, p55–64. Published by AWRA.

The Narragansett Bay Nonpoint Source Water Pollution Control Program was initiated in 1992 by the University of Rhode Island to protect water-supply reservoirs and the bay. A major thrust of the program is education of municipal decisionmakers about the relationship between land use and water quality. A GIS has been incorporated into the training scheme, because GISs are often used to develop future land use scenarios and to assess their impact on water quality. Decisionmakers can then choose the scenario that best fits their water quality goal. The GIS

training program is described, which was developed using personnel from Portsmouth and Middletown. Once the participants had gained an understanding of GIS and had worked with the software, several simple water quality models were used as illustration. The models effectively demonstrated to the participants the impact of future land-use practices on drinking water supplies. Both municipalities are now planning to use GIS for future planning purposes.

McCollough, D; Moore, K. 1995.
Issues and methodologies in integrating aerial photography and digital base maps.
Geo Info Sys 5(3):46–50.

The article discusses using aerial photographs to capture thematic data in digital form (wetlands inventory) for British Columbia, Canada. The article explores the advantages and disadvantages of alternative methods, including digital orthophoto, stereo analytical plotter, and monorestitution.

McConville, DR; Owens, TW; Redmond, AS. 1996.
Geospatial application: a geographic information system interface designed for use in river management.
National Biological Service, Environmental Management Technical Center, Onalaska, Wisconsin, July 1996. LTRMP 96-TOO3. 21 pp. + Appendixes A-B.

The main objective in developing the program for this project was to show planners how a GIS can assist in design and evaluation of a Habitat Rehabilitation and Enhancement Project (HREP). Frequent flooding and the resulting sedimentation can have negative effects on the biota in Calhoun Point at the confluence of the Illinois and Mississippi rivers in Calhoun County, IL. Flooding can kill tree seedlings if they are overtopped by floodwaters and can destroy moist-soil vegetation and agricultural crops used by wildlife. Sedimentation can also prevent the growth of aquatic vegetation and inhibit movement of and suitable spawning habitat for several species of fish inhabiting backwaters of Calhoun Point. The most important element of the management plan was determined to be recreation of the low-head levee system around the area to simplify water level management in the area, reduce frequency of flooding, and reduce sediment inflow. Data layers used in the Calhoun Point Interface included land cover/use, 1989; land cover/use, 1975; land cover/use, 1930; land cover/use, 1903; land cover/use, 1890's; land cover/use, 1817; wetlands coverages; soils; elevations; photocomposites; Calhoun Point Management Areas; roads; endangered species; historical or archeological sites; and fisheries research sites. The modeling components included elevation change impact, dike design, dike development, dike effectiveness test, and flood animation. The modular design of the interface facilitates modification of the program, and, as such, the interface could be readily adapted for use with another HREP in another area of the Mississippi River.

McGarigle, B. 1994.
Drawing the line: accurate data collection.
Geo Info Sys 4(10):29–33.

The Fish and Wildlife Division of the Department of Environmental Conservation of New York State is responsible for mapping more than 1.5 million acres of wetlands, assessing the environmental impact of numerous proposed projects, and protecting endangered and threatened species. Those responsibilities have led to creation of the GIS-based Master Habitat Data Bank (MHDB). This article describes a pilot program to explore use of differentially corrected global

positioning system technology for acquiring new data and updating previously acquired data for the data bank and other fish and wildlife applications. The MHDB project is an ongoing project to integrate and automate natural resource data for planning, protecting, and managing fish, wildlife, and their habitats in New York. GIS has the largest role in analysis and display of land management areas and habitat locations of rare and endangered species.

McGarigle, B. 1994.
Drawing the line: accurate data collection; evaluating DGPS support for New York's master habitat data bank.
Geo Info Sys 4(10):29–33.

This article describes the use of the differentially corrected global positioning system (DGPS) to update and acquire data for the Master Habitat Data Bank (MHDB) in New York. The data are used to support GIS applications for the Fish and Wildlife Division of the Department of Environmental Conservation of New York. DGPS was evaluated for a variety of uses, including mapping regulatory wetland boundaries and endangered species habitats; locating rare, natural community areas and forest-covers, and hiking trails; and monitoring sites for toxicity. GIS maps identifying habitats are used to determine if endangered species are located in areas of proposed activities; the same maps also may be used to study animal behavior and population fluctuation. DGPS may prove to be a more accurate means of collecting these data.

McGarigle, B. 1996.
Satellite imagery–higher resolution, lower prices.
Gov Comput News 9(12):17–19.

High-resolution satellite imagery, previously restricted to intelligence organizations, is about to make a commercial debut. In the next 2 years, U.S. companies plan to launch satellites carrying sensors capable of recording and transmitting images of the Earth's surface with 1-meter resolution. Fully processed images will be precise enough to meet U.S. accuracy standards for 1:2400 scale mapping–detailed enough to spot a motorcycle from 400 miles out in space. The combination of domestic and foreign competition may put the cost of high-resolution imagery well below that of aerial photography. France and Japan are now providing satellite imagery, with Russia selling 5- and 8-meter resolution data. The article discusses advantages and disadvantages of the various media, including black-and-white and multispectral color imagery. In addition, the article discusses the costs, and software and hardware requirements for the different media.

McGarigle, B. 1996.
High school students win national awards with GIS.
Gov Comput News 9(7):1–48.

An Oregon High School teacher and his students won the national Educational Model Program from President Clinton and EPA for forming the Coastal Studies and Technology Center. The Center provides opportunities for students to study GIS and other technologies while participating in environmental projects conducted by state and local government. In addition to serving as a research and development center for students, faculty, and the larger community, the center provides science programs that emphasize modern technology applications in coastal and watershed studies. One such study included formation of a jetty in Trestle Bay, off the Columbia River. The center provides a link between the community, students, government, and academia via real-life projects.

McGarigle, B. 1997.
Land-use planning by joystick.
Gov Comput News 10(6):20–22.

The city council members of Scottsdale, AZ, formed a team that came up with a prototype system that "flies" observers through three-dimensional digital terrain imagery and computer-generated models in real time. This replaced static images and lay interpretations of maps. The users can zoom in, pull back, show scenes from any perspective, and changes features on the fly to create "what-if" scenarios. Even better, they can visualize the appearance of proposed developments and designs. The visualization is a representation that lets decisionmakers focus on the issues, not the data. The system has been used in actual cases of land acquisition, general planning, zoning, and design.

Medina, IC; Schattanek, G; Nichols, Jr., F. 1994.
A framework for integrating information systems in air quality analysis.
URISA, Proceeings, 32nd Annual Conference of URISA (Urban & Regional Information System Association, August, Milwaukee, WI. Published by URISA, Vol. 1, pp. 339–348.

This paper outlines experience with linking air quality analysis and transportation planning for the Boston Central Artery/Third Harbor Tunnel project. This effort evaluated possible air quality impacts of several proposed alignments, predicting air pollutant levels over the 23 most congested and sensitive locations in the area by integrating transportation planning, vehicle emission, and air quality dispersion models. The vehicle emission factors model was EPA's MOBILE5, which is about to be upgraded. Challenges included sharing data between CADD and GIS computer systems and training staff in both.

Meiner, A. 1996.
Evaluation of AVHRR-based land cover data as input for regional modelling of nutrient load to the Baltic Sea.
Proceedings, HydroGIS '96: Application of Geographic Information Systems in Hydrology and Water Resources Management, April, Vienna, Austria. IAHS publ. no. 235, pp. 629–635.

The author examined the accuracy of land-cover data from satellite imagery by comparing AVHRR (ALC) with an existing map classified using TM data (LLC). The land-cover information will be used as part of a regional model of nutrient loads to the Baltic Sea. He investigated the classification of forest vs. open land. In order to compare the two, the LLC had to be generalized from a 30 m cell size to a 1110 m cell size. He did this using a filter and the majority value. He used ARC/INFO GRID and IDRISI to calculate correlations and the Kappa Index of Agreement. There was low agreement in the two data sets–only slightly above chance. Best agreement was achieved with coniferous forests and open/dry bogs. Landscapes with mixed patterns and small land-cover units are estimated the worst by the ALC.

Meiner, A. 1996.
Integration of GIS and a dynamic spatially distributed model for non-point source pollution management.
Water Sci Technol 33(4–5):211(8).

A GIS was extended to include a network model of nonpoint source pollution . The model integrates, over a watershed, a set of irregular, contiguous spatial objects and is thus a distributed-parameter, zero-dimensional, quasi-unsteady simulation technique.

Mellerowicz, KT; Rees, HW; Chow, TL; Ghanem, I. 1994.
Soil conservation planning at the watershed level using the universal soil loss equation (USLE) with GIS and microcomputer technologies: a case study.
J Soil Water Conserv 49:194–200.

This paper gives a procedure to integrate databases and geographic information to characterize the spatial distribution of the risk of soil erosion by water. This was used to identify areas suitable for three different possible management procedures to reduce erosion. The watersheds considered for planning tend to be relatively small, less than 20 km^2. The USLE was used to calculate the predicted annual soil loss rates. Soil survey, land-use inventory, property ownership, digital elevation data, and climatic atlases were used to generate the USLE factor values. Methods are described both in the methodology section and in two generalized flow charts (figures). The paper discusses how the authors developed the data. Ultimately, each factor in the USLE or management practices had a map with one set of unique polygons. The authors identified that the most limiting factor was the accuracy of estimating the USLE factor values in portraying the physical and management conditions of the watershed. This reviewer did not see any discussion concerning the resolution or accuracy of the work. This paper is a good reference to help design a GIS project. System used: Computer Aided Resource Information System (CARIS).

Mersey, JE. 1997.
Life after lectures: the internet as a resource for a senior undergraduate GIS course.
Cartographica 26:38–45.

The author reports on student reaction to an Internet site that was designed to help them out in their GIS course. The site included course information, bibliographical references, acquisition of digital maps and data sets, communication with GIS experts, listservers, and familiarization with post-graduation opportunities in GIS. Most useful were the search engines, which gave the students a starting point for beginning research on GIS-related projects.

Mikhova, D; Pickles, J. 1994.
Environmental data in Bulgaria: problems and prospects.
Prof Geographer 46(2):228–235.

Research projects dealing with transition in the former centrally planned economies of Eastern and Central Europe face great difficulties of data availability. Environmental problems arose as a result of virtually unregulated pollution by large state industrial and agricultural enterprises that placed production considerations above all others. In the process of economic and environmental reconstruction, a crucial need of researchers and policymakers is good data on production systems, technology use, energy and chemical inputs and outputs, and impacts on particular ecosystems. Many data are not available, and what are available are poorly documented or unreliable. This paper describes some of the problems of data availability in the context of environmental research in Bulgaria. It describes current efforts to upgrade national- level environmental monitoring capabilities, and argues for the need for the development of locally sensitive systems of data collection and analysis.

Miller, RL; Cruise, JF; Otero, E; Lopez, JM. 1994.
Monitoring suspended particulate matter in Puerto Rico: field measurements and remote sensing.
Water Resources Bull 30(2):271-282.

The spatial distribution of suspended particulate matter (SPM) was estimated in Mayaguez Bay on the west coast of Puerto Rico by using traditional ship board measurements and remotely sensed data acquired over 4 days during January 1990. This effort was part of a joint project between NASA and the University of Puerto Rico to develop techniques to monitor the water quality of a Caribbean coastal zone. This paper presents the methods and algorithms developed to map and analyze short-term changes in the source and spatial distribution of SPM in Mayaguez Bay by using remotely sensed data acquired by the Calibrated Airborne Multispectral Scanner (CAMS). A PC-based data acquisition system was developed to record continuous ship measurements of select in-water variables. Spectral reflectances derived from CAMS red and near-IR data were corrected for atmospheric effects and then used to generate GIS maps of SPM. These maps displayed SPM plumes associated with the mouths of the bay's three river systems. Significant day-to-day differences in the spatial characteristics were observed, suggesting that changes in river discharge occurred. However, a GIS analysis of estimated river discharge, sediment yield, local wind field, and thermal river plume indicates that observed sediment plumes result primarily from wind-driven resuspension events.

Millie, DF; Paerl, HW; Hurley, JP. 1993.
Microalgal pigment assessments using high-performance liquid chromatography: a synopsis of organismal and ecological applications.
Can J Fisheries Sci 50(11):2513-2527.

Past and current efforts at identifying microalgal phylogenetic groups rely largely on microscopic evaluation, which requires a high level of taxonomic skill, may take considerable time, can be variable among personnel, and does not allow characterization of the physiological status of the taxa. High-performance liquid chromatography (HPLC) has proven effective in rapidly separating and distinguishing chlorophylls, chlorophyll-degradation products, and carotenoids within monotypic and mixed algal samples. When coupled with absorbance and/or fluorescence spectroscopy, HPLC can accurately characterize phylogenetic groups and changes in community composition and yield information concerning microalgal physiological status, production, trophic interaction, and paleolimnology/paleooceanography. The recent widespread occurrence of toxic and noxious phytoplankton blooms has necessitated the use of remote imagery of pigment and reflectance "signatures" for monitoring and predicting bloom distribution. Because HPLC allows processing of large numbers of samples from numerous locations relatively quickly, it is ideally suited for large-scale "ground truthing" of remotely sensed imagery. Coupled with rapidly evolving GIS-based remote sensing technologies, HPLC-based pigment analyses may provide accurate assessments of aquatic biogeochemical flux, primary production, trophic state, water quality, and changes therein on local, regional, and global scales.

Mitchell, JE. 1996.
Effect of spatial resolution on estimating hydrologic response and economic value of an urban forest.
American Water Resources Association Symposium, GIS and Water Resources, September 1996. Ft. Lauderdale, FL.

This study uses *Quanti Tree* to estimate the economic contribution of urban forest to the local community. Factors analyzed include flood reduction, air quality improvement, and property value increases. This study shows that differences in the scale of spatial data can elicit large changes in inferences made from those data. In addition, data aggregation in space greatly

influences these results. This study examines the area known as Bayou Duplantier, in Baton Rouge, LA, and compares the economic value of the Bayou Duplantier generated from derived, aggregated data and from site survey. The original Parish-wide urban forest value was based on data derived from aerial photographs. Annual benefits are calculated for the following specific environmental impact categories as a function of the control strategy used to mitigate their impact on the local environment: particulates below 10 microns, NO_2, CO, SO_2, O_3, carbon storage, runoff, electric power, and gas utilization. Results of the study show that impacts from the planning district aggregated data are generally five times smaller than the site-surveyed data (i.e., total annual benefits of $978,600 [aggregated data] vs. $5,971,500 [site surveyed data] per year). Some differences are to be expected but a fivefold difference indicates a problem in the creation of the derived, district-level model input data.

Molenaar, M. 1997.
The extensional uncertainty of spatial objects.
In: Kraak, M; Molenaar M; Fendel, E, eds. Advances in GIS Research. Proceedings, Seventh International Symposium on Spatial Data Handling. London: Taylor & Francis, pp. 571–583.

The article begins by identifying types of uncertainty with respect to spatial objects: existential, extensional, and geometric. The article focuses on ways that "fuzzy functions" can be used to characterize the extensional and geometric uncertainty associated with spatial objects in both vector and raster format. It first presents how "crisp functions" are used to characterize spatial objects. Then, the author presents fuzzy variants of the crisp functions, showing how they can be used to characterize the extensional and geometric uncertainty of an object. Vector and raster examples are given of the application of fuzzy functions for photo interpretation.

Moragues, A; Alcaide, T. 1996.
The use of a geographical information system to assess the effect of traffic pollution.
Sci Total Environment Vol. 189–190:267–273.

A GIS was used to locate and assess traffic effects expected from the construction of a new section of a ring road around Madrid, Spain. Traffic information was input to a model of a standard day with unchanging weather conditions. The resulting ground-level pollutant concentrations were used to locate and quantify the affected population, as well as wildlife, historic, and archaeological features at risk.

Moss, MR.; Davis, LS. 1994.
Measurement of spatial change in the forest component of the rural landscape of southern Ontario.
Appl Geogr 14:214–231.

The major research objectives of this paper are twofold: first, to describe, quantify, and compare the evolution and change of the pattern of forest "islands" in southern Ontario between the early 30's and late 70's, and secondly to relate both land-use histories and other environmental factors to these changes in spatial relationships amongst the forest islands. At the first stage, all forest islands were digitized for four time periods; at the second stage; woodlot interaction was described using numerous measurements; at the third stage came regional landscape patterns; and the fourth stage was the conclusion–the transformation of rural landscapes in the wake of increased agricultural expansion and urban sprawl has led to a high degree of variance in size, numbers, and spacing of remnant woodlots, hedgerows, shelter belts, and other unique habitats.

Such large-scale modification of the landscape often translates into reduced spatial heterogeneity of resources, with hidden environmental costs resulting from altered soil and water conditions.

Mueksch, MC. 1995.
Airborne hyperspectral monitoring of lake, river, and estuary pollution in Great Britain and Germany.
Proceedings, SPIE International Society of Optical Engineering Conference (2503), pp. 122-130.

Hyperspectral monitoring is an increasingly popular method for satellite and airborne remote sensing. The rapidly developing optoelectronic technology of the last years has promoted this method. Regarding the characteristics of the VIS-spectrum, the most prominent features are located between 600 and 800 nm. High spectral resolution of 1–2 nm within this region shows various peaks correlated with organic compounds and microorganisms. Since pollution is often represented by presence and growth of organic substances and microorganisms, their kind, extent, and distribution in water environments can be detected by hyperspectrometry. The hyperspectral method is still limited by its recording velocities, while applied on high-ground-speed aircrafts. This has impacts on the data gain, quality, and interpretation. Airborne hyperspectrometry was applied for pollution detection in water environments such as lakes, ponds, rivers, coastal and ocean regions, and wetlands. Results were shown and interpreted through GIS integration.

Mulla, D; Perillo, C; Cogger, C. 1996.
A site-specific farm-scale GIS approach for reducing groundwater contamination by pesticides.
J Env Qual 25:419.

The authors evaluated the feasibility of varying pesticide application on different soil types to reduce ground-water contamination. Using data such as carbofuran (a weakly absorbed pesticide) concentration and pore water velocity, the authors estimated the risk of pesticide leaching using two models. The authors found that most of the variability in leaching risk resulted from velocity variations. Thus, the authors concluded that a soil's surface organic carbon content does not control leaching risk for weakly absorbed pesticides.

Muller, E; Decamps, H; Dobson, MK. 1993.
Contribution of space remote sensing to river studies.
Freshwater Bio 29(2):301-312.

A review is presented of types of satellite remote sensing data currently available and their recent uses in studies of river systems. Broad-scale assessments of relative water quality may be carried out, although precise indication of water quality requires that samples be taken in situ. In the event of flooding, the extent of inundation may be determined and damage assessed quickly. Some radar data allow measurements of flood water even when obscured by vegetation. Riparian vegetation may be mapped over large areas, although the recognition of specific tree species remains difficult. One of the most basic and widely used applications of remote-sensing data for rivers is that of mapping, both as a single event and over time to follow changes (e.g. channels in a delta). Entire catchments may be mapped, although the efficiency of detection of low-order stream depends on the characteristics of the system used.

Muller-Karger, FE. 1992.
Remote sensing of marine pollution: A challenge for the 1990s.

Marine Pollut Bull 25(1–4):54-60.

A summary of advances in satellite and aircraft remote sensing of marine pollution is presented. Remote sensing offers large benefits because of the high costs of monitoring using only traditional methods. Nevertheless, much work is needed to refine the technology to address even basic marine pollution problems. This paper briefly outlines studies of water quality assessment, including phytoplankton standing stock, turbidity, suspended sediment load, dissolved organic material, temperature, salinity, wind stress, wave direction and wavelength, current speed and direction, and light attenuation coefficients. The author states that an increasing number of techniques useful to monitor marine pollution will be available in the 1990s. As part of this effort, a solid scientific base for remote sensing methods should be established, and multidisciplinary, international training programs developed. It is capable human resources that we currently lack the most.

Mumford, Jr., TF. 1992.
Characterization of nearshore habitats of Puget Sound, Washington.
Proceedings, SPIE International Society of Optical Engineering 1930(2), pp. 611-625.

This project has determined the most cost-effective methods to inventory and routinely monitor distribution and types of marine and estuarine habitats of Puget Sound, Washington. Remote sensing and geographic information system technologies are used to update the US Fish and Wildlife Service's National Wetland Inventory (NWI) maps. The project is a cooperative effort between Washington's Department of Natural Resources (DNR), the Environmental Protection Agency's Environmental Monitoring Lab in Las Vegas (EPA EMSL-LV), and the Puget Sound Water Quality Authority (PSWQA). The project is now part of the Puget Sound Ambient Monitoring Program, now formalized as a CCMP. Existing inventories–the Coastal Zone Atlas (Ecology, 1980), the Puget Sound Environmental Atlas (PSWQA, 1987), and the National Wetland Inventory–all suffer from either outdated information, inadequate resolution, or inaccurate information, especially in subtidal regions. The data are classified by Dethier's system, which is compatible with the Cowardin classification system used in the NWI. Classified data are transferred to a vector-based GIS and used to update the marine and estuarine portions of the NWI data. Data structure is described. Uses of the data include proprietary management by the Department of Natural Resources to sustain long-term ecosystem and economic viability, wetland protection, oil spill response, natural resource damage, and mandated growth management planning by local governments. Future efforts will include: (1) inventorying the functions of these habitats, (2) determining the annual variation in these habitats and their functions, and (3) documenting long-term changes of habitat and functions.

Murphy, L. 1997.
Why aren’t business schools teaching business geographics?
Business Geogr 5(2):24–27.

Business geographics is one of the biggest applications of GIS, but it requires a champion, teaching with (not about) GIS, and acquiring data. Some commercial educational applications have been developed

Murphy, S. 1995.
Kansas City builds GIS to defray cost of clean water act compliance.
Geo Info Sys 5(6):39–42.

As part of Clean Water Act compliance, Kansas City, Missouri, created a GIS to calculate usage fees to cover the cost of management of its stormwater-runoff system. To ensure that users were being charged fairly and equitably, fees were based on the area of impervious land surface on each water customer's property. Aerial photos and land parcel maps were digitized, and the GIS would calculate the square footage of the hard surface areas (e.g., parking lot, driveway, patios), which directly affect the volume of stormwater runoff that flows into the city's storm system. It used a relational database environment so that fee calculations could be linked to billing addresses.

Murphy, S. 1995.
Kansas City builds GIS to defray costs of clean water act compliance.
Geo Info Sys 5(6):39–41.

Kansas City is enacting usage fees to cover cost of stormwater runoff control improvements. Fees assessed to property owners are based on amount of impervious cover owned. The author used aerial photos at 3500 feet and digitized orthorectified aerial photos and digitized data into GIS. This is an excellent application of GIS to environmental management.

Murphy, L; Smith, T. 1995.
Submerged in the past.
Geo Info Sys 5(10):26–33.

Biscayne and Dry Tortugas National Parks have been the subject of numerous small-area surveys, but have lacked the integrated database needed by resource managers and researchers to adequately map the area. Since 1993, the National Park Service has been conducting surveys designed to provide a comprehensive, cumulative natural and cultural resource inventory accessible through geographic database software. The NPS Submerged Cultural Resources Unit (SCRU) is conducting wide-area remote sensing hydrographic surveys in Biscayne and Dry Tortugas National Park to inventory both natural and cultural submerged resources. These underwater remote sensing surveys are some of the first to be designed specifically for GIS applications, and will be used to preserve the maritime, cultural, and natural history submerged in the Florida Straits.

Myers, R; McElvaney, S; Eberhardt, J. 1996.
GIS in the jungle: monitoring East Maui's rain forest changes from the ground, air, and space.
Geo Info Sys 6(11):16–23.

Habitat destruction is considered the most important factor in species loss, and in Hawaii, invasion of alien plant and animal species is considered the single worst threat to the Hawaiian economy and environment. Alien species have been shown to affect ecosystem function, community structure, and population dynamics. Out of concern for these issues, the East Maui Watershed Partnership (EMWP) was formed in 1992. The group developed a strategy to prevent new weeds from entering the watershed area and targeting those species that pose the greatest threat to native species. In 1995, a pilot watershed monitoring program was initiated to design monitoring protocols for collecting, converting, and integrating data from the ground, air, and space. The researchers coordinated all data collected in the different aspects of their research into a single GIS database. They compiled baseline data for roads, streams, island boundaries, rainfall, land use, vegetation cover, and county, state, and federal management areas, etc. The researchers used GPS (global positioning system) coordinates to link their relational database data to the

spatial database, including historical aerial photos. Using new methods of data integration, the researchers can now better monitor Maui's rain forests to carefully manage this unique ecosystem.

Myers, W; Patil, GP; Joly, K. 1996.
Echelon approach to areas of concern in synoptic regional monitoring.
Center for Statistical Ecology and Environmental Statistics, Pennsylvania State University. Technical Report No. 96-0601.

Echelons provide an objective approach to prospecting for areas of potential concern. They can be thought of as "stacked hillforms." The approach is applicable whenever the regionalized variable has at least ordinal strength of measurement. Echelons can serve as analogs of sampling units for a cumulative distribution function. The strategy is to identify regions of the surface that are staked relative to surroundings. Local peaks are identified first, followed by foundations. Stacking uses the parent-child relationship, with the several peaks belonging to one foundation. The concept is illustrated with data on the breeding occurrence of mammals in Pennsylvania using the EMAP grid. The program is written in d-Base Plus and is available as Shareware. See a related paper under Johnson et al. 1996.

Nachtnebel, HP; Furst, J; Holzmann, H. 1993.
Application of geographical information systems to support groundwater modelling.
Proceedings, IAHS/UNESCO, et al., Aplication of Geographic Information Systems in Hydrology and Water Resources Management International Conference, April 19–22, Vienna, Austria, pp. 653(12).

Experiences with using a GIS for regional ground-water modeling are discussed. Topics covered include data exchange with a GIS, ground-water model design, visualization and display of simulation results, analytical tools, and the open-system concept of communicating with other software tools. Use of the GIS improves spatial data management and preprocessing; other benefits are noted.

Narumalani, S; Jense, J; Hayes, M; Michel, J; Montello, T; Robinson, J. 1993.
Gulf War legacy: using remote sensing to assess habitat in the Saudi Arabian Gulf before the Gulf War oil spill.
Geo Info Sys 3(6):33–41.

The research described in this article assessed the habitat of two bays in Saudi Arabia before the Gulf War oil spill. These bays--Dawhat Al Musallamiyah and Dawhat Ad Daffi--were seriously affected by the oil. A LANDSAT Thematic Mapper scene acquired on 1 September 1990 was geometrically rectified and used as a base map for identifying the most appropriate locations for field transects. The data also were used to classify the physical and biological environments of the two bays. An extensive in situ investigation using global position systems obtained data on the vegetation, soils, and bathymetry of the area from 31 transects located across the bays. Statistical error evaluation techniques were used to compare the remote sensing-derived classification with the in situ data. The habitat database represents significant baseline information, which is being compared using GIS technology with data acquired in a postspill investigation of habitat now under way.

National Resources Defense Council (NRDC). 1997.
Benchmarking all emissions of electric utility generators in the eastern US.

Public Service Electric and Gas Co., Pace University, Mid-Atlantic Energy Project. April 1997. http//www.nrdc.org/nrdepro.

This article presents a comprehensive analysis of air emissions for electrical generation over the eastern United States. It describes the application of GIS to demonstrate regional variations in NOX, SO_2, CO_2, and Hg (mercury) emissions. It describes overlay of emissions on areas designated to be nonattainment, and applies point and pie graphics to demonstrate reductions. Also described are overlay of emissions on kriged visibility data and overlay model output, including a wind vector field from model output and emissions on the same map. Section 5.0 provides detailed procedures for data evaluation and cleanup.

New Jersey State Mapping Advisory Committee (SMAC). 1996.
New Jersey GIS resource guide--1996.
New Jersey Department of Environmental Protection (NJDEP), Information Resources Management, CN428-401 East State St., Trenton, NJ 08625-0428.

This is an excellent guide to GIS as it pertains to the overall operation of a state system and the outlook for national spatial data as part of the NPR and reinventing of government. It can serve as a primer and as a reference for gaining fundamental knowledge of GIS and the information (accuracy standards, mapping standards, data sources, etc.) needed to build and maintain a successful GIS. It is available for $20.

Nichol, JE. 1993.
Remote sensing of water quality in the Singapore-Johor-Riau growth triangle.
Remote Sensing Environ 43(2):139-148.

Remote sensing has not been used extensively in southeast Asia for resource development, partly for reasons of perennial cloud cover and low image availability. However, the low level of awareness of remote sensing among planning and environmental agencies is unjustified in view of the capabilities of high spatial and spectral resolution sensors such as the LANDSAT Thematic Mapper (TM), coupled with a general lack of physical resources data throughout the region. The main objective of this study is to demonstrate the application of LANDSAT imagery to the survey and monitoring of water quality in coastal regions affected by land drainage from peat swamp catchments, which are common in southeast Asia, and where dissolved organic matter (yellow substance) dominates the volume reflectance of coastal water. The TM 0.45-0.52 µm waveband was found to be capable of differentiating water with high concentration of yellow substance from nonplume water, but the addition of the 0.63-0.69 µm waveband was required for differentiating lower concentrations of yellow substance. The higher temperature of river plumes dominated by a yellow substance observed on the 10.5-12.5 µm waveband confirmed field observations. These findings have implications for water resource management in the region, since image-derived classes of water quality can be related to environmental standards for the main types of water use.

Nicholson, MC; Mather, TN. 1996.
Models for evaluating Lyme disease risks using geographic information systems and geospatial analysis.
J Med Entomol 33(5):711–720.

This is an excellent modeling example with figures showing the layers of data, such as roads, vegetation, land use, and hydrography, being overlaid to correlate with other data such as Lyme disease case distribution, nymphal ticks collected per hour, percentage of forest, etc. The

map of Rhode Island overlaid with a map depicting ticks of various sizes indicating nymphal tick densities was of particular interest–not exactly a good tourism map! The article also includes all the great statistical sleights of hand, kriging, for instance.

Nizeyimana, E; Petersen, GW; Anderson, MC; Evans, BM; Hamlett, JM; Baumer, GM. 1996. Statewide GIS/census data assessment of nitrogen loadings from septic systems in Pennsylvania. *J Environ Qual 25(2):346–354.*

The authors ranked watersheds in terms of their potential for nitrogen loading from septic systems. They relied on nitrogen estimates in septic system effluents, census data, and soil information. The objective was to derive the number of septic systems, the nitrogen content of effluent, and the population served for each watershed. They used GIS overlays of soil, census tract, and watershed boundary layers. Assumptions included that the number of housing units on septic systems is the same as the number of septic systems. Population density was the most important factor: population information from the census was overlaid with the watershed map and combined with assumptions regarding septic system outflow and the soil map. Based on this information, the authors grouped watersheds into high, medium, and low hazard ratings.

Nizeyimana, E; Petersen, GW; Anderson, MC; Evans, BM; Hamlett, JM; Baumer, GM. 1996. Statewide GIS/census data assessment of nitrogen loadings from septic systems in Pennsylvania. *J Environ Qual 25(2):346–354.*

The authors provide a detailed description of the methodology they used to compute nitrogen (N) loadings per watershed unit area in Pennsylvania using a GIS framework. They incorporated the following data: (1) location of septic systems and populations from the 1990 Census, (2) soil limitation information for septic system effluents from the State Soil Geographic (STATSGO) database, and (3) daily N estimates per capita in septic system effluents from the literature. They used ARC/INFO overlays of soil characteristics, census tract, and watershed boundary layers. They provided a flow chart and detailed descriptions indicating the steps to calculate the N loading estimates and where GIS was used. They presented three maps of the state, each showing the boundaries of the 104 watersheds and one of the following: (1) population density for each watershed, (2) N loading loss from the septic systems in each watershed, and (3) N pollution rankings of each watershed. The third map clearly showed that the watersheds with medium to high N pollution rankings were limited to areas in the southeastern and western parts of the state, where the population densities were the highest. The authors felt this methodology and resulting information would be useful to state and regional planning agencies as a screening tool to identify the most critical areas for septic system N pollution.

Nizeyimana, E; Petersen, GW; Anderson, MC; Evans, BM; Hamlett, JM; Baumer, GM. 1996. Statewide GIS/census data assessment of nitrogen loadings from septic systems in Pennsylvania. *J Environ Qual 25(2):346–354.*

Septic systems play a significant role in N contamination but little statewide information is available to document the relative importance of this source over broad areas. The study attempted to develop a methodology to assess septic-released N at the state scale and present estimates of loading in specific watersheds. The GIS-based process relied on many factors: septic systems and population data from the 1990 census, soil limitations for septic effluent purification from the STATSGO database, and daily N estimates per capita from the literature. Watersheds were ranked high, medium, and low according to N loadings. Higher producing watersheds were

generally in suburbs adjacent to larger metropolitan areas. Although this methodology focused on septic systems alone, parallel methods for agriculture and atmospheric N sources could be developed in the attempt to account for all N sources.

Nizeyimana, E; Peterson, GW; Anderson, MC; Evans, BM; Hamlett; JM; Baumer, GM. 1996. Statewide GIS/census data assessment of nitrogen loadings from septic systems in Pennsylvania. *J Environ Qual 25(2):346–354.*

A GIS framework was used to estimate the amount of nitrogen released from septic system effluents in watersheds in Pennsylvania and to estimate N loadings from septic systems delivered to surface and shallow ground-water in these watersheds. Census data were used to generate data on septic systems, soil limitations to septic-system performance, and amounts of N delivered to surface and ground-water. Watersheds were ranked high, medium, and low, according to their N loadings, and the ranges of median N loadings were 1.16-0.71, 0.66-0.41, and 0.38-0.03 kg/ha/yr, respectively. Statewide maps are presented that represent population density, the distribution of N loading loss from septic systems, and N pollution rankings of watersheds.

Nizeyimana, E; Petersen, G; Anderson, M; Evans, B; Hamlett, J; Baumer, G. 1996. Statewide GIS/census data assessment of nitrogen loadings from septic systems in Pennsylvania. *J Environ Qual 25(2):346–354*.

The authors report on the development of methods for assessing the amount of nitrogen released from septic systems in Pennsylvania. Using information on septic systems, census data, soil information, and daily nitrogen estimates per capita, the authors grouped the state into three classes of nitrogen loading. High loadings on watersheds were found in suburbs near large metropolitan areas. The authors hope to later combine the results with information from agriculture, acid deposition, and other nitrogen loadings to account for all nonpoint sources of nitrogen in the state.

Nobre, F; Romana, JM; Ramos, I. 1994.
The use of remote sensing data and GIS techniques in reservoir projects: environment impact and the decision-making perspective.
Proceedings: Advances in Water Resources Technology & Management, 2nd European Conference, Jun 14-18, Lisbon, Portugal, pp 389–392.

The environmental impacts of prospective reservoir siting and operation in the Avelames River Basin of Portugal were studied with the Integrated Land & Water Information System GIS. Topographic, land-use, and LANDSAT data were integrated into the GIS software environment. Submersed land areas and water volumes accumulated in different watershed levels were determined. Socioeconomic costs and benefits of reservoir development were also considered. Decisionmaking is aided by optimization analysis functions incorporated in the GIS.

Norton, D; Slonecker, ET. 1990.
The ecological geography of EMAP.
Geo Info Sys 1(0):32–42.

The Environmental Monitoring and Assessment Program (EMAP) has applied the concept of landscape characterization to document the composition and pattern of land cover and land use. These data were compiled using multistage remote sensing, and stored and analyzed in a GIS

database along with a variety of existing spatial data sets. This article describes EMAP's landscape characterization approach and discusses the growing role of GIS technology in national ecological monitoring. This article is useful to reference the role of GIS in EMAP.

Novak, JH; Dennis, R. 1993.
Regional air quality and acid deposition modeling and the role for visualization.
In: Goodchild, MF; Parks, BO; Steyaert, LT, eds. Environmental modeling with GIS. New York, NY:Oxford University Press, pp. 142–146.

The authors provide a summary of EPA's regional air quality and deposition models (Regional Acid Deposition Model, Regional Oxidant Model (ROM), Urban Airshed Model, and Regional Lagrangian Model of Air Pollution). They also briefly discuss an EPA GIS pilot project for spatial analysis related to interpretation of the regional air quality models. The pilot was conducted to evaluate the usefulness of a GIS, using ARC/INFO, for air pollution modeling research and assessment activities. The study area for the pilot project was the ROM domain covering the northeastern United States. Several data layers were prepared, including ROM-predicted pollutant concentrations, manmade point and area source emissions, natural hydrocarbon emissions, air quality measurements, land-use data, and census data. A pilot Interactive Display for Environmental Analysis System (IDEAS) was developed using ARC/INFO to enable the user to study relationships among (1) measured and predicted air pollution concentrations, (2) point and area source emissions, (3) land use, and (4) health effects. The results of the pilot showed that in this setting, GIS was useful for some activities but not for others. Because much of the preparation of emissions data for input to models involves spatial distribution of emission sources, human activities, active emission control legislation, and landuse and landcover, a GIS provides an excellent means to design emissions control strategies and then estimate the resultant emissions inputs to air quality models. The pilot study demonstrated that one of the major drawbacks of GIS for use in air modeling is the lack of ability to deal effectively with the element of time (a critical part of air modeling) in spatial data analysis. GIS software also has difficulty in adequately representing and exploring the three-dimensional fields of ambient air concentrations predicted by air quality models. As a result of this pilot, EPA initiated a project to design a third-generation modeling and analysis framework specifically to address the limitations of GIS identified by the pilot study. The authors briefly discussed the highlights of this new project, including the fact that a successful prototype system was developed that used a commercially available software package, Application Visualization System, as the user interface.

Nuckols, JR; Stallones, L; Reif, J; Calderon, R. 1995.
Evaluation of the use of a geographic information system in drinking water epidemiology.
Assessing and managing health risks from drinking water contamination: approaches and applications. Proceedings, Rome Symposium, September 1994. IAHS Publication no. 233, pp. 111–122.

The authors conducted a pilot study to evaluate the use of GIS technology in an epidemiology study of two populations served by different public water distribution systems in Colorado. The two distribution systems were matched for demographic composition and water supply source, so the primary difference was the disinfection practice. One system uses chloramination and the other chlorination, so the latter has much higher trihalomethane (THM) levels in the drinking water. The authors evaluated several reproductive outcomes in the two populations for any association between these outcomes and THMs levels. The authors

summarized how they used GIS in several parts of the study. For example, they used GIS to do address matching to geocode location of residence of the live births. They used GIS to map water distribution systems and overlay census block group data with the THM water sampling points to identify the block groups with either “high” or “low” THM levels. The preliminary results of the study showed no statistically significant association between low birth weight and water distribution system. The authors concluded that GIS was quite useful for this study, particularly for providing refinements of the exposed population and in developing input data for use in modeling the water in the distribution system.

O'Neill, NT; Royer, A; Cote, P; McArthur, L. 1993.
Relations between optically derived aerosol parameters, humidity, and air-quality data in an urban atmosphere.
J Appl Meteorol 32(9):1484-1498.

This paper deals with diurnal and mensual correlations between ground-based atmospheric observations of columnar and surface optical parameters, standard surface humidity parameters, and surface air-quality data. The implications of a significant portion of small, Rayleigh-free optical depths being attributable to continuum water vapor absorption are analyzed in terms of the impact on the computation of aerosol optical depth and Angstrom spectral coefficients in relatively clear atmospheres. Multiwavelength correlation analysis between aerosol optical depth and precipitable water indicators yielded a systematic, inverse-wavelength type of dependency in the extracted slopes that was suggestive of a simple correlation between precipitable water and the accumulation-mode number density of the aerosols. On a diurnal basis, increasing trends in aerosol optical depth were negatively correlated with surface relative humidity and thus resulted either from variations in the nature or abundance of dry aerosol or possibly from convection-induced increases in relative humidity at higher altitudes in the aerosol scattering layer. Correlations between diurnally averaged aerosol optical depths and 24-hour averaged surface sulfate measurements indicated the potential of satellite-based pollution monitoring using passive remote sensing data.

Ogden, JC; Porter, JW; Smith, NP; Szmant, AM; Jaap, WC; Forcucci, D. 1994.
A long-term interdisciplinary study of the Florida Keys seascape.
Bull Marine Sci 54(3):1059-1071.

The SEAKEYS (sustained ecological research related to management of the Florida Keys seascape) program is a research framework that encompasses the large geographic scale and long-time scale of natural marine processes and ecosystem variation on which human impact is superimposed. The need for interdisciplinary long-term research in coastal ecosystems is critical, because we anticipate extraordinary resource management obligations and scientific opportunities in the next decade. The core of the program is six instrumented, satellite-linked monitoring stations that span the 220 mile-long coral reef tract and Florida Bay and that since 1991 have documented the potential impact of summer heating, winter cold fronts, storms, and distant floods. Mesoscale physical oceanographic studies have documented the net flow of water from Florida Bay to Hawk Channel, which provides a potential mechanism to link water quality in Florida Bay with the waters of new Florida Keys National Marine Sanctuary. Water column and sediment nutrient studies have shown elevated nutrient levels in nearshore waters decreasing sharply to low levels near the offshore coral reef tract. There is a potential link of nearshore and offshore via a seaward deflection in the near-bottom flow. Regional nutrient dynamics are

complicated by periodic upwelling driven by the Florida Current. A series of long-term photomosaic stations have tracked coral community dynamics for more than 5 years and have indicated a loss of over 40 percent in coral cover at some sites. This loss may be linked to declining water quality in Florida Bay. As a large marine ecosystem, the new Sanctuary and adjoining parks and reserve must be studied and managed holistically if human use of the region is to be sustained.

Ollinger, SV, et al. 1996.
Modeling physical and chemical climate of the Northeastern United States for GIS.
U.S. Department of Agriculture Technical Report No. 4 NE-191.

This is a presentation of a simple physical and chemical model for New York and New England that can be integrated with a GIS. Regression with independent variables of latitude, longitude, and elevation was fitted with a digital elevation model to generate regional coverages of temperature, precipitation, and solar radiation, as well as wet and dry sulfur and nitrogen deposition.

Olsenholler, J. 1997.
Find the right fit: how to select the best data collection strategy.
GIS World 10(7):52.

This article talks about the differences between using field acquisition techniques (e.g., windshield surveys and sampling) and preexisting data. Many GIS software vendors have programs to connect users with data vendors. Users may need to find qualified contractors to acquire data if qualified staff members do not exist.

Onsrud, H; Johnson, J; Winnecki, J. 1996.
GIS dissemination policy: two surveys and a suggested approach.
Urban Reg Inf Syst Assoc 8(2):8–23.

This article presents evidence of current dissemination policies of local governments, analyzes implications of information from two surveys (national and Minnesota), and suggests an approach for GIS dissemination policy using open-access and revenue generation.

Ortiz-Casas, JL; Pena-Martinez, R. 1989.
Water quality monitoring in Spanish reservoirs by satellite remote sensing.
Lake Reservoir Manag 5(2):23-29.

A United States-Spanish Cooperative Program applied LANDSAT satellite digital imagery to eutrophication-related water quality monitoring in Spanish reservoirs. LANDSAT digital images were processed with concurrent surface sampling data to develop regression equation and water surface maps. Limnological parameters selected for the study were related to trophic conditions such as chlorophyll concentrations and Secchi transparency. Although thematic mapping based on single-date regression in equations proved feasible and reliable, more sophisticated processing is needed to develop equations for multiple-data assessment, that is, to enable assessment on any date on which remote sensing data are available, whether or not concurrent water surface measurements are available. The long-term goal of this project was developing updated, GIS-based, and cost-effective reservoir surveillance and classification on regional or nationwide basis.

Oswald, R. 1996.
Shared vision: Manitoba partners build land information data warehouse.
Geo Info Sys 6(1):36–38.

The members of the Manitoba Land Related Information System (MLRIS), composed of government departments, utility companies, and private sector agencies, are building a centralized data warehouse for storing, managing, and distributing shareable, land-related information and to develop end-user applications that use these data. Source agencies responsible for their own data layers upload a copy of the shareable portion of their data to a centralized data warehouse and retrieve data layers they are missing, rather than recreate these data layers. The article describes how MLRIS has used an information utility (IU) as the successful core of its venture. The impact of the IU concept has resulted in re-engineering of existing systems, which will advance levels of service to support the ever-growing demand for better land information.

Ottens, H; Van Beurden, J. 1997.
New digital land-use statistics reveal Dutch urbanization trends.
Geo Info Sys 50:32–37.

The article describes the conversion of Netherlands land-use statistics to digitized data. Collection of land-use statistics dated back to 1946, but their procedure resulted in data with significant variation among the municipalities. To increase accuracy and improve quality control, Statistics Netherlands decided to centralize and automate data capture. It used 1:10,000 monochrome topographical map sheets and 1:25,000 color topographic map sheets to digitize a geometrically correct topological framework. The authors used the new system for tracking urban and rural patterns from 1981 to 1989.

Parrish, DA; Townsend, L; Saunders, J; Carney, G; Langston, C. 1993.
U.S. EPA region 6 comparative risk project: evaluating ecological risk.
In: Goodchild, MF; Parks, BO; Steyaert, LT, eds. Environmental modeling with GIS. New York:Oxford University Press, pp. 348–352.

The authors conducted a project in EPA's Region 6 to compare the residual risk to human health, human welfare, and ecological systems associated with 22 environmental problem areas. This paper summarized some of the highlights of the ecological risk evaluation component, which incorporated GIS technology. The common denominator for comparing risks was the area of impact (AI). Region 6 was divided into 24 distinct ecoregions, each of which was an AI. The authors indicated that a GIS data layer of the ecoregions was used, but they did not give any details concerning the nature of the mapped data. An ecological risk index (ERI) was calculated, which took into consideration the AI, degree of impact, degree of vulnerability, and area of the ecoregion. Data on the ERI values and the ecoregions were loaded into a relational database so the authors could use GIS to display the results spatially and identify ecoregions at highest risk. The paper has a choropleth map showing the boundaries of the states composing Region 6, the boundaries of the ecoregions, and the ranges of the composite ERI values for each ecoregion. The paper also summarizes some of the data and GIS problems.

Pattiaratchi, C; Lavery, P; Wyllie, A; Hick, P. 1994.
Estimates of water quality in coastal waters using multi-date LANDSAT Thematic Mapper data.
Int J Remote Sensing 15(8):1571-1584.

An evaluation of LANDSAT Thematic Mapper (TM) data for routine monitoring of surface chlorophyll concentration (C) and Secchi disk depth (SDD, a measure of the water clarity) used Cockburn Sound as a study area. Multitemporal empirical algorithms to predict these parameters have been developed from the atmospherically corrected satellite-received radiance and field data collected at the time of the satellite overpass. Highly significant, predictive algorithms for the surface C (range: 0.2-2.7 µg/L) and SDD (range: 4-15 m) were obtained using bands 1 and 3 of the TM. It is shown that high confidence may be placed on the predictions using these algorithms, and therefore it offers a cost-effective tool for complementing regular monitoring programs.

Paulu, CA; Ozonoff, DM; Coogan, P; Wartenberg, D. 1995.
Making environmental data accessible for public health aims: the Massachusetts environmental database project.
Public Health Rep 110(6):776–783..

As in other entries in this bibliography, the authors of this article discuss how GIS and public health data can be combined and used in public health research. The authors present a convincing case for how and why the two fields (GIS and public health) should be joined to produce some very practical results. They present their work in the development of "the Massachusetts Environmental Database, a microcomputer-based data management system that accesses and integrates routinely collected environmental data." The article includes related information on developing an environmental database.

Paulu, CA; Ozonoff, DM; Coogan, P; Wartenberg, D. 1995.
Making environmental data accessible for public health aims: the Massachusetts environmetal database project.
Public Health Rep 110:776–783.

This article discusses linking environmental and health databases using GIS. The article is written from the viewpoint of a state health official who must respond to a phone call from a concerned citizen. The article cites ease of using GIS with easily accessible data on a PC. The authors provide an example whereby GIS can be used to draw parallels between various towns or counties and incidences of health problems reported. They show how GIS could identify the occurrence of similarities such as hazardous waste sites, water supply, or fuel storage tank location.

Peabody, WD; Hanscom, AD. 1992.
Cost effective airborne remote sensing in coastal environments.
Proceedings, SPIE International Society of Optical Engineering 1930(2), pp. 817-826.

Use of proven remote sensing technology applied from an airborne platform, coupled with recent advancements in computer/GIS technology, has given rise to a new cost-effective screening and monitoring tool for environmental applications. The new system, called a remote airborne sensing computer analysis link (RASCAL), can provide high-resolution remote sensing data at a fraction of the cost normally associated with remote sensing data acquisition and processing and can be used in a variety of applications. Properly applied and interpreted, the system provides quantitative screening data related to thermal characteristics of near surface soils and relative stress of vegetation. Future applications of RASCAL will include emergency response monitoring,

water quality assessment, coastal monitoring, agricultural and forestry management, and others, where timely, high-resolution environmental data are desired.

Pearson, M; Wheaton, S. 1993.
GIS and storm water management.
Civil Eng 6(9):63–72.

Anchorage, Alaska, used GIS to prepare an application for NPDES coverage of its municipal separate storm sewer system management program. GIS helped to overcome the spatial and temporal complexities associated with accessing stormwater quality and to economically analyze and present a variety of options for a management program. Mistaken assumptions in the beginning of the process had an impact on initial costs of the project. Even so, however, time and cost savings were significant compared with doing the same effort without GIS. An unexpected result was an improved overall product due to the balance of thought put into the project by the computer scientist and the water-quality scientist.

Petersen, M; Wall, M. 1995.
Exploring management of threatened Colorado trout stream using GIS.
Geo Info Sys 5(1):36–39.

The Yuma County (Colorado) Soil Conservation District (SCD) and the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) have been using GIS technology in an effort to protect the North Fork of the Republican River in eastern Colorado, where, for the past 20 years, deteriorating water quality and diminished riparian habitat have caused the fishery to decline in trout species and population. The North Fork project has demonstrated the successful application of four techniques, including applying GIS for natural resource concerns and contributing SCS data to cooperative geographic information studies.

Peterson, JL. 1995.
Teeth in the wind.
Geo Info Sys 5(2):20–27.

The article describes a pest management decision-support system built around GIS technology. The GIS system uses Global Positioning System (GPS) data and field data for input into ARC/INFO to indicate density of grasshoppers in crop land and rangeland.

Peterson, DE. 1996.
Grizzly country: GPS/GIS help monitor the great bear's fragile ecosystem.
GIS World 9(4):52(4).

The back country of Montana provides essential habitat for many different forms of wildlife, including grizzly bears. Human development pressures are forcing significant changes onto these areas of wilderness. These changes impact on the lifestyles of grizzly bears, which require large areas of diverse habitat for survival. The food sources grizzlies depend upon are quite fragile. Researchers are using portable field mapping equipment to study the habits of bears, including a Geolink GPS/GIS mapping system from GeoResearch, Billings, MT. This GPS/GIS system operates at a very fine level of resolution to help researchers classify small differences in habitat. In addition, the system can be used to follow disease patterns in vegetation.

Phuyal, BP; Schmidley, RW; Ramirez, JR. 1997.

Automated quality control for GIS data conversion.
Surveying Land Inf Syst 57(1):37–41.

This article discusses the automated quality control software developed for the GISOM (Generating Information from Scanning Ohio Maps) project. GISOM is a project of Ohio State University Center for Mapping, in which the 793 existing 7.5 minute 1:24,000 scale USGS topographic maps that cover the state are being converted into digital form by a two-step process of raster scanning followed by transforming the map image data into the USGS vector digital format known as digital line graph (DLG). The article begins by describing the six stages in the GISOM conversion model. Then, the quality verification software is described. The software checks the transformed data against the original source map for geometric accuracy and completeness. It does this by converting the final DLG line data into raster form and comparing it, pixel by pixel, with the digitally scanned image of the source contour map. Two tests are used to determine whether a given line segment is acceptable: (1) the centerline of a rasterized DLG line is compared with the pixels from the source map to determine the extent to which it falls entirely within the areal line and (2) the rasterized DLG line is thickened and its percentage of overlap with the source data is computed as an indicator of whether the vector line approximates the center of mass of the original line. The article then describes the specific algorithm that is employed and the resulting outputs.

Pikaz, A; Averbuch, A. 1997.
An efficient topological characterization of gray-level textures, using a multiresolution representation.
Graphical Models Image Processing 59(1):1–17.

The authors present a new method for texture characterization based on topological properties at different gray levels and different resolutions. The data structure proposed and described is the multiresolution clusters graphs (MRCG). The multiresolution method proposed performed well for textures whose basic element is big (macrotextures) and also for microtextures.

Poiani, KA; Bedford, B. 1995.
GIS-based nonpoint source pollution modeling: considerations for wetlands.
J Soil Water Conserv 50:613–619.

This is a nice review article. The authors discuss different aspects of using models in a GIS context. For example, they contrast empirical and mechanistic modeling approaches. Empirical relationships are used primarily to estimate annual averages and are generally not useful for assessing episodic events. Extrapolation between watersheds is not generally valid. Until recently, empirical-based models have ignored the spatial distribution of factors influencing model parameters. Process-based models have more complex equations and intensive data requirements that limit their use. Evaluating simulation models is labor- and cost-intensive. Linking models with GIS, and propagation of errors are also discussed. The particular problems associated with modeling nonpoint source impacts to wetlands are also discussed, such as that many wetlands lack an identifiable outlet that could be used to calibrate model results. Some wetlands do not even have water the entire year. Because many wetlands are dominated by ground water, any NPS model will need a sophisticated subsurface component.

Poiani, KA; Bedford, BL. 1995.

GIS-based nonpoint source pollution modeling: considerations for wetlands.
J Soil Water Conserv 50(6):613–619.

This review article concerns the coupling of GIS and models, specifically the application of a linked GIS/modeling process to nonpoint pollution of wetlands. As transitional areas between land and water, wetlands are highly vulnerable to nonpoint source (NPS) pollution problems. The article reviews types of NPS models that simulate transport and fate of sediments, nutrients, and contaminants on ground and surface waters. Special attention is given to validation problems and the propagation of geographic data error through the modeling approaches used. One problem is that validation is very costly and observed data are not always available. Methods of GIS and model linkage are also described, including linkage with shared data and separate interfaces compared with true integration of model and GIS with one resulting interface. A large list of GIS-model linkage projects is provided. The authors conclude that NPS/wetlands applications are possible and discuss the parameters of interest for GIS use and the considerations for minimizing error in the process.

Poiani, KA; Bedford, B. 1995.
GIS-based nonpoint source pollution modeling: considerations for wetlands.
J Soil Water Conserv 50:613–619.

The authors' objective was to estimate nonpoint source pollution potential for wetlands and to link this information to a watershed's spatial characteristics. The authors found that coupling models with GIS for wetlands is possible, but special issues arise. The models must have sophisticated subsurface components, and dilution and denitrification must be considered. In addition, measuring incoming water and chemicals is not always possible. The authors recommend that the coupled approach initially be used only for sites where water budgets can be obtained.

Preuss, C. 1997.
Protecting riparian resources.
Geo Info Sys 7(2):21–26.

A nonprofit program organized volunteers to collect riparian and watershed data, and implemented a GIS to organize and use the information for Coyote Creek Riparian Station and Guadalupe River watershed.

Prior, N; Wong, S. 1997.
GIS/IT integration reveals business solutions.
GIS World 10(6):38.

This article discusses GIS architecture evolution from "GIS centric" through "GIS dominant" and "peer to peer" to "GIS as servant." The discussion centers around changes in GIS software and how applications of GIS have evolved as software and database management have changed. This is related to article by Wegenast in *GIS World* concerning a partnership among several municipalities around Ontario, Canada. Basically, the municipalities banded together to develop a GIS system that would facilitate coordination of planning and services. Information in the database includes water and sewer inventory, roads and traffic inventory, and land-use planning. The point is that developing a comprehensive GIS tool is an expensive undertaking that is hoped to pay off through a common database. Through shared information, problems and solutions can be based on a regional perspective.

Public Technology, Inc. (PTI), the Urban Consortium, and the International City Management Assn. (ICMA). 1991.
The local government guide to geographic information systems: Planning and implementation. *Published by PTI & ICMA.*

This book is an excellent resource for anyone who needs background information on how GIS can be used by local governments. In addition, it provides practical advice on how GIS should be acquired and how common management/policy pitfalls can be avoided. It is an excellent resource for people who are contemplating how a GIS can be applied in a local government setting and for people who are putting the processes in place to acquire and use a GIS.

Quibell, G. 1992.
Estimating chlorophyll concentrations using upwelling radiance from different freshwater algal genera.
Int J Remote Sensing 13(14):2611-2621.

Upwelling radiance from pure cultures and natural populations of freshwater algae is examined. The effects of changes in the vertical distribution of the algae on the upwelling radiance are also explored. The different algae studied were spectrally very similar. The volume reflectance for any given chlorophyll concentration difference between the phyla was studied. This appeared to be due to the colonial nature of some species. Higher chlorophyll concentrations resulted in higher reflectance in all but the blue wavelengths, and correlations between reflectance in the near-infrared and Ln chlorophyll were the highest. This suggests that remote sensing of algae in inland waters should be based on increased scattering by the cells and not increased absorption by chlorophyll.

Ramirez, M. 1995.
Closing the gap: GIS in the high school classroom.
Geo Info Sys 5(4): 52–55.

The school district of Palm Beach County, Florida, in support of two reports published by national and state forums, developed a GIS high school curriculum. It was designed to meet needs in areas where students need improvement, including higher-order thinking, problem-solving skills, and synthesizing information, as well as to help prepare students for the future work force. The curriculum also encourages students to learn responsible decisionmaking about societal issues, by solving predefined environmental and urban problems.

Rapor, J. 1997.
Unsolved problems of spatial representation.
In: Kraak, M; Molenaar, M; Fendel, E, eds. Advances in GIS research. Proceedings of the Seventh International Symposium on Spatial Data Handling. London: Taylor & Francis, pp. 917–927.

This fascinating if somewhat unusual paper that maintains that current GIS practice is flawed by a "very narrow epistomology of spatial representation." The essence of this epistomology rests on continuous two-dimensional "absolute space and time" concepts. According to the author, this limited epistomology leads to an equally limited three-element GIS research agenda: (1) handling georeferenced computational geometry, reasoning with topological relations, and designing databases for alphanumerical data types and temporal sequences of

georeferenced geometry; (2) capturing data from conventional sources or using GIS and related software to establish inventories; and (3) studying how such systems can be used on an ergonomic level. Besides criticizing the current GIS research agenda, the author also criticizes the restricted dimensionality of spatial representation in GIS, the restricted nature of spatial representation primitives used in GIS, and the restricted sense in which a GIS represents the real world. After looking at possible alternative epistomologies of spatial representation from other disciplines (physics, mathematics, psychology, and social theory), the author suggests other frameworks for viewing space, including structuralism (location of entities are produced by the functioning of social systems), structuration (social structure reproduced across space and time through interaction), realism (social structure generates events and entities in an individualistic nongeneralizable fashion), and postmodernism (space is not ordered but a disordered mosaic-space that may be destroyed as a meaningful concept by new forms of interaction over communication networks). The article concludes by proposing an alternative research agenda that would include (1) attacking unsolved problems that can be tackled now (e.g., extending the current systems based on geometry and alphanumeric attributes to offer richer spatial representations (such as curves and mathematical functions, video and sound primitives, kinematics, intelligent agents adapted from computer science); (2) addressing unsolved problems that may become tractable (e.g., implementation of a spatial-temporal framework based on Minkowskian four-dimensional space, development of topologically realistic spatial representations that can store and analyze holes [tunnels] and handles [flyovers] or otherwise continuous 2.5-dimensional representations), and (3) dealing with larger unsolved problems.

Rechel, JL; Nicholson, MC. 1994.
Spatial pattern analysis of mule deer locations in the San Bernardino Mountains, California.
Proceedings, Annual Conference, GIS/LIS'94, Phoenix, AZ, October, pp. 647–657.

Spatial modeling of individual animal locations and movements can be used to understand spatial and temporal patterns and processes affecting wildlife populations. This study used 1988–91 radiotelemetry data from 29 mule deer on approximately 32,524 hectares in the Santa Ana River drainage in the San Bernardino Mountains. The degree of clustering of deer locations was evaluated using three types of point pattern analysis. Using multiple methods enabled detection of differences in habitat use on a seasonal basis by gender.

Reichhardt, T. 1996.
Environmental GIS: the world in a computer. Expanding data resources are spurring widespread use of geographic information systems in the environmental field.
Environ Sci Technol 30(8):340–343.

GISs represent one of the biggest growth areas in the computer industry. Much of this growth has been fueled by business applications, as companies realize the potential of GIS as a marketing tool. However, the environmental field continues to make up a large part of the GIS market as well. Environmental applications include site assessment and cleanup, wildlife management, pollution monitoring, risk analysis, vegetation mapping, and public information. Many natural resource managers are now using GIS, with one key reason being the increase in availability of different kinds of geographic data in electronic formats. As GIS becomes more common in environmental and other applications, it is being incorporated into more mainstream types of software.

Reichhardt, T. 1996.
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This article discusses environmental applications including site assessment and cleanup, wildlife management, pollution monitoring, risk analysis, vegetation mapping, and public information.

Reichhardt, T. 1996.
Environmental GIS: the world in a computer. Expanding data resources are spurring widespread use of geographic information systems in the environmental field.
Environ Sci Technol 30(8):340–343.

This article cites a number of GIS applications, many of which involve federal agencies such as EPA, NASA, and USGS. It states that the GIS software market is worth between $550 million and $1 billion and is growing 15–24 percent every year! An upcoming challenge identified for GIS models is the ability to deal with the fourth dimension of time to show environmental processes such as soil loss or nutrient flow in an aquatic ecosystem.

Reid, E; Quarmby, N. 1997.
Blanket coverage: mapping and assessing Scotland's bogs.
Mapping Awareness, 11(4):34–36.

A description of the use of satellite remote sensing imagery for the Scottish Blanket Bog Inventory. The blanket bog or mire is a natural habitat in Scotland. The Thematic Mapper sensor (LANDSAT 5) was used for data collection. Survey sites were targeted using a combination of local knowledge and a computer-aided aggregation of image data; polygons were superimposed onto the satellite images and blocks marked for ground surveying. The technique may provide a method for monitoring vegetation changes over time.

Reid, E; Quarmby, N. 1997.
Blanket coverage: mapping and assessing Scotland's bogs.
Mapping Awareness 11(4):34–36.

I have the mistaken impression that the British Isles have been inhabited for so long that there are no unknown or unmapped areas. The authors discuss the Scottish Blanket Bog Inventory and how they determined to carry out this inventory. They ruled out ground surveying and air photography and chose six Thematic Mapper image bands from LANDSAT 5 (June 1992). The article discusses the reasoning behind this selection and how use of remote sensing has been cost-effective for this task.

Rejeski, D. 1993.
GIS and risk: a three-culture problem.
In: Goodchild, M; Parks, B; Steyaert, L, eds. Environmental modeling with GIS. New York: Oxford University Press, pp. 318–331.

The author discusses the three "subcultures" of the risk world and four core issues that cut through these worlds. Those using GIS to model and estimate risks are "pioneers in this landscape," caught between the three subcultures of science, policy, and the public. The four core issues he discusses (believability, honesty, decision utility, and clarity) cut across the three risk

subcultures and have a great effect on model structure, data, and GIS technology itself. For each of these four core issues, the author discusses the impact on risk assessment, risk management, and risk communication, and he indicates how GIS has been able to help, or not help, resolve these issues. He also offers recommendations on new GIS approaches that need to be explored in order to start addressing these issues in a more successful manner. He also indicates analytical areas where GIS is greatly underutilized, and offers some interesting suggestions for more uses of this technology to help support decisionmakers. He also provides a critique of many of the shortcomings of GIS, particularly the lack of appropriate methods to incorporate and map measures of uncertainty.

Reybold, WU; TeSelle, GW. 1989.
Soil geographic data bases.
J Soil Water Conserv 44:28–29.

This paper briefly describes three databases that can be accessed for use: Soil Survey Geographical Data Base (SSURGO), State Soil Geographic Data (STATSGO), and National Soil Geographic Data Base (NATSGO). Components of map units are generally phases of soil series. Each database is briefly described, and its availability and sources are defined. This paper is useful to help the reader understand the specific databases often used in GIS work.

Rich, MJ. 1994.
The Providence Plan: using GIS to guide urban revitalization.
Proceedings, 32nd Annual URISA (Urban and Regional Information Association), conference, August, Millwaukee, WI. URISA Journal, Conference 32. Vol 1, p.496–508.

This article is an example of how a state and city are collaborating on a GIS project to identify areas of the capital of Rhode Island, Providence, for revitalization. (The Providence Plan refers to a nonprofit organization.) The study focuses on areas of poverty and neighborhood decline in order to identify initiatives appropriate for these areas. Factors modeled include poverty, children, crime, housing, supermarkets, and education.

Richards, C; Host, GE; Arthur, JW. 1993.
Identification of predominant environmental factors structuring stream macroinvertebrate communities within a large agricultural catchment.
Freshwater Biol 29:285–294.

The authors related macroinvertebrate community measures with environmental gradients including nutrients and habitat variables. The study area was predominantly agricultural. They used canonical correlation analysis to determine the major factors influencing stream community. The first three axes explained 69 percent of the variation in the data. Most of the variation was due to physical habitat attributes. The strongest chemical influence was from ammonia. The most important stream morphological features were related to substrate composition. Although the authors did not use GIS for this article, one can easily see how such a tool would enhance their work.

Richman, D. 1996.
Geographic database finds home on the 'net. (U.S. Board of Geographic Names, National Geographic Names Database).
Computerworld 30(12):45(1).

The National Geographic Names Database, a database of correct place names, is gaining popularity since it became available as a website in September 1996. The database is also available as a CD-ROM product, the Digital Gazeteer, and is priced at $57. The National Geographic Names Database is maintained by the U.S. Board of Geographic Names,
and the database itself is housed in a 1GB Oracle database. Currently it contains the locations and names of around 2 million geographic features in the United States, including arroyos, rivers, hamlets, and cities. Approximately 5000 to 10,000 names are made on a monthly basis, and plans call for the database to be completed by 2006. The Digital Gazeteer became available in September 1993, and 2000 CDs have been pressed since that time. The database was initially on an Amdahl mainframe, but it was ported to a client/server system to provide internet access.

Richman, M. 1996.
Management: BASINS software help determine maximum loads in waterbodies.
Water Environ Technol 8(12):29–33.

EPA has developed a software package designed for use by water quality analysis and watershed managers. Better Assessment Science Integration Point and Nonpoint Sources (BASINS) can be used to develop pollution limits for point sources, Best Management Practices (BMPS) for nonpoint sources, and total maximum daily loads (TMDLs) for a watershed. The databases, assessment tools, and models are integrated in the PC-based GIS software ArcView 2.1. The user of this software can visualize and explore a watershed. On a statewide basis, the user is able to determine where and what the pollutant loads are and if they exceed water quality criteria.

Rifai, HS; Newell, CJ; Bedinent, PB. 1993.
Getting to nonpoint source with GIS.
Civil Eng 63(6):44–46.

Galveston Bay National Estuary Program used GIS in its three-phase plan to prioritize estuary problems, scientifically characterize the problems, link them with causes, and create a series of action plans to solve identified problems. Based on the GIS database, areas within the watershed were identified according to those contributing the highest amount of pollutants to the estuary. Analysis was based on three rainfall cases: average year, 10-year return period, and single storm event.

Ringrose, S; Vanderpost, C; Matheson, W. 1996
The use of integrated remotely sensed and GIS data to determine causes of vegetation cover change in southern Botswana.
Appl Geogr 16(3):225–242.

The GIS technique of buffer analysis was applied to determine the extent to which herbivory (livestock) and the gathering of brush products by the local population were directly involved in the spatial distribution of savanna types. Digital Thematic Mapper (TM) imagery bands 2, 3, and 4 were obtained because these were considered most appropriate for vegetation cover analyses. Field work consisted of reconnaissance vegetation pattern mapping using 1:50,000 and 1:250,000 topo maps. Later a series of 46 sites was chosen to represent vegetation groupings in the area. Image processing intended to define different vegetation types was undertaken using ERDAS IMAGINE 8.1, running on a SPARC10 work station. Results of GIS

analysis show a positive correlation between the location of villages and boreholes and the location and extent of depleted land (sparse vegetation).

Ripple, WJ. 1994.
Remote sensing and GIS applications for forest ecosystem analysis.
ASPRS/ACSM, pp. 530–537.

The Environmental Remote Sensing Applications Laboratory, established by NASA to promote the use of remote sensing technology, worked with a few federal and state agencies to capitalize on the insights of the new field of landscape ecology in combination with remote sensing and GIS to evaluate forest and wildlife habitat resources. Technical advances at the landscape scale included developing techniques to measure forest landscape patterns important to wildlife species. A new automated method for determining the extent of forest fragmentation based on the percentage of closed conifer cover was used to plan a potential Pacific Northwest biological reserve system. The relationship between nest sites of the northern spotted owl and mature forests was investigated. A predictive model of vertebrate species richness was developed. The technology was adopted by the end users because they had been introduced to it, had capable staff interested in it, had a major need for the technology and the resulting spatial information due to resource management issues, and had funding available for it.

Robinson, KJ; Ragan, RM. 1993.
Geographic information system based nonpoint pollution modeling.
Water Resources Bull 29(6):1003-1008.

The reauthorization of the Clean Water Act reemphasizes the need for regional scale monitoring and management of nonpoint pollution loads. The magnitude of the task will require that local governments and their consultants integrate information systems and modeling if they are to manage the massive data sets and conduct the array of simulations that will be needed to support decisionmaking processes. Interfacing GISs and nonpoint pollution modeling is a logical approach. The objective of the present study was to use the 37,000-acre area defined by the Kensington Quadrangle sheet in Montgomery County, Maryland, to show that GIS-supported nonpoint pollution modeling is practical and economically attractive.

Roeters, PB; Buiteveld, H; Allewijn R. 1993.
Application of thermal infrared remote sensing for water quality management and monitoring in the Netherlands.
Proceedings, SPIE International Society of Optical Engineering 20, pp. 251-259.

In the Netherlands, the information need in water management is to a large extent met by water quality monitoring programs based on point measurements. Remote sensing techniques can provide additional information, as a synoptic view over larger areas. Thermal infrared remote sensing is used for water surface temperature mapping. The potential of this technique was tested in a number of projects with thermal scanner survey flights. Results of selected case studies are presented. It was concluded that the particular value is in effluent and waste water discharge detection, stream patterns, and modeling studies. Procedures for implementation were not formulated. Application of the technique is primarily in the framework of the Pollution of Surface Waters Act. Evaluation has shown that implementation at the user's level requires (near) real-time detection of discharges followed by rapid action by ground control teams. These requirements can be met by using the new remote sensing airplane of the Netherlands Coast Guard. Results of

a test program in the summer of 1993 were expected to show that this airplane using thermal infrared remote sensing is a powerful instrument in enforcement of environmental legislation.

Rogowski, AS. 1995.
GIS modeling of recharge on a watershed.
J Environ Qual 25(3):463(12).

A GIS was utilized to generate kriged overlays of soil hydraulic properties. Areas of recharge were predicted for a rural Pennsylvania watershed. Soil water content, bulk density, hydraulic conductivity, and depth to water were measured at 31 locations. The model output compared favorably with measured streamflows.

Rogowski, AS. 1995.
Quantifying soil variability in GIS applications: I. Estimates of position.
Int J Geo Info Sys 9:81–94.

GISs frequently use soil maps, descriptive text, and tables of attribute values. For optimal use, published soil maps first need to be digitized and registered, and then the variability associated with the soil attribute data needs to be quantified. Some problems of dealing with splicing together adjacent maps are noted. Errors associated with GPS and coordinate and elevation measures are mentioned. The validity of the field observations depends on the combined accuracy of an attribute estimate, sampling position location, and interpolation or extrapolation error among measured values. The accuracy of sampling position location was evaluated by comparing GPS field-measured values with visual estimates obtained from aerial photographs. Results showed that visual estimates of position (x,y), registered using standard procedures, could have considerable error. The author found that the best estimates of location were obtained from kriged position estimates (x,y) or a projection-type registration of position location. This paper has many good GIS citations in the reference section; it provides useful descriptions of problems associated with GIS and data used in GIS. Keywords: ARC/INFO, ERDAS, GPS, krige.

Rogowski, A. 1996.
GIS modeling of recharge on a watershed.
J Environ Qual 25:463–474.

The author used information on soil water content, bulk density, hydraulic conductivity, and depth to water in 31 locations as input for the GIS. Predictions of water flux distributions, travel time to ground water, and recharge flux pulse were made by using the GIS. Comparing these predictions with field observations, the author determined that flow may occur through part of the total pore space only. The results suggested that water at 0.6 m remains relatively stable.

Rogowski, AS. 1996.
GIS modeling of recharge on a watershed.
J Environ Qual 25:463–474.

The study used a watershed in Pennsylvania to investigate whether model and GIS linkage could simulate the primary characteristics of the site's recharge. The objective was also to delineate primary recharge contributing areas in the watershed. GIS parameters of interest included several field-measured parameters that were kriged to provide area data that were then overlaid. The methods used soil water content, bulk density, hydraulic conductivity, and depth to water table at 31 locations as the basis for the data layers developed for the GIS. Analyses were

used to predict distributions of water flux from below the root zone, travel time to the ground water, and recharge flux pulse at the ground water table. Comparison with field data suggested that flow may occur through only part of the available pore space.

Rogowski, AS. 1996.
Quantifying soil variability in GIS applications: II. Spatial distribution of soil properties.
Int J Geo Info Sys 10:455–475.

This paper addressed incorporation of spatial variability into soil databases using GIS. The study considered measured and published values of bulk density and hydraulic conductivity (or permeability) in the Mahantango Creek watershed, at both the farm and watershed scale. Fourteen published soil maps were spliced together and digitized in vector format using ARC/INFO. Individual map units and their properties were combined into the Great Soil Groups encountered in the study area. Sample locations were georeferenced and converted to UTM coordinates. Several levels of resolution were obtained, based upon pixels. A 300 × 300 m georeferenced UTM grid was superimposed over the watershed, and a 30 × 30 m georeferenced UTM grid was superimposed. Thus the watershed was represented by 1364 pixels and the farms ranged from 189 to 715 pixels. The minimum resolution of the soils map was 1.2 ha. The 300 m watershed grid was about eight times larger than the minimum resolution (1.2 ha). The 30 m farm scale grid was stated to be smaller and better adapted (less smoothed) to interpolation. Grid size was dictated by software limitations. Collection of measured and published data was described. Detailed maps (orthophoto) were available for slopes, land use, conservation practices, etc. Spatial analysis was conducted with GEO-EAS software. Semivariograms were determined and cross-validated. Block kriging was used to estimate (interpolate) BD and Ks at unmeasured points (pixels). These interpolated distributions were compared with maps derived from published data. Data were evaluated with consideration given to soil great groups and soil map units. The differences between published soil descriptions and data compared with measured soil descriptions and data were discussed. Possible problems and limitations were noted. The paper discussed differences between measured data collected at different scales (farm or watershed). The GIS procedure transformed the (vector) polygon data and attributes to be compatible with the kriged data (uniform grid-blocks). ARC/INFO POLYGRID was used for the transformation. Values were assigned to grid squares based on dominant soil type. Grid size affects resolution (different levels of resolution are noted above). By controlling the size of the grid, the extent of uncertainty becomes both scale and resolution dependent. Because published soil map data had a resolution of 1.2 ha, the size of the grid controlled the scale at which soil properties were averaged. The study found that published distributions of mapped soils can be related to measured values through a geostatistical procedure known as regularization. A procedure is recommended to combine measured and published values. Limitations are discussed. This is a good, detailed paper that uses GIS and geostatistics. Keywords: ARC/INFO, GEO-EAS, STATSGO, Geostatistics, soil map units, soil series, soil great groups, kriging, kriging variance, UTM, ARC/INFO POLYGRID.

Ross, JD; Schiebe, FR; Harrington Jr., JA; Grimshaw, HJ. 1991.
Satellite mapping of suspended sediment and its application to reservoir assessment.
Lake Reservoir Manage 7(1):89-95.

Lake Thunderbird, a 2428-hectare reservoir located in Norman, Oklahoma, was studied along with 15 other lakes in south central Oklahoma over a 2-year period. An objective of this

study was continued development and testing of satellite-based capabilities to assess the water quality variations within reservoirs. Lake measurements and water samples were obtained on each day of LANDSAT overpass. A mathematical model of the relationship between suspended sediment and reflectance measured by the satellite was calibrated to the 16 south central Oklahoma lakes. A series of multidate suspended sediment maps was generated for Lake Thunderbird with this model using LANDSAT MSS near infrared (Band 3) data. These maps were used to quantitatively evaluate the geographic extent of suspended sediment on each date investigated. The results demonstrate the feasibility of using LANDSAT data to routinely monitor and assess surface water bodies impacted by suspended sediment.

Roth, NE; Allan, JD; Erickson, DL. 1996.
Landscape influences on stream biotic integrity assessed at multiple spatial scales.
Landscape Ecol 11(3):141–156.

This article compares stream water quality with land use using the Index of Biotic Integrity and Habitat Index. Using field surveys, aerial photography, and GIS analyses, the paper provides assessment of water quality in relation to amount of forest cover and riparian buffer. Stream biotic integrity was highly correlated with extent of wetlands and forest in watershed, and found riparian buffer to be a weak secondary predictor of stream integrity.

Rundquist, B; Frank, D; Miewald, T; Lulla, K; McLaughlin, D. 1996.
GIS and astronaut training: first step into a new frontier.
GIS World 9(4):44.

By means of space shuttle photography, a hypertext browser will interface with a GIS database to help astronauts recognize sites on Earth, understand their scientific significance, and better obtain data during passes over each site. The browser will contain photographs from previous space flights and will allow astronauts to compare these older pictures with their current observations. The browser/GIS will also allow astronauts to become familiar with the features of Earth sites from outer space prior to space travel.

Rushton, G; Krishnamurti, D; Krishnamurthy, R; Song, H. 1995.
A geographic information analysis of urban infant mortality rates.
Geo Info Sys 52–56.

The article describes how the authors map infant mortality rates in Des Moines, Iowa. Instead of mapping infant death and birth rates according to census tract, they map data continuously using a spatial pattern of grid points and spatial filters surrounding those points. The article shows the advantages of using more flexible tools of geographic information analysis rather than mapping health data into predefined, census-defined areas, or any other exclusively defined area units, because it will often conceal spatial patterns. They are developing, with the support of the U.S. Department of Education, a CD-ROM that will provide instructional modules for implementing these methods.

Sabins, FF. 1987.
Digital image processing.
Remote sensing: Principles and interpretation, Chapter 7. New York: W.H. Freeman (22 pages, online text).

This chapter describes the major categories of image processing. Image processing methods are grouped into three functional categories: image restoration, image enhancement, and information extraction. The categories are further described and well illustrated in this chapter, using LANDSAT examples.

Salcido, E; Lovell, L; Williams, Q. 1995.
Applying U.S. technology to water supply problems in Mexico.
American Society of Civil Engineers. Integrated water resources planning for the 21st century. Proceedings, 22nd Annual Conference, May 7–11,Cambridge, MA, pp. 1153–1156.

Two GISs were used to manipulate LANDSAT remote sensing and other data to facilitate the estimation of runoff coefficients for use in calculating watershed yield in a water accounting model.

Sander, P, Chesly, MM; Minor, TB. 1996.
Groundwater assessment using remote sensing and GIS in a rural groundwater project in Ghana: Lessons learned.
Hydrogeol J 4:40–49.

The study goal was to use remote sensing data and GIS analyses to develop better well-siting strategies. Remote sensing data include LANDSAT Thematic Mapper (TM), SPOT, and infrared aerial photography. Other data include maps and well logs, and open literature. These data were analyzed for linear vegetation, drainage, and bedrock features that would indicate underlying fracture zones. Limitations in the remote sensing data and maps were discussed. GIS analyses focused on identification of factors that contributed to successful wells. (The GIS study framework is presented by the authors.) This would allow for better well location siting for future drilling. Linear features were examined in the field and integrated with 189 GPS-positioned bore holes (out of a total population of about 600 wells). They determined that the remote sensing data allowed for effective mapping of surficial features that were conducive to ground-water development. TM had the best correspondence to successful well placement. The authors clearly identified limitations or problems noted during their study. They concluded that the GIS was valuable for effective analysis but demonstrated the need for spatial reference and accuracy of data from different sources. GIS also increased the spatial accuracy of various data integrated by GIS.

Savabi, MR; Flanagan, DC; Hebel, B; Engel, BA. 1995.
Application of WEPP and GIS-GRASS to a small watershed in Indiana.
J Soil Water Conserv 50(5):477–483.

The study linked the USDA's Water Erosion Prediction Project (WEPP) model with GIS application. WEPP is a spatially and physically based hydrologic model that incorporates hydrology, soil physics, plant physiology, erosion, and hydraulics. WEPP simulates daily soil water balance, evapotranspiration demand, annual crop and forage production, water yield, drainage system, effects of management practices, and other traits. GIS was used to obtain many of the parameters needed to run the model, including soil type, bulk density, and texture; climate/precipitation and temperature; crop type, tillage and harvest dates; and slope steepness, length, and aspect. The evaluation of this application compared model-predicted storm runoff with measured values. The results were successful in that GIS use on recognizing relative influences of numerous types of hillslope configurations improved the model's ability to predict

storm runoff. Many models have become constrained by the number of parameters and of locations where these parameters are needed; the complete coverage of GIS data sets allows for virtually unlimited density of measurement in these kinds of settings, compared with the sparse incidence of field measurements previously used.

Savabi, MR; Flanagan, DC; Hebel, B; Engel, BA. 1995.
Application of WEPP and GIS-GRASS to a small watershed in Indiana.
J Soil Water Conserv 50:477–483.

USDA's Water Erosion Prediction Project (WEPP) model was applied to a watershed in Indiana. The objective of this paper was to investigate the utility of using the Geographical Resources Analysis Support System (GRASS) to provide input parameters for the model such as those related to soil and slope. Another objective was to compare the measured and model-simulated storm runoff values. The watershed was delineated by applying the GRASS watershed routine. A watershed basin analysis program was used to obtain flow direction and water flow accumulation. The parameters obtained using GRASS were output in ASCII files for use in WEPP. Storm runoff was calculated for three scenarios. Correlations between measured and predicted stormwater yielded r^2 values of 0.48 and 0.47, indicating that agreement was not strong. The authors concluded that GRASS was a useful tool for parameterizing complex models; however, more work is needed on appropriate cell resolution.

Savabi, M; Flanagan, D; Hebel, B; Engel, B. 1995.
Application of WEPP and GIS-GRASS to a small watershed in Indiana.
J Soil Water Cons 50:477–483.

The USDA-Water Erosion Prediction Project (WEPP) model requires information on hydrometeorological, soil, topograph, and land-use data. The Geographical Resources Analysis Support System (GRASS) GIS provided many of the necessary inputs for the WEPP model. The GRASS GIS was also used to identify hillslope profiles within the watershed's boundaries. The WEPP model was then used to predict storm runoff for a watershed in Indiana. These results were compared with field observations, and the authors concluded that the GRASS GIS was a powerful tool for providing input to a complex hydrologic model such as WEPP. In addition, the authors concluded that using the GIS to provide information on the watershed's boundaries improved the WEPP model's ability to predict storm runoff.

Savabi, MR; Flanagan, DC; Hebel, B; Engel, BA. 1995.
Application of WEPP and GIS-GRASS to a small watershed in Indiana.
J Soil Water Conserv 50(5):477–483.

The Geographical Resources Analysis Support System (GRASS) GIS was linked to the USDA Water Erosion Prediction Project (WEPP) model. Input parameter data, such as those describing hydrology, soil physics, plant science, erosion, and hydraulics, are harvested from GRASS and used in WEPP to evaluate the impacts of soil surface conditions, caused by various land uses, on erosion.

Schell, SP; Lockwood, JA. 1995.
Spatial analysis optimizes grasshopper management.
GIS World 8(11):68–72.

Swarming grasshoppers, or locusts, are a threat to food crops in many areas. In the western states, some of the 400 known species are the greatest above-ground herbivores on the rangelands. Control measures reached $22.75 million during the last outbreak in 1985-86. GISs have been adapted to analyze the population dynamics of these insects on the plains of Wyoming. USDA grasshopper survey maps have been combined with state templates and processed using Global Positioning System (GPS) technology to determine outbreak sites. These sites share spatial features, as evidenced by maps of vegetation type, precipitation, elevation, evapotranspiration, and landform-soil type.

Schlagel, JD; Newton, CM. 1996.
A GIS-based statistical method to analyze spatial change.
Photogrammetric Eng Remote Sensing 62(7):839–844.

The authors discuss the pros and cons of several methods for displaying temporal trends of spatial data using GIS. They indicate that the null hypothesis (i.e., no trend exists in a single variable measured at multiple locations over time) can be tested statistically in conjunction with using common GIS overlay operations. To accomplish this, they use the Mann-Kendall trend statistic, a nonparametric test for zero slope of the linear regression of time-ordered data versus time. They summarize the steps involved in preparing raster data and calculating the Mann-Kendall test statistic. They then apply this procedure to a real watershed area to investigate whether changes in the spatial pattern of animal waste application that occurred over time could be adversely affecting water quality. They use a set of land-use data collected from 1983 to 1990 in the Jewett Brook Watershed at the north end of St. Albans Bay of Lake Champlain. They provide tabular summaries of the time trend of annual manure application rates derived from the Mann-Kendall test. They also provide choropleth maps of the watershed indicating areas where no manure was applied and where there was a downward trend in application rates, an upward trend in application rates, or no significant trend in application rates. They also use GIS to develop buffers at varying distances from Jewett Brook to determine if manure application rates change with distance from the river. By overlaying the boundaries of the farmlands, they also are able to identify the single farm responsible for most of the increase in manure application.

Schmidt, MG; Schreir, HE; Shab, PB. 1995.
A GIS evaluation of land use dynamics and forest soil fertility in a watershed in Nepal.
Int J GIS 9(3):317–327.

Land-use changes between 1972 and 1990 and soil fertility were investigated. Soil carbon content maps and composite fertility index maps were developed for forest, plantation, and shrubland areas in a watershed. GIS showed soil fertility was poor, and this can be used for problem identification and planning. This is a useful example with some description of GIS methods for comparing land cover with water quality.

Schulman, RD. 1997.
Modern technology meets traditional farm practices.
Geo Info Sys 7(2):32–37.

Modern farmers face many complex challenges including water and fertilizer management, crop selection, and finances. Large-scale farming without the ability to measure and control site-specific spatially related farm elements contributes to pollution of nearby rivers, streams, and well water. GIS-based precision farming practices permit better monitoring and control of farm

practices such as application of pesticides and herbicides and help provide an environment for higher crop yields. GIS allows farmers to manage and fine-tune specific sites. It provides a way to ingest, visualize, analyze, and manage many aspects of farming. There are many obstacles to the use of GIS and precision agriculture, including some traditional farmers' reluctance to adopt new technologies, and the perception that it will mean heavy initial costs for equipment, software, and technical expertise.

Schwartz, J. 1996.
Using a geographic information system to identify the Chesapeake Bay watershed's strategic agricultural land: why is it necessary and how is it done?
Proceedings, Watersheds 96–Moving Ahead Together: Technical Conference and Exposition, June 8–12, Baltimore, MD.

The objective of this project is to use GIS to identify strategic farmland that could be protected as a multiple-purpose resource. A map of strategic farmland is being developed in Maryland. Factors to be mapped are soils, land use/land cover, productivity, development pressures, protected lands, cultural implications, and environmental implications. The result will be a series of county and state maps, color-coded to highlight the most strategic agricultural land. The maps will be available to the public and to private entities for their use in planning.

Sengupta, S; Patil, RS; Venkatachalam, P. 1996.
Assessment of population exposure and risk zones due to air pollution using the geographic information system.
Comput Environ Urban Syst 20(3):191–199.

The authors chose to use GIS technology to assess spatial distribution of air quality and its human health impacts, because of the large database needed. A GIS package was developed to assess exposure and health risk of the population of the Greater Bombay region from atmospheric pollutants. An air quality index was calculated and related to population density and projected growth to identify five pollutant risk zones. The resulting map was used to develop air pollution management strategies.

Shaffer, L. 1997.
Managing national wetlands with digital data.
Geo Info Sys 7(2):28–32.

The article describes the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) and identifies a sample of agencies (local, state, and federal) that use the NWI. The NWI provides location, classification, status, and trend information regarding the nation's wetlands. It contains digital vector data for more than 17,000 quadrangles. Information about NWI can also be obtained by accessing NWIS's homepage: http://www.nwi.fws.gov.

Shaffer, L. 1997.
Managing national wetlands with digital data.
Geo Info Sys 7(2):8–30.

This article identifies three levels of government (local government planning, state-level assessment, and Federal habitat protection) that use the National Wetlands Inventory (NWI) digital wetlands data for environmental protection.

Shaffer, L. 1997.
Managing national wetlands with digital data.
Geo Info Sys 7(2):28–32.

This article discusses the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) project, which provides location, classification, status, and trend information regarding the nation's wetlands. The article provides seven examples of use of NWI digital wetlands data across the country. With the NWI as a data layer, GIS is used to evaluate various situations on different governmental levels. The article also lists how the information can be accessed via the internet and downloaded for use in ARC/INFO.

Sham, CH; Bradley, JW; Moritz, MA. 1995.
Quantifying septic nitrogen loadings to receiving waters: Waquoit Bay, Massachusetts.
Int J GIS 9(3):463–473.

The authors demonstrate that it is necessary to incorporate spatial and temporal characteristics of ground-water flow and land-use data to accurately quantify nitrogen (N) loading into the watershed. They compare residential land parcels with septic N loading over time. The article provides a useful example with some description of GIS methods to compare land cover with water quality. The article was also useful because this reviewer may use Waquoit Bay as the site of a project.

Shamsi, UM. 1996.
Storm-water management implementation through modeling and GIS.
J Water Resource Plan Manage-ASCE 122(2):114(14).

A planning-level GIS integrated with a lumped-parameter hydrologic model, the Penn State Runoff Model, was used to develop a watershed release rate map for use in developing a watershed-wide stormwater management plan. The model was used to simulate runoff hydrographs for a range of durations and frequencies, from which peak flow presentation and release rate tables were generated.

Shaver, E; Maxted, J; Curtis, G; Carter, D. 1995.
Watershed protection using an integrated approach.
In: Torno, HC, ed. Stormwater NPDES-Related Monitoring Needs. Proceedings, Engineering Foundation Conference. Crested Butte, CO, August 7–12. New York: American Society of Civil Engineers, pp. 435–459.

The authors begin by describing ARC/INFO as user-friendly. That must be a first! The authors used SWMM to model stormwater runoff influencing Silver Lake, Delaware. The ARC/INFO macro language was used to enhance the user interface of SWMM and to integrate it into the GIS framework. Data for the model are stored in ARC/INFO coverages and files. Outputs from SWMM will be linked to WASP to predict lake concentrations. The GIS modeling tool will be used for effluent permitting and stormwater control. The effects of stormwater runoff will be measured using biological and habitat measures. These measures will indicate when stormwater management efforts are adequate or need refinement. In order to implement the project, the state of Delaware needed to buy a work station. Total costs of the 3-year project are anticipated to be $740K, or $95/hectare.

Shearer, J. 1994.

NOAA relies on tracing technology to speed ocean mapping.
Geo Info Sys 4(2):22–25.

NOAA's Strategic Environmental Assessment (SEA) group initiated a major project to update and digitize maps of approximately 65,000 miles of U.S. shoreline, including the Gulf of Mexico, Atlantic and Pacific coasts, and the Great Lakes. With the advent of new technologies such as aerial photography, changes can be detected more quickly and accurately. This ability means that it is now possible to build GISs to study the world's oceans. Researchers can extrapolate additional information, for example, where schools of fish are to be found, likely sites for oil or gas reservoirs, and possible recreational areas, and can identify areas that are potentially at ecological risk. NOAA plans to use interactive tracing technology to convert the 260 plus charts, thus cutting the time from 2.5 to 1.5 years. The article describes the technical process of converting the data to electronic format.

Sheng, T; Barrett, R; Mitchell, T. 1997.
Using geographic information systems for watershed classification and rating in developing countries.
J Soil Water Conserv 52:84.

The authors explain that the best approach for using a GIS to classify watersheds and establish management priorities is to (1) develop a watershed classification scheme, (2) conduct a reconnaissance survey and assess watershed data, and (3) prioritize the watersheds. To develop a classification scheme, the authors suggest combining community input with government policy guidance. Criteria should be concentrated on major national concerns and watershed problems. Once the watershed classification scheme is completed, one needs to design a data collection process that focuses on key data that will be useful for the classification scheme, and on data that are easy to collect or are readily available. After these data are input into the GIS, the GIS can be used to prioritize the watersheds.

Short, M. 1997.
Ten years after Chorley.
Mapping Awareness 11(6):40–41.

In May 1997, the "Chorley Report" predicted the future of GIS in the United Kingdom. The author of this article sees opportunities still ahead but is frustrated by the barriers caused by problems such as lack of freely available, affordable digital-map data. This problem is not highlighted as a problem in the United States, but that note gives rise to a United Kingdom cry that American digital map data are not as good as the United Kingdom's. This short article was not very enlightening but did give a more international perspective of at least the data accessibility issue.

Sloss, P. 1996.
Enhancing NOAA's image.
Earth Syst Monitor 7(1):1–5.

Images from the National Geophysical Data Center (NGDC) have appeared in numerous publications, including *National Geographic, Scientific American, Geo, Newsweek,* and *Encyclopedia Britannica*. The images, which are available on WWW, can also be found on CD-ROMs including the award-winning *Small Blue Planet* and *Oceans*. Many examples are described. Digital raster elevation data from ETOPO5 were processed into color-shaded relief

imagery. Two publications used the same shading algorithm, but the map projections used were Mercator for the poster and gnomonic for the Icosahedron. Desktop PC software can render global views using texture mapping to simulate the lighting of topography and to apply a specific coloration to the simulated landscape. The most intensive rendering computations are involved in perspective views of a polygon-modeled surface. NGDC has a new poster in preparation that uses 2.9 million polygons to represent the age of crustal material on the ocean floor draped over world topographic relief.

Smith, KD. 1995.
Remote sensing instruments for water monitoring.
Nat Environ J 5(5):27-28.

The most prominent force in the development and installation of remote monitoring sensors and remote data collection technology is the need to reduce the high costs incurred in conventional sampling and monitoring methods. Conventional sampling and analytical methods usually require manual functions followed by wet chemical analysis in laboratories, which are often located considerable distances from the sampling point. Manual sampling requires assembling and transporting to the sample site numerous sample containers, chemicals to stabilize the samples, and refrigeration and portable monitoring equipment. Additional disadvantages of conventional sampling include inconsistent sampling techniques, time-consuming preparation of sampling equipment, delays in analysis, and exposure of personnel to potentially dangerous sampling locations and adverse weather conditions. Sensors are widely available for remote monitoring of physical measurements. Most physical sensors are well developed and acceptable for most remote monitoring requirements where only trends or pollution indicators are required.

Smith, CL; Steel, BS; List, PC; Cordray, S. 1995.
Making forest policy: integrating GIS with social processes.
J Forestry 93(5):31–36.

The authors discuss how GIS is used to address changes to land use and landscape. Users are only now starting to investigate ways to include social and value dimensions in any land-use analysis. They offer a way for identifying the missing information layer, which they call the superstructure layer, with other information in future versions of GIS. They also include several example analyses that include the superstructure layer.

Smith, RH; Sahoo, SN; Sunkara, SS; Moore, LW. 1995.
Grass integrated synthetic sediment routing model (GISSRM).
American Society of Civil Engineers. Integrated water resources plan for the 21st century. Proceedings, 22nd Annual Conference, May 7–11,Cambridge, MA, pp.1069–1072.

The Grass Integrated Synthetic Sediment Routing Model (GISSRM) uses the GRASS GIS to generate sediment yield estimates using topographic, edaphic, land use, and meteorological data. The model could be used to determine watershed sediment yield reductions after grade control drop structure construction.

Smith, SE; Dewitt, BA; Gonzalez, EP; Hurt, GW. 1995.
Georeferencing of satellite imagery for digital soil mapping.
Surveying Land Inf Syst 55(1):13–20.

This article describes the procedure used by the Soil Conservation Service in Florida to convert traditional soil maps into digital format. The focus is on the process used to georeference satellite imagery to the digital soil maps so that they can be used as a background layer for the resulting GIS. The project chose to use LANDSAT Thematic Mapper rather than SPOT Multispectral for its satellite imagery, because of LANDSAT's greater number of spectral channels and because with LANDSAT fewer scenes were required to cover the state. Georeferencing is defined as the process of converting the arbitrary coordinate system of the satellite image into the geographic coordinate system of the GIS. A two-dimensional affine transformation was used to relate the satellite image coordinates to the map coordinates. This entailed, first, locating a set of at least three control points (36 were actually used) with known UTM coordinates in the satellite image by their row and column coordinates. Using these control values, the parameters of the affine transformation's two equations (one for row, the other for column coordinates) are derived by least squares. With the resulting equations, any cell in the GIS image layer can be related to the corresponding location in the satellite image. The article then describes the resampling subprocess needed to translate the noninteger column and row coordinates generated by the affine transformation into integer coordinates usable in the GIS. Resampling involves interpolation. Three interpolation techniques are explained (nearest neighbor, bilinear, and bicubic) along with their respective advantages and disadvantages. For this project the bilinear interpolation was chosen as a compromise between the faster speed of the nearest neighbor and the better detail and smoother appearance of the bicubic interpolation.

Somers, R. 1994.
GIS development alternatives: 10 years vs. 10 days.
Geo Info Sys 4(8):20–58.

This article discusses the management strategy to successfully implement a GIS system in less than the traditional 10-year timeframe. The author suggests that rather than conducting a full-blown user requirements analysis, one should obtain the core characteristics for essential components which can be modified later. The author describes the management issues to evaluate, including alternatives, immediate benefits for immediate costs, sidelines to major system development, multitracking development, and so forth. Strategic planning should be an iterative process that changes the GIS online.

Somers, R. 1995.
Should we stop and think about this more?
Geo Info Sys 55:19–20.

The article discusses causes of delays of GIS projects and ways to move past the delays. The article emphasizes that the crucial first step is to develop a clear vision of the system's role in the organization and the scope of the project. It also emphasizes moving past delays because they increase costs.

Somers, R. 1996.
How to implement a GIS.
Geo Info Sys 7(1):18–21.

This article discusses various issues related to implementing GIS. It outlines five basic phases and the issues that must be addressed in each phase: (1) planning (establishing resources, activities, and schedules; (2) analysis (determining the organization's requirements); (3) design

(determining what type of system will meet the organization's requirements); (4) acquisition and development (acquiring the software, hardware, and data, and crafting them into a personalized system); and (5) operation and maintenance (using and keeping the system current). It also provides references for other publications on GIS implementation.

Soracco, M. 1995.
NOAA satellite information system (NOAASIS).
Earth Sys Monitor 6(2):12–14.

World Wide Web sites provide access to environmental satellite-related products and information. The site serves as a central location for disseminating satellite information provided by various contributors within NESDIS (NOAA's National Environmental Satellite, Data, and Information Service) and the external satellite community. There are 3000 users routinely accessing the site per week. The data provided are not imagery; rather, they are the information necessary to collect and process imagery data. Other information available includes satellite and sensor descriptions, publications, available data services, links to other sites, and upcoming events. Files are accessible via anonymous FTP.

Soutter, M; Pannatier, Y. 1996.
Groundwater vulnerability to pesticide contamination on a regional scale.
J Environ Qual 25(3):439–444.

A case study is presented that describes a methodology for developing a ground-water vulnerability index. The method combines environmental point models with geostatistical techniques.

Specht, J. 1996.
Mapping Earth's endangered biodiversity.
GIS World 9(3):42–46.

The largest resources of biological diversity are found in some of the world's poorest countries. The use of GISs to promote species conservation and ecological protection is described. A case study of deforestation trends in Madagascar is used to highlight the need for these types of programs. From 1950 to 1985, some 50 percent of Madagascar's forests were cleared for timber, agriculture, and firewood. Conservation International (CI) (Washington, DC) has used data from satellite images to identify some of the most endangered regions on the planet. The CI Sistema de Informacion Geographica (CISIG) was created to assist in scientific field analysis programs aimed at conserving species diversity.
Techniques used to train local workers to use the CISIG system are described.

Stallones, L; Nuckols, JR; Berry, JK. 1992.
Surveillance around hazardous waste sites: geographic information systems and reproductive outcomes.
Environ Res 59:81–92.

This article basically describes the potential to use GIS in reproductive epidemiology but does not go so far as to apply GIS to actual data, so it is a bit disappointing. The authors state that a lot of information is available about toxic waste sites, the chemicals at the sites, potential routes of transport and human exposure. The authors also note that birthweight has been used as an indicator of environmental influences. They show examples of overlaying information using

GIS, and talk about the application of spatial statistics, but there are no health data being modeled.

Stauffer, B; Wang, X. 1995.
Application of GIS for environmental impact analysis in a traffic relief study.
Proceedings, National Conference on Environmental Problem-Solving with Geographic Information Systems, September, EPA/625/R-95/004, pp. 322–330.

A multidisciplinary team evaluated the environmental and socioeconomic impacts of various potential highway alignments in the Pocono region. GIS technology was used to develop a natural and cultural resource inventory, identify contamination sources, assess environmental constraints, and evaluate alternatives. The authors considered the GIS environment to be ideal for analyzing data, applying models, and making decisions, and the high-quality GIS maps enhanced the quality of public presentations and reports. This was one of the first Environmental Impact Statement (EIS) projects funded by the Pennsylvania Department of Transportation to use a GIS.

Steffenson, J; Dippon, D. 1994.
Building a GIS for the president's forest ecosystem management assessment team.
Proceedings, American Congress on Surveying and Mapping/American Society of Photogrammetry and Remote Sensing (ACSM/ASPRS), April, Reno, NV. Vol. 1, pp. 617–623.

At the April 2, 1993, Forest Conference, President Clinton challenged his administration to create an interagency spatial database and to use it to prepare a report critiquing strategies for managing the 26 million acres of federal lands within the range of the northern spotted owl within 100 days. Vector data were converted to GRID raster format and merged into a single grid (400 m × 400 m) with a multitude of attributes representing each of the original map layers and then exported to Oracle for analysis. Linking each grid cell to the database enabled the analysis of new alternatives within 24 hours of having a completed ARC/INFO coverage. Database development issues in developing 10 alternatives included the lack of information standards and the mechanisms for sharing data. Many questions were raised about having consistent, current, accurate resource data and making decisions that cross agency boundaries, which may have been partly addressed by the formation of an interagency team to maintain and enhance the interagency databases. The leader of the Forest Ecosystem Management Assessment Team, Jack Ward Thomas, became Chief of the Forest Service.

Stehman, SV. 1992.
Comparison of systematic and random sampling for estimating the accuracy of maps generated from remotely sensed data.
Photogrammetric Eng Remote Sensing 58(9):1343–1350.

There is a need to assess the accuracy of land-use and land-cover classifications developed from remotely sensed data. This paper is useful because it compares the accuracy of systematic sampling with random sampling designs.

Stevenson, P. 1995.
The problem of data conversion.
Geo Info Sys 5(2):28–32.

The article discusses the various tools and methods used to convert hard-copy maps into digital vector format for use with GIS, possible directions for developing better conversion tools,

and the need for concerted research to minimize future expenses. The conversion tools included manual digitizing, scanning, heads-up digitizing, line following, and automated vectorization.

Stockwell, JR; Sorenson, JW; Eckert, Jr., JW; Carreras, EM. 1993.
The U.S. EPA geographic information system for mapping environmental releases of toxic chemical release inventory (TRI) chemicals.
Risk Anal 13(2):155–164.

The authors use the EPA GIS to map environmental releases of TRI chemicals in the southeastern United States in order to define those regions which may be potential exposure zones and which could be strategic targets for future risk screening efforts. They used the 1987–1989 TRI database to identify total releases and transfers of all chemicals to all media, by county. They also used EPA's Office of Toxic Substances "Toxicity Index Profile" or "TIP" score as a very crude measure of potential human health and ecological effects associated with each TRI chemical. The TIP score for a chemical is calculated by checking off a list of seven human health effects (e.g., cancer, developmental toxicity, reproductive toxicity) and three ecological effects (environmental toxicity, persistence, bioaccumulation) that the literature indicates have been associated with exposure to that chemical. The composite TIP score can have total value from 1 to 10, just based on the number of these effects reported in the literature. The authors multiplied the value of the TIP score by the total annual pounds of each chemical released or transferred into all media for each TRI facility. The authors developed and provided the following mapping products: (1) choropleth map based on the 1980 Census data showing population densities (people/sq.mi.) for each county in the southeastern United States overlaid with the location of the top 25 emitting TRIs; and (2) four choropleth maps showing emissions of TRI chemicals, ranked from high to low by county, based on their TIP scores multiplied by the total releases and transfers. Each of these four maps dealt with one of the following four human health effects: carcinogenicity, mutagenicity, developmental toxicity, or reproductive toxicity. The authors found that the top 25 ranking TRIs, based on total releases and transfers, were located in counties having population densities exceeding 100 persons/sq.mi., and that the largest releases and transfers are usually in the most densely populated areas. They concluded that the most useful result of this methodology and study was to identify areas for future risk assessment follow-up study, based on mapping of the combination of population, chemical release, and toxicity information.

Stockwell, JR; Sorenson, JW; Eckert, Jr., JW; Carreras, EM. 1993.
The US EPA geographic information system for mapping environmental releases of toxic chemical release inventory (TRI) chemicals.
Risk Anal 13(2):155–164.

This article was written early in the genesis of application of GIS to Toxic Release Inventory (TRI) data, by EPA colleagues in Region 4 (southeast United States). This was an early attempt to link what we know about the health effects of specific chemicals to the releases of these same chemicals reported by industry under TRI.

Strand, EJ. 1997.
Will GIS face a year 2000 problem?
GIS World 10(7):20–30.

This article suggests that GIS should not be affected by the year 2000 problem (because GIS is more concerned with "where" questions than "when" questions). GIS, however, has its own significant problem, of which those in the field should be aware and take care to address. The problem concerns naming conventions, such that, for example, wrong names are given to entities or one name is mistakenly given to many entities. Among the reasons for these errors are the changing of names over time and the variation of names that may exist among different source data.

Stumpf, RP; Tyler, MA. 1988.
Satellite detection of bloom and pigment distribution in estuaries.
Remote Sensing Environ 24:385–404.

Using a form of vector analysis of satellite spectral data, it is possible to distinguish algal pigment concentrations based on changes in turbidity. It is possible to identify algae blooms in estuaries.

Sudhakar, S; Pal, DK. 1993.
Water quality assessment of the Lake Chilka.
Int J Remote Sensing 14(14):2575-2579.

A judicious management plan for natural lake ecosystems based on ecologically sound principles warrants a reliable database updated on a suitable temporal cycle. Large water bodies, particularly shallow ones, are of immense economic, scientific, cultural, and aesthetic value, and it has been well established that they play a key role in regulation of local hydrological and microclimatic conditions.

Sui, DZ; Giardino, JR. 1995.
Application of GIS in environmental equity analysis: a multi-scale and multi-zoning scheme study for the city of Houston, Texas, USA.
Proceedings, GIS/LIS '95, Volume II, Annual Conference and Exposition, November, Nashville, TN, pp. 950–959.

Authors used ARC/INFO and ArcView on 1990 TRI and census data (in the Houston metro area) to examine effect of different areal aggregations on the results of environmental justice (EJ) analyses. Although many studies have been published to evaluate EJ, few have addressed the issue of how the selection of the study area unit of analysis can significantly affect the study results. The authors' results show that "if the effects of geographic scale and zoning schemes are not considered, ...it is possible to find almost any desired results simply by re-aggregating the data to different scales and areal-unit boundaries." They examine the TRI and census data at three different scales–census block group, census tract, and zip code–and three different zones–concentric rings (1.5, 3, and 4.5 mile) around the major population centers, 1.5-mile buffer zones along major highways, and sectoral radiating patterns from Houston's three major ethnic enclaves. Although they provide no detail on the queries they performed, they do show the results of two models that look at the relationship between the number of TRIs and the size of the minority population, per capita income, and population density, or the number of TRIs and the percentages of black, Hispanic, and Asian populations. The results show that both the scale and the zones selected have significant effects on the magnitude and sign of the model coefficients and the goodness of fit of the model.

Sun, X; Anderson, JM. 1994.
Evaluation of the application potential of a variable interference filter imaging spectrometer for the water environment.
Marine Technol Soc J 28(2):37-45.

This paper evaluates the application potential of a variable interference filter imaging spectrometer (VIFIS) for the water environment by analysis of the experimental data acquired in recent airborne tests. It shows that VIFIS can be configured to fly in different sensing modes to satisfy a variety of applications. In sunglint-free sensing mode, VIFIS supplies regular wavelength-spectral images of the solar diffuse reflection of the body of water. In the front(rear)-sunglint sensing mode, VIFIS supplies unique directional-spectral images of the specular reflection of the surface of water. Two kinds of wavelength-spectral image examples, which consist of a frame of the progressively variable-filtered sensor imagery and a set of multispectral track-recovery images respectively, are illustrated. The first allows efficient access of the simultaneous spectrum of a homogeneous water area within a whole sensed frame. The other is applicable to areas of general interest for both spatial inspection and pixel spectrum analysis. These regular wavelength-spectral data sets are of interest for monitoring the subsurface scattering that is usually relevant to water quality, phytoplankton, shallow-water fish schools, and other subsurface materials. With the unique directional-spectral images, VIFIS has extra capabilities of enhancing the contrast of the anomalies and other regular surface features, such as oil spills, floating materials, ship wakes, and frontal patterns between different water bodies, on the general water background.

Swanson, C. 1994.
From sword to plowshares: GIS technology helps San Francisco's historic Presidio army post convert to urban national park.
Geo Info Sys 4(11):22–30.

The Presidio military base (San Francisco, CA) is being transformed into a unique national park. The project's final general management plan calls for preservation of 600 structures, with possible uses ranging from innovative community-service programs, to a global think tank, to ongoing scientific and medical research at Letterman Hospital. The National Park Service's Presidio Transition Team has developed a GIS called the Presidio Graphic Management Information System (PGMIS), which has three major functions: as a planning tool to aid in the base-conversion process; to present complex alternatives to the public, decisionmakers, and other government agencies in an easily understandable format; and to be easy to use and update. The management plan also calls for protection, preservation, and restoration of the natural landscape. Because of the unique status, personnel must apply not only the skills required to maintain a rural national park but also skills normally reserved for a city planner, environmentalist, and archaeologist. Because of the scope and complexity, the GIS system (PGMIS) was developed.

Szergoe, J. 1994.
Estimating and mapping the impact of environmental influences on a dynamic population.
European Geographic Information Sytem, Proceedings, EGIS '94, March, Paris, France. Utrecht, Netherlands:EGIS Foundation, pp. 997–1006.

The author considers environmental impact analyses to be among the least developed techniques for urban and regional planning. Using real population data from the third largest city in Sweden and fictional air pollution assumptions, he modeled the concentration of air pollution

on a 100 × 100 m grid network. This method can be used to project future patterns based on expected urban growth.

Tassan, S; Ribera d'Alcala, M. 1993.
Water quality monitoring by Thematic Mapper in coastal environments: a performance analysis of local biooptical algorithms and atmospheric correction procedures.
Remote Sensing Environ 42(2):177-191.

The Thematic Mapper sensor's ability to monitor localized phenomena associated with anthropogenic pollution in coastal waters has been investigated with reference to experimental data collected on a test site in the Gulf of Naples. In situ measurements yielded the biooptical algorithms for chlorophyll and sediment retrieval as well as an optical model for computation of the subsurface reflectance as a function of water composition, specific to the site. The algorithms' performance was assessed through a sensitivity analysis, taking into account correlation among chlorophyll, sediment, and yellow substance contents, as well as stratification characteristics of the water body. Sensitivity analysis techniques were similarly used to evaluate the performance in the coastal environment of three atmospheric correction models, which assume uniform aerosol load and composition, uniform aerosol composition, and varying aerosol load and composition, respectively. A comparison with sea-truth data collected for the LANDSAT overpass of 22 June 1988 showed a satisfactory correspondence between measured concentrations and concentrations retrieved from the TM data using the above atmospheric correction procedures and "local" biooptical algorithms. Consistent with indications of the sensitivity analysis, the best agreement was obtained by the atmospheric model assuming varying aerosol load and composition.

Tayer, MJ; Gee, GW; Rockhold, ML. 1996.
Estimating recharge rates for a groundwater model using a GIS.
J Environ Qual 25:510–518.

The study was done to estimate possible routes and amount of transport of contaminants from buried wastes into ground water at the Hanford nuclear site in Washington state. GIS was used to identify all possible combinations of vegetation and soil type and assign to each an estimate of recharge rate. Estimates were based on field data and supplemented when needed with simulations. GIS was then used to estimate annual recharge volume for the 120 vegetation/soil combinations. Calculations showed recharge volume estimates were several times higher than expected runoff and ground-water flow from adjacent uplands, but this may illustrate the higher recharge rates associated with a 1984 fire and with disturbed soil surface onsite. Model error was estimated at around 20 percent. A more rigorous analysis of error could be performed with GIS, for example, by factoring in road surface area (not in the vegetation map) and subtle vegetation changes. The map product is useful for focusing and refining further analysis of recharge on the smaller areas within the site that are of concern for contaminant burial and migration.

Tempalski, BJ. 1994.
The case of Guinea worm: GIS as a tool for the analysis of disease control policy.
Geo Info Sys 4(11):32–38.

The article describes how GIS technology was used to analyze spatial patterns of Guinea-worm disease. GIS used data collected by UNICEF to identify and map West African villages that had high rates of infection in order to analyze the spatial pattern of the disease. The method

proved useful in locating and identifying areas with a high prevalence of the disease. Health officials were able to target these areas for assistance and health education programs.

Terui, N; Kikuchi, M. 1994.
The size-adjusted critical region of Moran's I test statistics for spatial autocorrelation and its application to geographical areas.
Geo Anal 26:213–227.

Critical regions of Moran's I statistic have been based on the assumption of asymptotic normality, which had been previously proven. This assumption is probably not valid for small sample sizes of 10–50. Cliff and Ord (1971) proposed a Monte Carlo method for small sizes. The authors used the Edgeworth-type approximation to improve these critical values. The size adjustment proved advantageous in tests of the "Queens Case" of spatial pattern. The authors provide a table of critical values for 1 percent and 5 percent, but only for limited sample sizes of PR_1 to P_7.

Teso, RR; Poe, MP; Younglove, T; McCool, PM. 1996.
Use of logistic regression and GIS modeling to predict groundwater vulnerability to pesticides.
J Environ Qual 25(3):425–432.

A significant logistic regression model was developed, based on soil-particle–size class composition of wells sampled for 1,3-dibromochloropropane (DBCP). The California Soils Map Unit Inventory database was used to provide soil data. Probability scores for over 15,000 sections located in the San Joaquin Valley, CA, were generated. GIS was used to generate images of the probability scores, and four distinct probability classes of DBCP contamination were mapped. It was concluded that particle-size class can be used to successfully estimate contamination status for DBCP.

Teso, R; Poe, M; Younglove, T; McCool, P. 1996.
Use of logistic regression and GIS modeling to predict groundwater vulnerability to pesticides.
J Environ Qual 25:425–432.

The authors are concerned that there are no guidelines for interpreting the generic soil texture terms found on pesticide labels. They used California’s Soils Map Unit Inventory database to assign probabilities of DBCP well contamination to sections in the San Joaquin Valley in California. A GIS was used to provide visual images of the assigned probabilities. The authors concluded that particle size may be useful in interpreting the soil references found on pesticide labels. They also found that combining a GIS with data models was useful in conducting the study.

Theocharopoulos, S; Davidson, D; McArthur, J; Tsouloucha, F. 1995.
GIS as an aid to soil surveys and land evaluation in Greece.
J Soil Water Conserv 50:118.

This was one of the first uses of GIS in a country bordering the Mediterranean. The authors developed a GIS for soil survey and land evaluation. They found that GIS technology benefitted the soil survey and land evaluation project, particularly through the provision of results very quickly after field and lab work was completed.

Thomas, JP. 1995.

Remote sensing and relating coastal development to living marine resources and their habitats. *Natural Areas J 15(1):21-36.*

Coastal ecosystems, including those with natural areas (e.g., reserves, refuges, parks), receive virtually all of the water flowing off the continental United States. As the human population increases, so do waste loads and use of the terrestrial surface. Changes in land use result in changes in land cover, which affect water quality and, subsequently, coastal and estuarine habitats and their living resources. Lack of understanding of the cumulative effects of land cover and changes in land cover on these habitats and their resources has limited appropriate management of landscape activities. Additionally, in the United States, as elsewhere, human population in the coastal region is increasing at an ever-quickening pace. Our ability to monitor resultant land-cover and habitat change has not kept pace with the change, and management, thus, has been more reactive than proactive. Remote sensing is a key element of monitoring land-cover changes over broad areas of the coastal zone in a synoptic, relatively inexpensive, and dependable way. Such information, when assimilated into a GIS and integrated with transport and process-oriented models, would allow us to relate land cover and changes in land cover (i.e., development in the coastal zone) to effects on living marine resources; it also would permit proactive responses to continuing degradation and loss of coastal and estuarine habitats and their living marine resources.

Thompson, T; Forster, CB. 1996.
Seeing the future for the trees: big business goes green.
Geo Info Sys 6(9):20–24.

Louisiana-Pacific (L-P), a wood-based building products company, is applying "environomics"–using GIS technology to balance how natural habitat is managed–to develop sustainable land-use policies in partnership with leading environmental groups. The GIS also simplifies communication between L-P's resource managers and upper management regarding data about the company's California timberlands. Since 1991, L-P has applied a group of GIS-based technologies and spatial tools to better understand the environmental impact of timber harvesting, both now and as many as 120 years into the future, in its California forests. The company's GIS provides a scientific base for using field-verified information for compliance reports and forestry management activities. The company is seen as a partner by leading environmental groups. GIS information can be shared and mutually viewed as a planning tool in the early phases of land management. L-P believes applying environomics will greatly influence worldwide habitat preservation. Science can provide paths for sustainable use of resources such that profit is made both now and in the future, balanced with habitat preservation. Long-term plans for the GIS system include making it available to others in government, academia, and industry, both nationally and internationally.

Thrall, G; Bates, B; Ruiz, M. 1994.
A history of implementing an urban GIS. Part two: two solutions toward a working GIS.
Geo Info Sys 4(10):46–51.

This article describes the learning experiences of Alachua County, FL, in attempting to implement a GIS system. Their first attempt was a failure. Even so, the county still was impressed by GIS, and the failure allowed them to articulate what they did and did not want in a new GIS system. ACPAO identified three categories of criteria: automated map graphics capabilities, general GIS capabilities, and general system requirements. The new system had to

read all the maps from the first system. The two key GIS players use different tools to access the data and each requires different forms of analysis; however, they use the same base map of land features.

Tim, US. 1995.
Review: the application of GIS in environmental health sciences: opportunities and limitations.
Environ Res 71:75–88.

This review covers both GIS–describing software, hardware and functions–and the application of GIS to public health data. It is very well done! The author describes the evolution of GIS and how GIS can impact data management. The author then goes on to provide an example of applying GIS to public health data in Iowa. The database included: environmental data (soil, geology, etc.), environmental monitoring data (some information from EPA or the state), demographic data, agrochemical data, and infrastructure data (hydrology and transportation). The article includes sample ArcView screens showing maps with morbidity data, indicating some of the capabilities of using GIS software to explore public health data.

Tim, US; Jolly, R. 1994.
Evaluating agricultural nonpoint source pollution using integrated geographic information systems and hydrologic/water quality model.
J Environ Qual 23:25–35.

The authors claim that GIS enables considerable progress in advancement of the many forms of nonpoint source pollution models because of the speed efficiency and accuracy with which they can handle large volumes of information. The study they performed was focused on using the AGNPS model with GIS to examine an agricultural watershed. The GIS was used primarily as an organizational and processing/analysis tool, whereas the model was used to provide estimates of several water quality variables. These included soil erosion and sedimentation. The linked model-GIS approach was used to estimate potential effectiveness of several alternative management strategies for reducing sediment pollution. When the GIS-assisted strategies were implemented, a 71 percent reduction in sediment yield was made possible.

Tim, US; Jolly, R; Liao, Hsiu-Hua. 1995.
Impact of landscape feature and feature placement on agricultural non-point-source-pollution control.
J Water Resources Plan Manage 121(6):463-470.

The authors used the AGNPS model plus GIS to evaluate the impact of width and placement of buffer strips on sediment yield in a watershed. Efficacy increased with increasing width (from 10 to 30 m). The effects of placement varied from a 3 percent reduction to 26 percent reduction. The larger reductions were seen when buffer strips were placed in an area with few other controls. ARC/INFO was used to combine data layer–AGNPS was run for each grid cell.

Tobias, RA; Roy, R; Alo, C; Howe, H. 1996.
Tracking human health statistics in Radium City.
Geo Info Sys 7(7):50–53.

Sites in Ottawa, IL, were declared to be Superfund due to excess radiation from 14 unrestricted sites (caused by radium dial companies). To determine health outcomes/statistics

surrounding the sites, the Illinois Department of Health-Division of Epidemiologic Studies received funding to study incidence of cancer and adverse pregnancy using GIS. They first geocoded the cancer cases and birth problems records and matched them to addresses in the city. They then conducted a health statistics review at the subcounty level. Finally, they studied the spatial distribution of the cancers and birth defect cases relative to the radiation sites. For the spatial analysis, three techniques were used: zone analysis, clustering analysis (nearest neighbor analysis), and Poisson chi-square mapping. However, they were not able to discuss the result of the study, only the methodology and analyses. It appears that there is a higher incidence of people of lower socioeconomic status and minorities around the radioactive sites.

Torgersen, CE; Poage, NJ; Flood, MA; Norton, DJ; McIntosh, BA. 1996.
Airborne thermal remote sensing of salmonid habitat for restoration planning in Pacific Northwestern watersheds.
Proceedings, Watersheds 96–Moving Ahead Together: Technical Conference and Exposition, June 8–12, Baltimore, MD.

This project focused on using forward-looking infrared (FLIR) imagery as a monitoring tool for assessing salmonid habitat in several rivers and streams in Oregon, Washington, and Idaho. The primary use was to supplement water temperature information from in-stream data loggers with spatially continuous thermal image data composing entire river reaches. Stream temperature is a critical factor in salmonid populations success. Approximately 1600 river km of FLIR coverage were obtained for analysis during the heat of summer 1995. The authors developed diurnal water temperature curves from data logger locations to predict expected stream temperatures on the hottest days of summer. The imagery proved useful for both classifying river reaches according to thermal characteristics and detecting cool-water refugia of critical importance to salmonids.

Tsou, M-H; Buttenfield, BP. 1997.
A direct manipulation interface for geographical information processing.
In: Kraak, M; Molenaar, M; Fendel, E, eds. Advances in GIS Research. Proceedings, Seventh International Symposium on Spatial Data Handling. London:Taylor & Francis, pp. 905–915.

This article describes how object-oriented programming can be used to create a point-and-click iconic direct manipulation graphical user interface (GUI) in ArcView for visualizing, performing, standardizing, and sharing GIS operations and capturing the complete data flow. The article begins by showing the system design and resulting icons for representing vector data objects (i.e., points, lines, and polygons). Then, the article describes the system design objects and resulting icons used to represent vector overlay operations. Two classes of overlay operations are identified: those involving a single vector object (reselect and buffer) and those involving multiple vector objects (erase, update, identify, intersect, union, and clip). With these building blocks presented, the article then describes the GUI that is used to manipulate both the data objects and the operation objects. Next, the article shows and describes the resulting screen display of the icon flow in a case study involving selection of a potential housing site based on six geographic criteria. The article concludes with a discussion of the advantages and limitations of the proposed approach and proposals on the direction of future research.

Tuomari, D. 1996.

Rouge River watershed illicit sewer connection detection program: a GIS application. *Proceedings, Watersheds 96–Moving Ahead Together: Technical Conference and Exposition, June 8–12, Baltimore, MD.*

The Rouge GIS has enhanced the Illicit Connections Detection program of Wayne County which is an intensive effort to identify and correct improper connections to stormwater sewers. The GIS contains an illicit connection application, which is a computer-automated technique for prioritizing priority drainage areas and sites for field investigations. The GIS has made the program more efficient by reducing planning and research time before going into the field. The program has also become more effective because the whole watershed is now being evaluated. A total of 573 illicit connections were found.

U.S. Environmental Protection Agency. 1993.
Geographic targeting: selected state examples.
U.S. EPA, Office of Water, EPA-841-B-93-001.

This Office of Wetlands, Oceans, and Watersheds (OWOW) report describes geographic targeting at the watershed level and includes several state highlights for ranking and targeting approaches. Much of the information is based on information from the Clean Water Act 305(b) reports and its use of indexes and beneficial use designations. It also contains a chapter entitled "EPA Data Sources and Targeting," which may be of interest.

U.S. Environmental Protection Agency. 1994.
Spatial integration program implementation plan.
Office of Wetlands, Oceans, and Watersheds (OWOW), Office of Water, U.S. EPA, Washington, DC. September 1994. Direct questions to Thomas G. Dewald, mailcode 4503F.

This is the OWOW planning document for integrating GIS and spatial data analysis into their program activities. It is a decent reference if one is to "sell" a system to management. It contains a short, but important bibliography and the Executive Order for "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure."

U.S. Environmental Protection Agency. 1994.
GIS/Key™ environmental data management system: innovative technology evaluation.
EPA Report No. 540/R-94/505, March, 151 pages.

As part of the Superfund Innovative Technology Evaluation program, the GIS/Key™ Environmental Data Management System has been developed to manage the myriad chemical, geological, and hydrogeological data at Superfund sites. The system has been evaluated in the following areas: setup, map management, data entry, data queries, contouring, calculations, products, hardware configuration, project planning, training, and documentation and support services. GIS/Key™ is a custom-developed software system that uses several commercial off-the-shelf products to produce a variety of site-specific tables, graphs, and maps to facilitate collection, reporting, and analysis of site-management data. The products available from the system include boring logs, structure maps, geologic cross-sections, isopleth maps, chemistry and hydrology graphs, and tabular reports. An overview is presented of the various functions of the data-management system, which has been shown to effectively manage the necessary data with a high quality and relatively low cost.

U.S. Environmental Protection Agency. 1995.

Acid deposition standard feasibility study report to congress.
EPA Report No. 430-R-95-D019, October.

Many parts of this study have information relative to GIS. It includes an analysis of areas of influence on sensitive receptors using gridded model output and scenario variation. The Eastern United States is segmented into irregular polygons based on analysis of source attribution and similarity of emissions patterns and source meteorology.

van Hoef, JM; Cressie, NAC; Glenn-Lewin, DC. 1993.
Spatial models for spatial statistics: some unification.
J Veg Sci 4:441–452.

The authors relate the spatial statistical methods of Nested ANOVA, Two-Term Local Variance (TTLV), and Paired Quadrant Variance (PQV) through the common element of a variogram. Nested ANOVA and TTLV can estimate an aggregated variogram, and PQV is a variogram estimator. Because of possible correlations between nearby quadrats, Nested ANOVA is likely to be inappropriate for testing hypotheses. This is because Nested ANOVA models spatial heterogeneity as variation in nested blocks of deterministic mean structure, and assumes independent residuals. In contrast, variograms model spatial heterogeneity has autocorrelated random error with a constant mean structure. Even though most of the proofs were above this reviewer's level of knowledge, it is helpful to know that the variogram can be used to tie together these different tests.

van Oosterom, P; Vijlbrief, T. 1997.
The spatial location code.
In: Kraak, M; Molenaar,M; Fendel, E, eds. Advances in GIS research. Proceedings, Seventh International Symposium on Spatial Data Handling. London:Taylor & Francis, pp. 101–117.

This article describes a database indexing system (known as Spatial Location Codes) for GIS objects that is claimed to provide the capability of approximating both the location and extent of objects by a single code. To provide these capabilities, the system combines features of quadtrees, Morton codes, and field trees. The latter is an indexing system consisting of several levels of grids, each with a distinct resolution and displacement. Field trees offer the advantage of storing polygons and polylines in a nonfragmented manner. Objects are stored in the smallest field (grid cell) in which they fit and, because of the use of different resolutions and grid sizes, objects never have to be stored more than three field levels above the resolution level in which they fit. The article gives a summary of the basics of quadtrees, Morton numbers, and field trees. It then describes the concepts and coding employed in Spatial Location Codes, including advantages and disadvantages. It concludes with a description of two benchmark tests comparing the retrieval speed with and without Spatial Location Coding. Directions of future research are indicated.

van Smallen, JWN. 1997.
A hierarchic rule model for geographic information abstraction.
In: Kraak, M; Molenaar, M; Fendel, E, eds. Advances in GIS research. Proceedings, Seventh International Symposium on Spatial Data Handling. London:Taylor & Francis, pp. 215–225.

This article addresses the problem of structuring geographic data so that they are most useful to the user, particularly at the desired level of detail. The article presents a model for geographic information abstraction, described as a "pre-stage to graphic generalization," a process for creating datasets that are best suited to the particular spatial analysis to be performed.

The model is designed to handle thematic and topological data. A hierarchy of object classes is first defined to represent terrain features. Relationships (e.g., "is-a" and "part-of" relations) are then assigned to the different classes, which are used to create superclasses and supersets. Then, a set of abstraction rules (e.g., generalization, aggregation, and selection within a class) are presented, which are used to create the datasets at the desired level of detail. The system relies on the input of an "expert user" who participates in a two-phase process: a definition phase and a generalization phase that implements the abstraction process.

van Stokkom, H; Stokman, G; Hovenier, JW. 1993.
Quantitative use of passive optical remote sensing over coastal and inland water bodies.
Inter J Remote Sensing 14(3):541-563.

Adequate water quality management requires information on actual concentrations, spatial distribution, and temporal variations of water constituents. Using passive remote sensing, synoptic information on a limited number of water parameters can regularly be obtained. Monitoring purposes and the study of the functioning of the aquatic ecosystem require quantitative processing and analysis rather than visual interpretation of remote sensing imagery. The quantitative use of remote sensing over water bodies is hampered by insufficient understanding of the physical mechanisms involved and by technical limitations of the instruments used. Items that play an important role in this respect are connected to the object characteristics, the geometry of the sun, object and sensor, the atmosphere, the remote sensing instruments, and the data processing involved. These items are critically assessed successively. Practical solutions and recommendations concerning implementation of remote sensing in operational water management practice are given.

Vantuono, WC. 1995.
Mapping new roles for GIS.
Railw Age 196(3):45–49.

The GIS, which combines spatial data with tabular data to produce visual results, is finding new applications in railroad transport. In this application, data can be integrated from many different functional areas. GIS can be used for asset management, maintenance planning, stock maintenance, marketing and customer service, emergency planning, capital resources management, and traffic planning. Customized GIS applications are in development for six major railways, and others are considering applications. Although GIS software was first developed 15 years ago, it has only recently become cost effective for large-scale railway use.

Varekamp, C; Skidmore, AK; Burrough, P. 1996.
Using public domain geostatistical and GIS software for spatial interpolation.
Photogrammetric Eng & Remote Sensing 62(7):845–854.

The purpose of this study was to (1) identify suitable public domain software for geostatistical (and GIS) analysis, (2) link these separate geostatistical and GIS programs into a system for spatial interpolation, (3) test the system with a case study, and (4) highlight how the system is useful for GIS analysts. The authors describe how they have linked a set of publicly available subprogram components developed by different geostatistical and GIS packages into a system in order to convert point data into maps that can be used in GIS. They provide detailed descriptions of what programs they used and how they linked them to perform exploratory data analysis, parameterization, validation, and interpolation and display. They described how they

tested this interpolation system to map forest soils at Nullica State Forest in Australia. In doing this test, they selected several soil variables and described how they accomplished each of the four steps of exploratory data analysis, parameterization, validation, and interpolation and display.

Vester, C; Toutin, T. 1996.
RADARSAT in stereo: a training tool kit.
Internal Report, Canada Centre for Remote Sensing, p. 119 (abstract only)

This is a description of a training package designed to demonstrate the use of stereoscopy with respect to RADARSAT data. RADARSAT is Canada's first Earth observation satellite. It has the ability to provide images of any of the Earth's surface, in any climates, and at any time (night and day).

Vine, MF; Degnan, D; Hanchette, C. 1997.
Geographic information systems: Their use in epidemiologic research.
Environ Health Perspect 105:598–605.

This paper provides an overview of GIS capabilities and their application to epidemiology. The authors review a few examples of GIS being used in epidemiological studies (the Guthe article above is one). They also focus on the geocoding function and cite some of the technical issues that came up in their North Carolina study. The authors investigate whether residents living near pesticide dump sites were more likely to have evidence of immunosuppression than residents living further away from those sites.

Wade, T; Wickham, J. 1995.
Using GIS and a graphical user interface to model land degradation.
Geo Info Sys 5(2):38–42.

GISs are increasingly being used to model arid ecosystem characteristics. This article describes the usefulness of GIS to model the susceptibility to desertification of arid lands. The GIS model and graphical user interface (GUI) were developed for a 100,000 km^2 area in the Colorado Plateau Region in southeastern Utah. The GIS model is packaged as a GUI that allows land managers and other scientists not necessarily familiar with GIS technology to create different environmental scenarios and displays the outcomes on a computer screen for comparison. Using spatially explicit data in a GIS allows scientists and land managers to easily import and display indicator data, create synthetic maps of susceptibility to desertification, and compare results based on simulating change in environmental conditions.

Walker, D; Black, RA; Linn, JK; Thomas, AJ; Wiseman, R; D'Attilio, MG. 1996.
Development of geographic information systems-oriented databases for integrated geological and geophysical applications.
GSA Today 6(3):1–7.

This article discusses the use of GIS to analyze large data sets to present surface geological information (geologic maps), which if entered with geologic contact, rock unit, and structural measurement, produces a data set useful for a variety of applications for a variety of people.

Warwick, JJ; Haness, SJ. 1994.
Efficacy of ARC/INFO GIS application to hydrologic modeling.

J Water Resources Plan Manage 120(3):366–381.

This study used a hypothetical watershed and GIS to provide spatial data input to the Corps of Engineers model HEC-1. The GIS performed the tedious tasks well and time-efficiently; these included spatial averaging functions such as basin areas, and average runoff curve numbers. Using a Triangulated Irregular Network (TIN) to assess average rainfall intensities was marked with inaccuracies, however. The analysis of these problems showed that the density of contouring intervals was proportionately related to the degree of estimation error. The highest density of contouring intervals enabled a less than 1 percent overestimation. The number and location of rainfall gauges also imparted error to the average rainfall estimation.

Watson, AFR; Barker, S; Ardern, KD. 1995.
Initial investigation into the potential link between air pollution and asthma using geographical information system based technique.
Proceedings, Air Pollution Engineering and Management, International Conference on Air Pollution, Vol. 2, pp. 447–454.

A GIS was used to compare the distribution of nitrogen dioxide (NO_2) with a zip-code distribution of emergency asthma hospital admissions. There was a significant correlation between adult asthma admissions and traffic-sourced NO_2. The combination of air quality monitoring with epidemiological studies within a GIS demonstrated that this tool could be used for rapid public health monitoring.

Weisman, A. 1994.
Journey through a doomed land: exploring Chernobyl's still-deadly ruins.
Harper's Magazine, August, pp. 45–53.

On May 27, 1994, the government of Ukraine reversed its decision to close down Chernobyl's two remaining active nuclear reactors. Defying pressure from anxious European neighbors, the newly formed republic resolved that its wrecked economy and urgent need for electricity compelled it to operate the plants indefinitely, despite the risk of further damage. In the 8 years since history's worst nuclear accident, thousands of new safety violations have been reported at Chernobyl. Despite the presence of excessive levels of radiation in the landscape, both Ukraine and Russia intend to build more nuclear reactors. Although hundreds of families were evacuated from the most radioactive villages, it has been impossible to relocate several million. This article discusses the development of a GIS program to create a multilayered computer rendering of the landscape around Chernobyl in order to locate and assess hot spots of radioactive accumulation, and determine which crops would be best to grow and how soil could be treated to minimize transfer of radiation to humans.

Werner, RJ. 1997.
Toxic releases and demography in Minneapolis/St. Paul: a GIS exploration.
Proceedings, ESRI International User Conference, San Diego, CA, July 8–11. (www.esri.com)..

This study compared race, age, and income in areas near and far from toxic releases in the Twin Cities metropolitan area. They were using Toxic Release Inventory (TRI) data gathered by the EPA on industrial facilities. The author describes having to correct for locational accuracy in the TRI data and the need for analyzing the data using different sizes of buffers around the TRI sites. The author notes: "if results were similar for different buffer distances, one might have

more confidence in the results." This is a good example of a thoughtful evaluation of data. The study found that minorities and low-income people are closer to toxic releases.

Werner, R; Hedlund, C. 1995.
Putting children first: St. Paul uses GIS to prioritize lead pipe replacement.
Geo Info Sys 5(10):44–47.

This article describes how GIS is used to study the relation between lead service pipes (which are used to transport drinking water) and the number of children less than 5 years old in St. Paul, Minnesota. The purpose is to maximize the reduction of lead exposure to children by prioritizing pipe replacement.

West, E; Ban, L. 1994.
Elk habitat analysis in the Kansas prairie.
GIS/LIS, pp. 818–824.

Elk successfully transplanted to the Cameron National Grassland in Kansas were studied using 1990–1992 radio telemetry and a GIS to determine their prairie habitat preferences. The results can be used to maintain a healthy grassland elk population, protect elk habitat, and integrate competing human land uses with elk habitat. This project is supported by the Rocky Mountain Elk Foundation, the Kansas Department of Wildlife and Parks, and the USDA Forest Service.

Westort, C. 1997.
Generalized operators for sculpting digital topographic surfaces.
In: Kraak, M; Molenaar, M; Fendel, E, eds. Advances in GIS research. Proceedings, Seventh International Symposium on Spatial Data Handling. London:Taylor & Francis, pp. 491–504.

This article addresses the need to develop a set of active tools for manipulating the geometry of digital topographical surfaces at a regional rather than a "local" (i.e., single vertex) or "global" (i.e., the entire topographic data set) level. The article begins with a survey of nondigital and digital surface manipulation methods that have been generally used. Nondigital methods include sculpting, contour line manipulation, model-making, and the various actions of agricultural and gardening tools (e.g., piling, digging, filling, leveling, roughening, and smoothing). Digital methods include filtering, masking, manipulation of contour lines, revolving, translating, and rescaling. Based on these surveys, the author proposes a generalized surface manipulation toolset for regional geometric control. The toolset consists of four component parts: (1) sculpting operators, (2) library of topographic geometric forms, (3) dynamic operators, and (4) generic CAD functionality.

Wettstein, C; Cohen, W. 1995.
High resolution digital imagery applied to ecosystem management.
Geo Info Sys 5(6):24–25.

The Siuslaw National Forest in western Oregon was once abundant in old-growth vegetation and provided habitats for many species. A combination of catastrophic fires in the mid 1800s and intensive timber harvest during the past several decades has reduced and fragmented the older forest habitats. In an effort to protect and restore ecosystem health in the Northwest, while also minimizing negative economic impacts to timber-dependent communities, the U.S. Forest Service is using airborne and satellite imagery to provide information for watershed

analysis and to conduct ecological assessments. The project goal is to identify opportunities to improve endangered species habitats by returning as much of the forest to its natural range of habitat conditions as possible. After the assessment is complete, projects to improve and enhance fish and other threatened wildlife habitats will be proposed. The long-range goal is to allow the forest to return to its natural conditions, while still providing sustainable levels of commodity outputs.

Wickham, JD, et al. 1996.
Landscape 'contagion' in raster and vector environments.
Int J Geo Info Sys 10:891–899.

The landscape contagion (LC) is a quantitative index of spatial pattern used by landscape ecologists to estimate the tendency of patches in a land cover map to cluster. Calculation of LC is a three-step process. First, the pixel edges of a raster land-cover map (LANDSAT data classified for land cover) are scanned and classified according to the land-cover types they separate. This classification is commonly labeled as edges of type ij, where i and j are the land-cover categories. The number of possible type combinations is equal to t^2, where t is the number of land-cover types, and assumes that edge type ij is different from edge type ji. Classification of edge types is represented as a square matrix (A_{ij}), where rows and columns of the matrix are the land-cover types. A_{ij} is also known as a co-occurrence matrix or adjacency matrix. The second step is to fill the matrix with the proportions that each edge type contributes to the total sum of pixel edges in the land-cover map. Third, the LC is often calculated with a Shannon or entropy type indicator: Shannon = $(-\sum\sum A_{ij}\ln A_{ij})/2*\ln*t$. The denominator is the maximum possible value of the numerator when all edge types have equal proportions. The equation expresses the ratio of actual to possible value for a given number of cover types in a map. The Shannon number ranges between 0 and 1. Small values indicate that the land-cover types in the map are clustered into a few, large patches. The purpose of the paper was to show how a contagion metric could be calculated in a vector environment, and how the value differs between raster and vector calculations. The authors found that the standard contagion metrics could not be applied to a vector environment. For the vector environment, measures comparable to contagion will need to come from other related measurements such as patch size or number of patches. This complicated paper would be easier to understand if actual data were presented. Keywords: ARC/INFO, ARC AML, AAT, PAT

Wickham, JD; Norton, DJ. 1994.
Mapping and analyzing landscape pattern.
Landscape Ecol 9:7–23.

The authors propose a method for identifying and classifying areas with heterogeneous land-cover types (Landscape Pattern Types or LPTs). Each LPT consists of up to three land-cover types in roughly equal percentages (mosaics) or disparate percentages (matrix and patch). The accuracy of the method was assessed by comparing LPTs determined by two analysts with each other and with GIS-calculated LPTs based on LUDA. Similarity was 75 percent between the two interpreters and 62 percent between the interpreters and the LUDA LPTs. The greatest errors occurred in LPTs with a residential or urban mix. Disagreement was also attributed to the 15-year difference in comparison data sets. The utility of LPTs was shown by using the technique to analyze questions, for example, about how road densities increase and stream densities decrease with increasing urbanization. These questions were analyzed using GIS overlays. In

addition, the authors compared distributions of LPTs and land-cover types across ecoregions. The analysis showed that additional information on spatial distribution of forests, for example, is provided by LPTs.

Wilke, T. 1991.
Computer software for displaying map projections and comparing distortions.
J Geo 90:264–266.

This article discussed different software packages that can be used to teach geography students about map projections. Although this reviewer has no immediate use for such software packages, it is interesting to note that the whole topic of map projections must be confusing to other people too, because otherwise there would not be the need for these types of products.

Wilkening, CR.; Johnson, LE.; Herr, J. 1994.
Using a GIS to develop input for 2-dimensional unsteady hydraulic models.
Proceedings, Effects of human-induced changes on hydrolic systems symposium. Annual Symposium of American Water Resources Association (AWRA), June 26–29, Jackson Hole, WY, pp. 83–92. Published by AWRA.

Input to two-dimensional hydraulic models is often time-consuming. The USGS Diffusion Hydrodynamic Model, which calculates downstream hydrography based on equations of unsteady flow, is detailed and applied to a reach of Cherry Creek in Denver, CO. The input data are derived from GIS software used to develop a Digital Elevation Model (DEM) of the reach using USGS Topo30 files. The development of the DEM is detailed. The outflows and water-surface elevations computed by the Diffusion Hydrodynamic Model are shown to provide the necessary data to determine the limits, attenuation, and timing of a flood wave as it moves downstream.

Wilson, JD. 1996.
CAD/GIS convergence creating the next generation GIS.
GIS World. May, http://www.geoplace.com/print/gw/1996/0596/0596feat.html.

The article describes how CAD and GIS technologies continue to overlap and intertwine, which has caused software companies to develop new software that brings geographic functionality to CAD packages. The common features of the new products include: out-of-the-box functionality, desktop access and convenience, low cost, and object-oriented environment. The article provides an overview of companies and their products that are at the forefront of the CAD/GIS convergence movement, including Autodesk, Bentley Systems, ESRI, and Intergraph.

Wilson, JD. 1997.
GIS goes global.
GIS World 10(10):36.

This article looks at GIS usage throughout the world, in Asia, Europe, and the United States. The article touches on the need for data standards and making data more accessible. One problem in Europe is that data are expensive to obtain. Barriers to the application of GIS technology in Vietnam are discussed.

Wilson, JD. 1997.
Technology partnerships spark the industry.
GIS World 16(4):36.

This article describes some of the alliances being formed between companies (such as ESRI and IBM) to extend functionality beyond traditional GIS domains. There is a focus on customer needs and the need to apply GIS solutions across an enterprise, utilizing a variety of databases. The article mentions SHL VISION* Solutions, which maintains relationships with "best-of-class" vendors of data stores, CAD, and development tools. This same company was mentioned in the Prior and Wong article (see above) as putting together a GIS solution for the regional municipalities of Ottawa. The author describes how GIS software is being worked into other areas of business.

Wong, KM; Strecker, E; Stenstrom, MK. 1997.
A picture worth more than 1,000 words: geographical information system provides fine detail for nonpoint source model.
Water Environ Technol 9(1):41–46.

A team from the University of California at Los Angeles combined an empirical urban runoff model with a GIS to identify catchments and estimate pollutant loadings from nonpoint sources to the Santa Monica Bay. Los Angeles City and County uses information from this model to determine types of Best Management Practices (BMPs) and where they should be located for the best effect. The City and County also uses the model to determine the effects of land-use changes within the study area.

Wood, WB.; Smith, DG. 1997.
Mapping war crimes: GIS analyzed ethnic cleansing practices in Bosnia.
GIS World 10(9):56–58.

When the available data are reliable, a GIS can be used to demonstrate populations of an area, such as Bosnia, before and after "cleansing" has occurred. Data layers, consisting of numbers of dead and missing, and locations of destroyed cultural institutions, concentration camps, and mass graves, can be spatially and temporally linked to identify and monitor war crime activities. A prototype Bosnia war crimes GIS was created using ArcView and datafiles from a variety of sources were described.

Wood, WB; Smith, DG. 1997.
Weave maps across the web.
GIS World 10(9):46–48.

This article describes how GIS is used to analyze ethnic cleansing in Bosnia. GIS can demonstrate the intent and design of ethnic cleansing, showing the population compositions of an area before and after cleansing has occurred. The numbers of dead and missing from genocidal action; the location of destroyed cultural institutions, concentration camps, and mass graves; and the areal extent of effective control by a military force. The National Committee of the Red Cross has long been a respected neutral support for POWs. In Bosnia, it took on the task of compiling a database of mission people using ArcView and building from data layers provided by several distinct independent sources. In 1993, the UN Security Council mandated creation of an International Criminal Tribunal for CITY, but was frustrated by the lack of cooperation by the parties involved. For GIS, they used (1) the ethnic population distribution from the Yugoslavia 1991 census, (2) a list compiled by CITY of damaged or destroyed religious sites, (3) ICRC (International Committee of the Red Cross) database on missing persons, (4) control zones provided by UN forces, (5) ARC/INFO coverages of the region's international and internal first-

order administrative boundaries, as well as the interentity boundary line agreed to at the November 1995 Dayton Peace Accords. None of the databases was created with GIS in mind; e.g., place names of religious sites had to be individually located on the xy coordinate system. Considered by authors to be a novel application, GIS-based human rights monitoring is a critical need in a world beset by violent ethnic conflict.

Wright, D. 1996.
Rumblings on the ocean floor: GIS supports deep-sea research.
Geo Info Sys 6(1):22–29.

This article describes the pioneering use of a GIS aboard the *Atlantis II* deep-sea oceanographic research vessel, in concert with the *Alvin* diving submersible vehicle, to explore and map sites along a sea floor-spreading center in the Pacific Ocean and Washington coastline. *Alvin* was used to carry out extensive, integrated sampling features that were discovered and mapped on previous expeditions to the study area. GIS equipment aboard *Atlantis II* helped oceanographers manage and interpret data gathered by *Alvin*. By using GIS to provide detailed and accurate predive maps of important hydrothermal and geological features, *Alvin'*s time on the ocean floor could be managed for optimum productivity. GIS operations were also valuable after the dive in providing maps of dive tracklines and sample locations in relation to geological features, and in assessing their navigational accuracy.

Wu, S; Walker, DJ; Brusven, MA. 1996.
Economic and environmental impacts of planting flexibility and conservation compliance in the 1990 farm bill.
Proceedings, Erosion control technology. . . bringing it home, International Erosion Control Association, Conference XXVII, Feb 27–Mar 1, Seattle, WA, pp. 273–289.

A GIS linked with optimization/policy and physical simulation models was used to evaluate 1990 Farm Bill commodity program policies in improving soil conservation. The tool was used to evaluate planting flexibility and erosion limit/reduced tillage alternatives for a highly erodible watershed in Idaho.

Wysession, ME; Fischer, KM; Clarke, TJ; Al-eqabi, GI; et al. 1996.
Slicing into the Earth.
EOS, 77(48):477–482.

This article discusses the deployment of portable broadband seismometers to map the deep earth structures through the Missouri-Massachusetts (MOMA) project.

Young, RD; Dahl, TE. 1994.
Use of GIS in assessing areas of rapid wetland change.
GIS/LIS, pp. 851–859.

The U.S. Fish and Wildlife Services National Wetlands Inventory is using national coverages in ARC/INFO to identify counties where wetland losses may be occurring faster than the national average. This process relies extensively on temporal color infrared aerial photographs. Once identified, the areas are prioritized for further investigation work based on wetland occurrence and resource priorities. This is an improvement over past methods in being more timely, more efficient, and less subjective.

Young, RH; Green, DR; Cousins, SH. 1993.
Landscape ecology and Geographic Information Systems.
Taylor and Francis, New York, NY, 296 pp. ISSN 0-7484-0002-8.

The chapters in this book present a series of papers broken into sections describing aspects of the interface between GIS and landscape ecology. The book shows that spatial studies of ecology and environment require tools capable of handling and analyzing spatial data. It is a useful reference because it offers insight on applications of GIS in landscape ecology and describes pitfalls and problems.

Yulsman, T. 1996.
The seafloor laid bare.
Earth: 5(3):42–51.

This is an extended article on the use of GIS with the Geosat satellite to map in greater detail than ever before the topography of the ocean floor, which took $80 million and 18 months.

Zapletal, M. 1994.
Use of geographical information systems for spatial modelling of the sulphur dioxide gas deposition on the territory of the Czech Republic.
EGIS, pp. 233–242.

This project was one of the Czech Republic's efforts under the UN ECE program of mapping critical pollutant loads and levels. Atmospheric deposition rates were related to land-use types and meteorology. Covering 882 10 x 10 km grids, maps were made of SO_2 concentration and deposition classified into 9 categories across the Czech Republic.

Zhang, Y. 1997.
Adaptive ordered dither.
Graphical Models Image Process 59(1):49–53.

This article describes a new ordered dithering method–adaptive ordered dither–that does half-toning by using a space-filling curve to perform an adaptive variation of the cluster size. In the new method, dithering thresholds are assigned to the pixels of the image under half-toning by subdividing a space-filling curve over the image into segments, making it possible to produce images with clustered dot patterns efficiently. A 256 × 256 real image of a boat scene was used to demonstrate the performance of the new method.

Zhang, Z; Dossey, T; Weissmann, J; Hudson, WR. 1994.
Urban GIS integrates paving and infrastructure management.
Better Roads 64(11):33–35.

Researchers at the University of Texas, Austin, are investigating the potential use of GISs for urban roadway and infrastructure management systems. As part of these efforts, a conceptual evaluation of GIS technology was conducted. Different GIS software packages were compared. A pilot application was then developed based on digital geographic information for an urban area. The GIS approach comes at a time when the prices for personal computers and software are declining significantly, making GIS systems economically attractive. The benefits and drawbacks of various platforms and GIS packages are discussed. The design of a GIS for urban roadway management is detailed.

Zhang, R; Hammerlinck, JD; Gloss, SP; Munn, L. 1996.
Determination of nonpoint-source pollution using GIS and numerical models.
J Environ Qual 25(3):411–418.

GIS methods were compared with numerical modeling methods in assessing ground-water contamination sensitivity. The method was a modified DRASTIC (D*r* = depth to ground-water table rating; R*r* = net recharge rating, A*r* = aquifer rating, S*r* = soil media rating, T*r* = topography rating, I*r* = impact of vadose zone, C*r* = aquifer hydraulic conductivity rating). The site selected was Goshen County, Wyoming. Base maps were developed using GIS, describing the sensitivity of ground water to pollutants; numeric simulations were used to model flow and chemical transport in the vadose zone; ground-water sensitivity indexes were developed from the simulation results and compared with the map results. Parameters included depth to ground water, net recharge, hydrogeologic units, vadose zone soil properties, land surface slope, and saturated hydraulic conductivity (aquifer). Results from both methods were comparable, with excellent agreement in high sensitivity areas.

Zhang, R; Hamerlinch, J; Gloss, S; Munn, L. 1996.
Determination of nonpoint-source pollution using GIS and numerical models.
J Environ Qual 25:411–418.

A GIS was developed using environmental characteristics that affect contaminant transport. Sensitivity ratings were assigned to each of these characteristics. Ground-water sensitivity indices were compared with the resulting GIS map to verify the map's reliability. The two methods both generally agreed in their ratings. The authors concluded that GIS is an efficient method for large-area mapping, but that numerical modeling is better for detailed and site-specific results of water flow and solute transport. However, the authors are working on developing reliable rating functions to be used in the GIS.

Zucker, LA; White, DA. 1996.
Spatial modeling of aquatic biocriteria relative to riparian and upland characteristics.
Proceedings, Watersheds 96–Moving ahead together: Techical and Exposition Conference, June 8–12, Baltimore, MD, pp. 571–574.

The objectives of the study are to (1) determine patterns of riparian conditions that are beneficial for instream biological integrity, (2) characterize watershed stressor and modifier components in a digital GIS, and (3) determine the significance of impacts from upland stressors relative to characteristics of riparian modifiers. A predictive model of the relationship between riparian and upland characteristics and biotic integrity was built using ordinary least-squares regression. The extent and width of each riparian cover type was recorded for patches of vegetation observed on 1:40,000 air photos of the Big Darby Creek Basin. The success of the spatial model indicates that riparian conditions can modify and buffer the impacts of stressors across the watershed.

Zybach, B; Barrington, M; Downey, T. 1995.
Converting historical information to GIS, political boundaries of the Douglas Fir region, 1788–1995.
J Forestry 93(5):15–20.

Combining GIS products and research of historical records, the authors were able to describe the political boundary settings in the west coast Douglas Fir region in 1788.

REFERENCES HAVING ONLY INTERNET ADDRESSES

Conterminous U.S. land cover characteristics data set: 1990 prototype.
http://www.lib.noaa.gov/uhtbin/cgisirsi/190/9

This article describes the acquisition of the distinct land cover regions using the NOAA AVHRR satellite imagery. It can be used as a base cover, with its final 159 land-cover regions processed through several steps. These final steps include using ancillary data sets and statistical and visualization tools. Discussed are the raster data and the map projection, spatial resolution 1-km), composite images derived from Normalized Difference Vegetation Index (NDVI), and inclusion of attribute tables and thematic data sets developed as part of the process. Data come on CD-ROM and list directory tree structure. This data set could complement higher resolution imagery such as LANDSAT and SPOT.

GIS development in the hazardous waste geology section.
Office of Solid and Hazardous Waste Management, Indiana Department of Environmental Management.
http://www.esri.com/library/userconf/proc97/PROC97/T0400/PAP381/P381.htm

GIS and GPS are used in this heavy industrial area to document cleanup efforts for an integrated steel mill and a closed hazardous waste landfill. However, the study has identified many unique, undisturbed areas, on which GIS can display the physical and spatial relationships between the regulated and unregulated entities. The study used first the combined digital data sets of others. Interest in GIS has spread rapidly across all the state agencies.

Library of Congress adds more than a touch of history to GIS.
Government Computer News, June 10, 1996. (Visit the website to order back issues.)
http://www.gcn.com

This article is about digitizing many of the nation's historical maps and the contributions that several companies have made to make the National Digital Library a reality. It states that one of the most important aspects of GIS is the study of change, with the 5 million items in the library's various collections a rich source. The library plans to digitize 80,000 maps in 5 years! The map collection has 4.5 million maps and 60,000 atlases, some of which are 500 years old. The goal is to store this historical information in electronic format, add layers of information with which to study any environmental or urban change, and place this information on the World Wide Web.

Transportation has both hands on GIS wheel.
Government Computer News, June 10, 1996. (Visit the website to order back issues.)
http://www.gcn.com

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) spurred numerous GIS efforts in the Bureau of Transportation Statistics (Department of Transportation [DOT]). The website can be found at http://www.bts.gov. BTS has expanded the effort to handle DOT's spatial databases in its Center to support consolidation of its regional offices and to address national transportation emergencies. The system uses two GIS software packages: ARC/INFO to develop high-quality maps and TransCAD (Caliper Corp.) for transportation analysis in quick response situations. The Center has a plotter to plot maps up to 34 × 44 inches

(HP DesignJet 650C). There are six different categories on the website, one being a GIS services page that includes National Transportation Atlas, GIS-T Links (TIGER data, FGDC, etc.), Conferences and Workshops, GIS-T Newsgroup, GIS-T Reference Library, and FGDC Ground Transportation Subcommittee. The Center plans to develop more map and spatial data products for the general public and place it on the website.

EPA cleans up its data to support a healthy environment.
Government Computer News, June 10, 1996. (Visit the website to order back issues.)
http://www.gcn.com

EPA's Andy Battin, national GIS program manager, quotes political guru, James Carville–"It's the data, stupid"–to describe EPA's task to not only have data for its 700,000 facilities, but to make sure the data are accurate. A main task for the national office is to populate the EPA Environmental Spatial Data Library (ESDL), which is based on the Census Bureau TIGER data set. The data set is at the Washington Information Center (WIC) and is the sum total of EPA's nationally integrated spatial databases. Regional versions are replicated in the 10 EPA regional offices. ESDL also contains boundary data for the National Priority List (NPL) and the relational database (Oracle) containing other EPA databases. A second task is to ensure accurate data using the "key identifier project" to better define locational data and other environmental data. EPA works with several groups to expand use of accuracy codes and place information on its website.

Geospatial tools added to Earth vision.
Government Computer News, July 8, 1996. (Visit the website to order back issues.)
http://www.gcn.com

The short article describes a geospatial analysis tool (Dynamic Graphics, Inc. Alameda, CA) that can create shaded three-dimensional graphics, and also can build base and contour maps, cross-sections, and fence diagrams. This tool could lend itself to three-dimensional visualization of hazardous waste sites and well profiles for geospatial analysis.

CAD software.
Government Computer News, July 8, 1996. (Visit the website to order back issues.)
http://www.gcn.com

This general article about CAD lists systems under $2000 that can be used by many different professions, including enforcement officers, who are using it to plot crime scenes. It's not just for engineers and architects anymore!

Digital maps keep the pace.
Government Computer News, July 8, 1996. (Visit the website to order back issues.)
http://www.gcn.com

An interesting article on how the Army and the Defense Mapping Agency used digital (terrain) elevation data to produce maps for the Dayton Accords to set the boundaries of the countries of the Croat, Bosnian and Serb negotiators. The software (PowerScene, McLean, VA) combined digital elevation data with satellite imagery to create a three-dimensional landscape. The highly classified information showed exact locations of houses, bridges, and road intersections. The team also used GIS (Erdas, Inc.) to calculate the changes in the percentage of land allocated to each party after each revision of the boundaries. The three Balkan presidents

were up until 6 am on the morning after the Accord was announced by President Clinton, checking particularly sensitive spots on the boundaries.

ESRI ARC NEWS. 1996.
ARC NEWS 18(3). For reprint information go to www.esri.com.

Numerous articles on the applications of GIS to police departments, BLM at Glen Canyon dam, investigation of the ValuJet flight 592 in Florida, GIS projects in the inner city of downtown Detroit, firefighting in Alaska by providing maps to assess the fire's path, public service uses in Anaheim, CA, to bring all the data sources under GIS, soils mapping for USGS, displaying data on leukemia in Sweden as a result of the Chernobyl nuclear power plant accident and restoration and renovation work in Greece and Jordan.

TV digital maps aid news presentations, 1996.
Business Geographics 4(8). For reprint information go to www.gisworld.com.

This article describes how important maps are to tell people where something is happening and not just tell a story. In particular, it talks about the use of maps in news reporting and covering the weather.

Capture digital imagery for your GIS.
GIS World, September 1996. For reprint information go to www.gisworld.com.

Three ways of obtaining digital imagery for use in GIS applications are discussed and compared. Grabbing frames from a video camera was judged superior to use of a 35mm camera and digital camera in this comparison based on cost and image quality.

EOSAT Notes 11(1) Spring/Summer 1996. Available on the internet at http://www.spaceimage.com/home/pubs/notes/vol11no1/index.html.

Articles summarize the Indian Remote Sensing (IRA) program, which the Foreign Agricultural Service (FAS) of the USDA uses as a supplement to its LANDSAT and other data. FAAS has used remote sensing data since 1978 to report on global agricultural commodity production.

Potomac News, Friday, November 29, 1996. For article information, contact the newspaper at www.potomacnews.com.

This local newspaper article explains how the local bus service will use a software program (Intelligent Transportation System) to reroute buses to off-routes when a passenger requests a ride and to advise operators on the location of buses that are traveling at any time. Even though the software has problems, the system should be able to check each bus schedule, current load, and timeliness. The system will use GPS, which will eliminate the need for on-street time checks. A study found that 7 percent of county residents use the system and that 17,000 people have used the system. The new procedures should help the system both to grow and to save money, through eliminating the on-call system for ridership now in use.

You are...where, exactly?
Potomac News, Sunday, November 17, 1996. For article information, contact the newspaper at www.potomacnews.com.

This article is on the local firm of Larry N. Scartz which uses GPS technology to map out Prince William County. Use of the 24 satellites from the "cold-war defense technology" and the decrease in cost for the systems has put this company at the forefront of mapping. The firm has worked in Oregon to set navigation points for a small airport, in North Carolina to record precise locations and elevations of beachfront homes wiped out by Hurricane Fran, and to plot coordinates at Dulles Airport. That project recorded 40 points (over 1 week) that were accurate to 1 millimeter. Other work was to plot sewer lines and values in a GIS format.

News briefs: EPA announces $2 million in grants for various lead-related projects. 1996. *Asbestos and lead abatement report. October 7, 1996, Vol. 9, No. 20). ISSN: 0893-858X.*

The article reports EPA's announcement concerning Community/University Partnership (CUP) grants. The CUP program was developed to address environmental justice issues in a partnership between community groups and higher education institutions. The article reported the award of $2 million to three projects, each related to lead (Pb) exposure and lead poisoning prevention. This article was particularly interesting because it highlighted how little communication there is within EPA between the people who work in the program offices and the people who work in the grants office or the environmental justice program.

GIS SOFTWARE COMPANIES

COMPANY NAME: Bowne Management Systems Inc.
Address: 235 E. Jericho Tpk.
Mineola, NY 11501
Telephone: (516)746-2350
Fax/Telex: Fax(516)742-1396
Established: 1982
SMSA Coverage: Nassau-Suffolk, NY
Description of Services: Custom design and implementation of geographic information systems

COMPANY NAME: Informed Management Environment Inc.
Also known as: Informed Management Environment
Address: Informed Management Environment
1720 Bolsover St.
Houston TX 77005
Telephone: (512)522-0057
Fax/Telex: Fax(512)524-9704
Established: 1987
SMSA Coverage: Houston, TX
Description of Services: Developer of geographic information systems

COMPANY NAME: Mapping Automation Inc.
Also known as: Mapping Automation
Address: Mapping Automation Inc.
335 N. Alma School Rd., #A
Tempe AZ 85224-4301
Telephone: (602)829-3090
Established: 1984
SMSA Coverage: Phoenix, AZ
Description of Services: Geographic information systems consultant

COMPANY NAME: UGC Consulting Co.
Also known as: Utility Graphics Consultants Inc.
Address: UGC Consulting Co.
6200 S. Syracuse Way
Englewood, CO 80111
Telephone: (303)773-6166
Fax/Telex: Fax(303)773-1242
Established: 1985
SMSA Coverage: Denver, CO
Description of Services: Geographic information systems consulting firm

COMPANY NAME: Mentor Software Inc.
Address: Mentor Software Inc.

3907 E. 120th Ave., #200
Thornton, CO 80233-1600
Telephone: (303)252-9090
Fax/Telex: Fax(303)450-9859
Established: 1987
SMSA Coverage: Denver, CO
Description of Services: Developer of automated mapping and geographic information systems software

COMPANY NAME: EIS Inc.
Address: EIS Inc.
3387 Poplar Ave., #329
Memphis, TN 38111
Telephone: (901)458-7800
Established: 1989
SMSA Coverage: Memphis, TN-AR-MS
Description of Services: Developer of custom and prepackaged geographic information systems software

COMPANY NAME: Terra-Mar Resource Information Services Inc.
Address: Terra-Mar Resource Information Services
1927 Landings Dr.
Mountain View, CA 94043
Telephone: (415)964-6900
Fax/Telex: Fax(415)964-5430
Established: 1976
SMSA Coverage: San Jose, CA
Description of Services: Developers of customized and prepackaged software for image processing and geographic data analysis, systems integration, and suppliers of turnkey systems

COMPANY NAME: Sidwell Co.
Also known as: The Sidwell Co.
Address: 28 W. 240 North Ave.
West Chicago, IL 60185
Mailing add: Sidwell Co.
P.O. Box 920
West Chicago, IL 60186
Telephone: (708)231-0206
Fax/Telex: Fax(708)231-8206
Description of Services: Mapping and geographic information systems services

COMPANY NAME: Sanborn Mapping and Geographic Information Services
Also known as: Sanborn Map Company Inc.
Address: Sanborn Mapping and Geographic Information Services
629 5th Ave.
Pelham, NY 10803

Telephone: (914)738-1649
Fax/Telex: Fax(914)738-1654
Established: 1876
SMSA Coverage: New York, NY
Description of Services: Map publishing Services; Computer database developer