⬭EPA

Geographic Information Systems

Case Studies Of EPA's Implementation

ERL-C

Oregon
CWS

EMSL-LV

VIII

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RTP

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I. INTRODUCTION

This report on Case Studies of EPA's Implementation of Geographic Information Systems has been prepared by American Management Systems, Inc. for the U.S. Environmental Protection Agency's (EPA) Office of Information Resources Management (OIRM), Program Systems Division (PSD). This work represents Deliverable 2 under Task Order Number N4B688015 of GSA Contract Number GS-00K-85AF-D2777. The objectives of this report are to document current GIS applications and those under development within EPA and to identify management, technical, staffing, and other "lessons-learned" from implementing GIS programs.

This report is part of a larger effort being undertaken by OIRM and PSD to further the goals and objectives of EPA's GIS program, which were identified in a GIS management study done in cooperation with the Office of Research and Development and the Office of Policy, Planning and Evaluation. In addition to this report on GIS case studies, PSD has initiated the following information resource management studies as part of its effort to further agency GIS goals:

- Analysis of requirements for an EPA GIS workstation;

- Identification of EPA GIS training requirements for managers, technical staff, and end-users and recommendation of a training curriculum to satisfy those requirements;

- Development and implementation of a pilot GIS application using ARC/INFO software currently installed by EPA on the Washington Information Center (WIC) PRIME.

This report updates a previous GIS case studies document produced over a year ago for OIRM/PSD. Five sites visited for the previous document were revisited for the current report. The current report presents a new picture of GIS at these sites, since many changes have occurred during the past year, including acquisition of new software and hardware and new GIS applications. These five sites are EPA Regions I, III, and IV, the Chesapeake Bay Program, and the Environmental Research Laboratory at Corvallis.

Four additional sites were also visited under the current task. Case studies are presented for these sites of EPA Regions VII and VIII, the Environmental Monitoring Systems Laboratory at Las Vegas, and the National Data Processing Division, National Computer Center at Research Triangle Park. A case study is also included for the Oregon Clean Water Strategy, which is a cooperative GIS project between EPA Headquarters and the Oregon Department of Environmental Quality. Interviews for all of the sites described in this document were conducted from August through October, 1988.

This report is organized into the following major parts:

(1) **Section I: Introduction**

(2) **Section II: Findings and Conclusions;** GIS applications for the case studies are summarized, and key success factors and constraints to the implementation of GIS are identified.

(3) **Section III: Case Studies of GIS Implementations;** A case study is presented for each of the following sites:

- Region I
- Region III
- Chesapeake Bay Program (CBP)
- Region IV
- Region VII
- Region VIII
- Environmental Monitoring Systems Laboratory at Las Vegas (EMSL-LV)
- Environmental Research Laboratory at Corvallis, Oregon (ERL-C)
- National Data Processing Division, National Computer Center at Research Triangle Park (RTP)
- Oregon Clean Water Strategy

Each case study is divided into the following sections:

- Executive summary

- Overview of GIS at the site, followed by descriptions of the site's current and planned GIS applications

- Implementation issues related to the use of GIS, grouped into five topics:
    - Management/Communications
    - Data
    - Staffing
    - Software
    - Hardware

- Constraints

- Conclusion

(4) **Appendix A: List of Interviewees**

Findings and Conclusions

II. FINDINGS AND CONCLUSIONS

This section presents findings and conclusions drawn from the case studies of EPA GIS implementations. These findings and conclusions are organized into four topics:

- Summary assessment of GIS implementation within EPA
- Approaches for GIS implementation
- Key success factors for GIS implementation
- Constraints on GIS implementation

A. Summary Assessment of GIS Implementation within EPA

EPA's use of GIS has been marked by substantial progress since the production of a previous case studies document over a year ago. Significant activities have included the following:

- Installation of GIS hardware and software at Regions I, III, and VII and the forming of GIS teams at Regions III, VII, and VIII;*
- Establishment of a GIS Support Group at the National Data Processing Division at Research Triangle Park;
- Planned GIS hardware/software installation and staffing at Regions V, VIII, and X;
- Use of GIS products and results at Agency GIS sites in support of environmental programs and analyses.

It is this last point, i.e., the application of GIS to support EPA programs, that underscores the progress that has been made throughout the Agency in its use of GIS. GIS is assisting EPA in identifying and assessing environmental problems and trends. Although some of EPA's GIS sites are still in the pilot stage of implementing the technology, both these newer GIS sites as well as the more experienced GIS sites have conducted analyses and generated useful products from GIS in support of Agency programs. A few examples of this support include the following:

- **Region I** is identifying potential contamination sources for ground water in two river basins with GIS and will use this information to develop wellhead protection plans.

- **Region III** has also used GIS to identify sources of ground water contamination relative to receptors, to identify and map locations of high-risk underground storage tanks, and to develop wellhead protection plans.

- With GIS, **Region IV** identified and ranked which RCRA sites should be assigned to the National Priority List as Superfund sites. Region IV is implementing a system that will utilize GIS as a tool to target regulatory activities based on environmental problems and risks and to determine if programs are improving environmental quality.

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* GIS teams had been established at Regions I and IV at earlier dates.

- **Region VII** is assisting the state of Missouri in utilizing GIS to develop an emergency response management plan for hazardous spills that may contaminate water supplies.

- **Region VIII** is using GIS in conjunction with other technologies to determine the fate and transport of the Denver Brown Cloud. With GIS, a distant smokestack was identified as a contributor to the Brown Cloud problem.

- **EMSL-LV** is assisting other units in building GIS data bases for the Clark Fork River NPL sites that will be used for many years for remedial investigation and cleanup activities.

- Both the **CBP** and .**ERL-C** use GIS extensively to support their ongoing research activities. With GIS, the CBP has examined the relationships between habitats required for living resources and water quality in the Chesapeake Bay. ERL-C uses GIS in its work with ecoregions for resource management.

Table 1, which is presented in the following pages, summarizes the program applications of GIS at the sites visited. Because some of the applications may support numerous activities, either presently or in the future, only the major uses of the applications have been listed. The applications are described in greater detail in the individual case studies of this document.

The programs for which the most GIS applications have been implemented are the water programs, especially ground water protection. Applications done in support of the Superfund and RCRA programs are the next most frequent, and these usually have a ground water component involved as well.

An important next step in the implementation of GIS at EPA is the integration of GIS as a tool in support of management decisions related to environmental policies and programs. To date, most of the Agency's uses of GIS have focused on identification and prioritization of environmental problems and trends. Some efforts towards using GIS as a management tool have begun, however, such as Region IV's work on a Results/Risk Analysis and Management System which will utilize GIS to target regulatory activities based on environmental risks and to determine if programs are having an impact on environmental quality. Similar systems that support management decision-making need to be undertaken as the Agency seeks to expand its use of GIS. Section II.D describes challenges that must be addressed and resolved as such expansion occurs.

Table 1

Summary of Program Applications of GIS
at Sites Visited

<u>**Site**</u>   <u>**Program Applications**</u>

<u>**Region I**</u>   **Ground water protection**

- Cape Cod Aquifer Management Project
  • Assess risks to ground water from contaminants
  • Identify sites for new public wells
  • Develop planning scenarios for impacts to ground water quality
- Ground water mapping
  • Identify wellhead protection areas
  • Map and prioritize water supplies at risk and potential contamination sources

Radon risk assessment

• Map radon hotspots
• Identify populations at risk
• Identify priority areas for additional sampling

Bays Program

• Map discharge and samples data in Quincy Bay for presentation at public meetings

Ozone monitoring

• Map ozone monitoring stations and areas exceeding ozone standards for presentation at meetings

Superfund site support

• Characterize extent of site problems
• Identify contaminant migration routes and populations/ locations at risk
• Map sites subject to legal actions (future use[1])
• Evaluate proposed cleanup strategies (future use)
• Plan and prioritize enforcement activities (future use)

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1. Future use: Uses for GIS applications that have been considered, but probably will not be done during the pilot project.

Region III   **Ground water protection**

- Map sources of contamination relative to receptors
- Identify potential vulnerability of areas to ground water contamination
- Develop a management plan for wellhead protection
- Prioritize inspection and enforcement for underground storage tanks (future use)
- Target and prioritize other sites (e.g., Superfund) for inspection and enforcement (future use)

Radon evaluation

- Examine predictive value of selected variables for high radon readings
- Identify populations at risk, and prioritize high-risk radon areas
- Identify rural areas and private wells at risk
- Effectively communicate findings to the public

Wetlands protection (planned[2])

- Evaluate requests for wetlands permits
- Cumulative assessment and advanced identification
- Study and assess trends of wetlands loss

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Chesapeake Bay Program   **Research and analysis on the Chesapeake Bay and land conditions impacting the Bay**

- **Non-point source pollution analysis**
  - Transform data for watershed modeling
  - Identify areas for Best Management Practices (BMPs) and evaluate BMPs' effectiveness
  - Examine relationships between land use practices and water quality

- **Living resources analysis**
  - Study impact of water quality on living resources

- **Water quality monitoring**
  - Integrate data from water quality monitoring program with other analyses

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2. Planned: Projects that may be implemented in the future. This does not include projects that have begun and are in the planning or scoping stage.

Region IV

Environmental priorities initiative

- Identify and rank RCRA sites for the Superfund National Priorities List (NPL)

Superfund site evaluation

- Map Superfund sites and wells for identifying and ranking new NPL sites

Drinking water vulnerability

- Prioritize well inspection efforts and reduce inspection costs

Ground water protection

- Allocate inspection efforts for water contamination from woodtreaters, and prioritize other enforcement actions

Construction grant evaluation (planned)

- Determine if construction grants and loans are being used in problem areas and have improved water quality

Air program (planned)

- Assess adequacy of air monitoring network
- Identify pollution sources
- Analyze ambient air quality trends

Region VII

Non-point source pollution analyses

- Determine best land management practices to minimize runoff
- Effectively communicate results to farmers

Emergency response to hazardous spills

- Develop wellhead protection plan
- Develop an emergency response management plan for hazardous spills

Ground water protection

- Map results of DRASTIC ground water vulnerability analysis
- Develop wellhead protection plan

Prioritization of RCRA sites

- Prioritize RCRA sites on environmental hazard and quality indices

Wetlands protection (planned)

- Prioritize inspection efforts
- Prioritize wetlands for protection
- Evaluate requests for wetlands permits

Region VIII

Surface water quality assessment

- Map aquatic life use and impairment data for streams by ecoregion, and identify patterns of impairments
- Identify attainable water quality goals to be used in resource management strategies (future use)

Air pollution exposure assessment

- Determine optimal locations for air quality monitors
- Determine fate and transport of Denver Brown Cloud
- Identify and locate pollution sources

Ground water protection

- Map results of DRASTIC ground water vulnerability analysis
- Identify locations of underground storage tanks
- Delineate wellhead protection areas

Superfund site evaluation

- Characterize nature and extent of site problems

Environmental Monitoring
Systems Laboratory at
Las Vegas

Superfund site analysis

- Characterize nature and extent of site problems for remedial investigation
- Perform macro and micro site analyses
- Support monitoring activity
- Assess human and environmental exposure and potential risks from contaminants

- Identify potential polluters through contaminant pathway analysis

Air pollution exposure assessment

- Validate new technology for monitoring atmospheric particulates
- Assess populations at risk from particulate pollution

Wellhead protection

- Map results of DRASTIC ground water vulnerability analysis
- Develop wellhead protection plan

Intertidal habitat analysis

- Integrate GIS with remote sensing to assess habitat exposure

Point and non-point pollution monitoring

- Monitor nutrient contributions to pollution problems

<u>Environmental Research Laboratory at Corvallis</u> **Regional geography and ecoregion analysis**

- Map data to assist in analytical definition of regions
- Use ecoregions as basis of resource management strategies

Direct/Delayed Response Project -- Acidic deposition

- Understand long-term impacts on surface water of continued acidic deposition
- Assess current status of and forecast acidic deposition
- Predict causes and effects of acidification

Surface water quality assessment (with Region VIII)

- Map aquatic life use and impairment data for streams by ecoregion, and identify patterns of impairments
- Identify attainable water quality goals to be used in resource management strategies (future use)

National Lakes and Streams Survey

- Characterize chemical status of lakes and streams

Ground water protection

- Map Superfund and RCRA sites in relationship to aquifers

Other research efforts

- Infer historical water quality through paleoecology research
- Examine contribution of road salt to chloride concentrations

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<u>Research Triangle Park</u> **Ozone and air pollution research**

- Conduct quality assurance analyses by comparing modeled and monitoring ozone data
- Review the effectiveness of control strategies for meeting National Ambient Air Quality Standards
- Evaluate the relationship of air quality data to health statistics

B.   Approaches for GIS Implementation

The current GIS programs in EPA reflect several approaches to implementing GIS. Although all of the GIS work at a site does not fit neatly into one of these approaches, this categorization helps to obtain a broad overview of the range of approaches to GIS implementation. These approaches are listed below, and examples are described in the following paragraphs.

(1)   Site-specific pilot or demonstration projects

(2)   Development of regional data bases

(3)   Cooperative projects with states

(4)   Support to ongoing programs and activities with a research orientation

(5)   Projects at multiple scales of analysis

1.   Site-specific Pilot or Demonstration Projects

Much of the GIS work conducted by Region I, Region III, and EMSL-LV consists of pilot or demonstration projects for specific sites. These sites range in size from a small section of a harbor to a large site consisting of four National Priority List sites and 150 river miles.

The demonstration projects conducted by EMSL-LV are typically done as a mechanism for transferring its GIS knowledge and expertise to EPA Regions and programs. As EPA's GIS Center of Excellence, EMSL-LV's GIS activities extend far beyond conducting demonstration projects, as described in the case study for EMSL-LV.

2.   Development of Regional Data Bases

A major emphasis of GIS work at Region IV is developing regional data bases that can be used by multiple regional programs. Several programs, such as the Environmental Priorities Initiative, Superfund, and Drinking Water, require the same data but use that data from different perspectives. By concentrating on data base development, Region IV plans to support the use of GIS in managing regional environmental programs and in relating programs to improvements in environmental quality.

Most of the Regions have indicated that regional GIS data bases will be developed over time. Regions VII and VIII have begun initial work towards that goal. However, regional data base development is not the overriding emphasis of current GIS work at these Regions in the same manner that it is in Region IV.

3.   Cooperative Projects with States

Region VII's GIS pilot projects are being done as cooperative efforts with the Region's states. Formal agreements in the form of grants from Region VII to each of its four states are

funding the pilot projects. The projects are true cooperative efforts in which both parties share responsibilities and work for the projects. The Oregon Clean Water Strategy is another example of a cooperative project being done with a state.

4. Support to ongoing programs and activities with a research orientation

The Chesapeake Bay Program (CBP) uses GIS for many tasks to support its ongoing work with the Bay and the surrounding land. Rather than conducting enforcement and program management activities like EPA Regions, the CBP focuses on analyses that can support the programs of the political jurisdictions and agencies with responsibility for the Bay and its watersheds.

As EPA's center for atmospheric, terrestrial, and aquatic ecological research, ERL-C also has a research orientation in its use of GIS. Much of ERL-C's work is based on an analytical approach focused on ecoregions. GIS is used as a tool in support of this research.

The primary goals of the RTP pilot project are tied to the major research laboratories involved in the pilot. These goals are related to air pollution modeling and monitoring, assessment of the effectiveness of control strategies for meeting air quality standards, and an evaluation of the relationship of air quality data to health statistics.

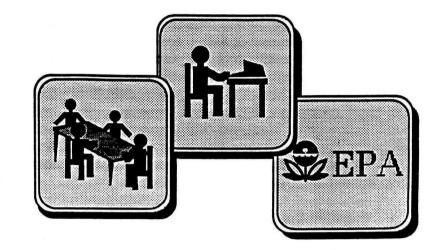### 5. Projects at Multiple Scales of Analysis

Most of the sites have implemented GIS projects at more than one scale of analysis. For example, Region VIII has initiated GIS pilot projects at the state, metropolitan, and site-specific scales. In addition to their site-specific pilot projects, Regions I and III have radon projects that may include their entire regions.

In evaluating these various approaches to GIS implementation, the GIS programs at the EPA Regions are still too new to determine which, if any, of these approaches is the preferred method for initiating a GIS capability. Each of the approaches has benefits if projects are done with proper planning and are staffed by a sufficient number of skilled staff. Site-specific pilot and demonstration projects provide an effective means for Regions to acquire GIS expertise through projects of manageable size. Successful pilot projects produce tangible results within a limited time frame. Through these tangible results, which may be GIS-produced maps, the capabilities and potential of GIS are demonstrated, which may in turn gain additional support for using GIS with regional programs. Development of regional data bases will provide direct support to numerous regional programs and will be required if GIS is to support program decision-making on a broad basis throughout a Region. Region VII's cooperative projects with its states have served to bring the states along in their use of GIS at the same time that the Region is acquiring GIS expertise. The seed money provided by the Region's grants to the states has also resulted in additional funds being allocated to GIS by the state legislatures.

At the CBP and ERL-C, GIS is a tool that supports the missions of those organizations. Their approaches to the use of GIS serve their organizations well but would not meet all of the decision-support needs of the Regions' regulatory programs.

C. Key Success Factors for GIS Implementation

Key factors that have been instrumental in the successes of GIS to date in EPA are described in the following paragraphs. These success factors are also essential as the transition is made throughout EPA from using GIS on a pilot basis to using GIS as a tool that supports management decisions.

• **Management commitment:** The successes of GIS to date have depended on upper management support of GIS at the deputy regional administrator and assistant regional administrator levels as well as on support by program managers. Successful GIS implementation requires that upper management provide the resources and support needed to initiate a GIS capability, especially by providing a sufficient number of personnel to form a viable GIS staff. Program management support is also a key factor. For GIS to be used ultimately as a tool to aid environmental programs and for environmental decision-making, program managers must fully support the use of GIS in their programs. Such support means providing funding for projects that are utilizing GIS, funding the acquisition of data that are required to support their GIS applications, and allocating staff time to participate actively on GIS project teams.

• **Staffing:** One of the most important factors for the success of GIS is a skilled GIS staff. The ideal GIS staff consists of a multi-disciplinary team in which the team members have expertise in an array of environmental sciences and EPA programs. An understanding of fundamental concepts of maps and geographical analysis is also essential, as well as general problem-solving skills. Although some experience with computers is necessary, degrees in computer science are not required for GIS team members. Most of the GIS sites that were visited emphasized the importance of having a GIS staff with environmental expertise as opposed to a staff of computer scientists.

• **Agency support:** GIS work within EPA has been placed on a firmer base during the past year. This improvement has stemmed from the support given to the Regions and other GIS programs by EPA Headquarters in terms of hardware, software, and training. Without the hardware provided to the Regions, GIS programs could not have been established. Provision of key peripherals, especially electrostatic plotters that produce high-quality maps, has also done much to garner support for GIS. EPA's selection of ARC/INFO as the Agency's GIS software of choice has simplified the process of establishing a GIS capability. By having a common GIS software package throughout EPA, Agency expertise, processing techniques, and common procedures can be shared more easily between Headquarters, the Regions, and the Labs. Finally, the efforts to provide ARC/INFO training to all the Regions with GIS capabilities have helped to increase the number of those with GIS expertise within the Agency.

D. Constraints on GIS Implementation

Areas in which there are constraints to the use of GIS and especially to the use of GIS as a tool to support management decisions are described below. Because GIS has been demonstrated within EPA to be a useful tool with broad application for helping the Agency to fulfill its mission, these constraints should not be viewed as roadblocks to the implementation of GIS but as challenges to be addressed as the Agency seeks to implement GIS to its fullest potential. For each of these constraints, EPA should formulate a plan for its resolution and then provide the necessary resources to implement the appropriate solutions. Although the recommendation of specific solutions to these constraints is beyond the scope of this document, actions through which EPA has already begun to address these constraints are mentioned, along with other possible actions that should be considered.

• **Spatial data:** The quality of locational data in EPA's data bases is often poor. Locational references, such as latitude and longitude coordinates, are frequently missing or are inaccurate when present. Because GIS is a spatially-based technology, the successful implementation of GIS requires accurate and complete locational data. The need for good locational data will become even more apparent as more programs seek to use GIS in support of their activities. Determining accurate locations is often an expensive and time-consuming task that may increase the cost of a project, especially if extensive field verification work must be done.

EPA has taken a few initial steps towards addressing the problem of poor locational data, specifically:

- A spatial data policy has been drafted which, when approved as Agency policy, will require the collection, management, and reporting of locational data and will establish Agency roles for implementing this policy.

- EMSL-LV and OIRM are conducting research on and evaluating alternative geopositioning techniques for Agency use.

- EPA's Office of Water has initiated a program to improve locational data accuracy and coverage in the Permit Compliance System (PCS).

EPA should seek to provide sufficient funding for efforts to improve the quality of locational data in the Agency's national data bases.

Another aspect of spatial data that is a constraining factor on using GIS is the lack of quality indicators for spatial data and GIS products. Because GIS is a technology that can combine data from a variety of sources, the maps produced by GIS may contain cumulative errors that are the result of combining data with different levels of accuracy. Since EPA's mission includes enforcement of environmental regulations, knowing the accuracy of information used to support legal actions is of the utmost importance. Without quality indicators for GIS products, it will be difficult, at best, to use GIS to support legal actions. Quality indicators are also required to gauge the cost and effort required to improve the accuracy of EPA's data bases.

To address this problem, EMSL-LV should receive funding for research on GIS QA/QC issues. This funding should not be tied to a specific Agency program, since the need for quality indicators for spatial data and GIS products extends across all programs using GIS. Cooperative efforts with academia for research and development of spatial data/GIS quality indicators should be encouraged and supported by the Agency.

- **Staffing:** The need for more GIS staff is critical to the expansion of the use of GIS throughout EPA. Many of the GIS teams at the sites visited are supporting near their maximum workloads for GIS. Without additional staff, developing GIS data bases and applications to support EPA programs will require too much elapsed time.

The demand for additional staff to support GIS includes the need to have program staff that can work on GIS projects. GIS projects require that program staff serve on the project teams and be able to devote a sufficient amount of time to the projects. The need for this type of support is tied to the constraint described below on program management commitment.

For each fiscal year, staffing needs for current and planned GIS applications should be carefully evaluated. When inadequate staffing resources are projected, steps should be taken to hire additional staff. This may require cooperative efforts in sharing the funding for a new FTE position by the GIS unit and the program for whom an application will be developed. In preparation for hiring additional staff, job descriptions and categories for GIS staff that can be used across the Agency should be prepared so that hiring can proceed quickly when authorized.

- **Program management commitment:** As stated above under key success factors, GIS must be used as a tool to support environmental programs and environmental decision-making if it is ultimately to be successful within EPA. These uses of GIS require full commitment to GIS from program managers. With some exceptions, which have contributed to the successful use of GIS in the Agency, program managers within EPA are either very tentative towards the use of GIS or do not understand how it may help their programs. On the other hand, environmental scientists in the Agency who have been exposed to GIS are often excited about the potential that GIS has for assisting them in their work. Application of GIS to Agency programs needs program management support, because the participation of program staff is key to successful GIS implementation. Program management commitment must extend beyond financial and staff support to a clear long-term commitment to using GIS as a day-to-day analytical decision-support tool.

In a recent document on GIS training recommendations for EPA, an Executive Briefing for upper and mid-level managers was identified as an important part of a training program for GIS. Development and presentation of this Executive Briefing should proceed as one method of educating managers on the benefits that GIS may have for their programs. As managers understand how GIS can assist them in managing their programs and meeting their program objectives, management commitment to supporting GIS should follow.
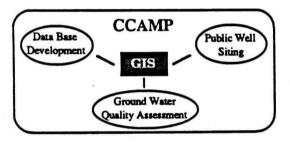
- **Non-project specific research and development funding:** GIS is a technology that cuts across all EPA programs. Consequently, the development of advanced techniques and preferred methods for using GIS can be of great benefit throughout the Agency. Such techniques and approaches include data standards, quality assurance and control measures and procedures, data base design standards and guidelines, common routines and macros to be shared among users, new methods of applying GIS towards environmental analysis, and integrating other
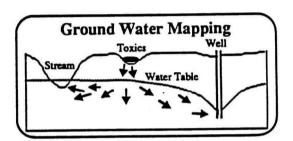
technologies, such as remote sensing, with GIS. Such research and development work needs a separate source of funding that is not tied to specific projects or programs.
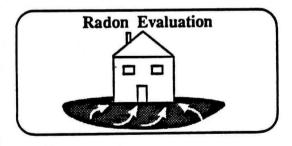
- **Communications:** The need to know what others within EPA are doing with GIS was expressed by numerous individuals that were interviewed. Effective communications between GIS teams at EPA Headquarters, the Regions, and the Labs must be established to foster sharing of knowledge and to prevent the same errors from being made more than once. Much useful information can be gained from the experiences of others who have worked with the same data sets or who have implemented GIS applications in support of the same programs at different sites. This report on GIS case studies is one mechanism initiated by EPA Headquarters to support communication on GIS applications within the Agency. As recommended in the document "EPA Training Recommendations for Geographic Information Systems," a mechanism should be developed for effective GIS technology transfer, so that others in EPA can take advantage of the knowledge gained by the Agency's more experienced GIS users, including EMSL-LV, ERL-C, Region IV, and NDPD.
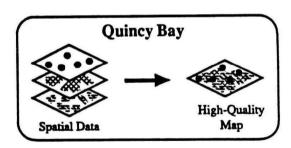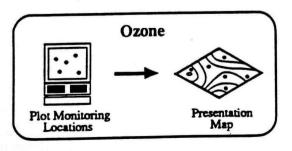
III. CASE STUDIES OF GIS IMPLEMENTATIONS

Region I

GIS at Region I: Implementation at the Pilot Level

CCAMP

Data Base Development

GIS

Public Well Siting

Ground Water Quality Assessment

Ground Water Mapping

Stream

Toxics

Well

Water Table

Radon Evaluation

Quincy Bay

Spatial Data

High-Quality Map

Ozone

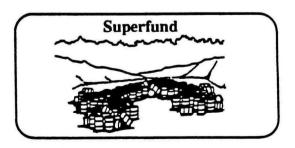Plot Monitoring Locations

Presentation Map

Superfund

EXECUTIVE SUMMARY

GIS at Region I has been implemented successfully in support of several pilot projects. These projects have utilized GIS-produced maps as tools to assist engineers, scientists and managers to visualize environmental data. The planned completion of a pilot project in ground water protection in December, 1988 has enabled Region I to take the first steps towards the application of GIS as a day-to-day tool in support of ongoing environmental programs.

The following programs are being conducted or planned at Region I:

CCAMP -- As part of the Cape Cod Aquifer Management Project, GIS was used to assess environmental risks to ground water, to determine new sites for public wells, and as a planning tool for development of ground water protection scenarios.

GROUND WATER MAPPING -- GIS is being used to visualize ground water environmental characteristics and potential contamination sources and to identify hazardous waste sites in wellhead protection areas.

RADON EVALUATION -- High-risk radon areas will be identified with GIS, and correlations between those high-risk areas and bedrock geology will be examined.

QUINCY BAY -- A high-quality map of various environmental attributes of Quincy Bay was produced for presentation at public meetings.

OZONE -- The locations of forty ozone monitoring stations situated throughout the region will be mapped with GIS.

SUPERFUND -- This pilot consists of several planned projects in which GIS could assist in environmental analysis and the planning and prioritizing of enforcement activities.

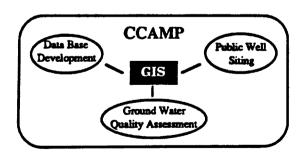Region I's GIS work has depended upon four key factors:

o   Continual efforts of Region I's Information Management Branch in communicating the usefulness of GIS;

o   Support of program management in some areas;

o   A GIS team staffed by systems and graphics experts; and

o   Help from states in terms of their ARC/INFO expertise and data sharing.

GIS at Region I

As part of the Planning and Management Division, Region I's Information Management Branch (IMB) has been supporting regional program data integration needs, including various types of geographical analysis, for many years. During the past year Region I's IMB implemented GIS at the pilot level. The recognition by program managers that GIS maps are powerful communications tools has stimulated Region I's GIS work. Further adoption of GIS as a day-to-day tool will depend, in part, on program managers' recognition that GIS can be used to enhance data quality and to support program decision-making.

Region I began its entry into GIS by using the ARC/INFO system located at the USGS District Office. In December, 1987 Region I acquired its own ARC/INFO software and installed it on a PRIME 2755. Since that time additional peripherals, including graphics terminals, a digitizer, and a plotter have been acquired. Region I's GIS staff consists of two EPA staff members and three Computer Science Corporation contractors.

The six GIS pilot projects of Region I are described in the following sections.

Region I has almost completed work on the Cape Cod Aquifer Management Project (CCAMP), which has examined existing groundwater protection programs at the federal, state, regional and local levels of government. The project has been a collaborative effort between Region I, the Massachusetts Department of Environmental Quality Engineering, the U.S. Geological Survey and the Cape Cod Planning and Economic Development Commission.

Initially, CCAMP participants selected a series of ground water management issues to be examined and set up three specialized work groups to focus on these issues. The work groups, consisting of an Aquifer Assessment Group, a Data Management Group, and an Institutions Group, were concerned with development of scientific understanding of the aquifer, management of data pertaining to the aquifer, and analysis of institutional arrangements to govern use and abuse of the ground water resource, respectively.

GIS has been the springboard for the identification of appropriate data sets, collection of new data, and extensive quality control/quality assurance of acquired data sets for CCAMP. 'Base' maps were generated from an assemblage of digital data including:

- primary transportation routes
- town boundaries
- well locations
- aggregated land use (commercial, residential)
- water-table contours
- groundwater flow lines

The risk to the quality of groundwater near existing and planned public water-supply sites has been assessed by overlaying ground water and well data with data for possible sources of contamination. Contaminant data include:

(1)   Underground Storage Tanks (UST). Attribute data desirable for analysis include number, volume, age, material, content, and

location by land parcel.

(2) Toxic and Hazardous-Material Sites. Regulated facilities, location by parcel, volume, character of material, and known contamination extent.

(3) Waste Water. Municipal sewage-disposal sites, ground water discharge sites, sewered/unsewered areas, feed lots, known septic systems.

(4) Road Salt. Salt storage areas, volume, type of cover (shed, plastic, no cover), road application rates (if available).
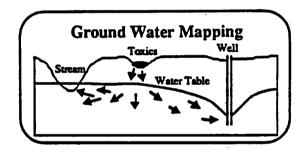
GIS was used in CCAMP to determine new sites for public wells in the towns of Barnstable and Eastham. Based on land use data, requirements were defined for locating well sites, and a series of overlays were developed. Only two possible well sites were identified.

GIS was also used to help local officials predict which underground storage tanks (UST) pose the greatest risk to public wells. Utilizing a USGS model of leaking underground storage tank (LUST) dispersion and well risk, factors such as UST composition, UST age, and ground water flow patterns were entered into the GIS. The resulting area of contaminant contribution was then delineated and referenced to well locations. This GIS application clearly demonstrated the utility of GIS in assisting officials to prioritize management of UST risks and potential hazards.

CCAMP was Region I's first GIS project and was considered to be a valuable learning experience. Indeed, the main purpose behind Region I's involvement in CCAMP was to gain experience in GIS. The benefits derived from this project include:

(1) Use of GIS as a planning tool for the development of risk scenarios by the Cape Cod Planning and Economic Development Commission.

(2) The assimilation of dispersed and non-standardized environmental data from numerous agencies into a uniform, accessible data base.

(3) Development of a data base with extensive QA/QC.

(4) Demonstration of the utility of using GIS for developing Wellhead Protection plans and understanding relevant issues.

(5) Region I's belief that the development of the GIS will assist future modeling efforts, ground water risk assessments, and support State environmental management programs.

Region I's second largest GIS project after CCAMP is its Ground Water Mapping Project for Rhode Island's Branch River Basin and southern New Hampshire's river basin near Nashau. The study is examining the relationship between ground water/surface water resources and their potential contamination from sites such as:

- Superfund
- RCRA
- Waste water treatment plants
- Salt storage
- Underground storage tanks
- Auto salvage yards

The objectives of this project are to:

(1) Identify wellhead protection areas. By

highlighting facilities for hazardous wastes in wellhead protection areas, this information can be presented to local officials for planning purposes.

(2) Present data on one map. By showing sources and affected areas on one map, the information can be communicated easily.

GIS is used in this project to visualize various parameters (i.e., waste volume, waste toxicity, distance to underground drinking water, etc.) that are input to the Superfund Program's Hazard Ranking System to make up a hazardous waste site "score". This will enable programmatic staff to prioritize and rank hazardous sites throughout Region I, and has helped them attempt to reach their goal of more accurately mapping the hazardous sites.

Base data layers obtained include:

- Hydrography
- Aquifers
- Cultural boundaries
- Administrative boundaries
- Roads
- Surface water basin/sub-basin boundaries
- Ground water/surface water monitoring sites

The Ground Water Mapping Project is expected to finish by December, 1988, after which more basins may be studied. Region I considers this project to be successful and believes it may be the first project to move from pilot stage to production.
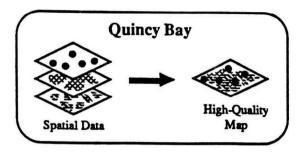

Radon Evaluation

Region I's Air Division is conducting a GIS pilot project that will identify potential high-risk radon areas. The project will both map sample radon values and investigate the correlation between geology and radon air data. The data layers have not yet been overlayed, as the Air Division is still determining what other information is needed, and deciding on the best method for performing the analysis.

Region I's objectives for the project are as follows:

(1) Create maps to show radon hotspots.

(2) Determine health risks by analyzing radon data with population data.

(3) Statistically determine where more radon samples should be taken.

(4) Input radon data by town instead of by zip-code. More exact latitude/longitude location data can be determined from town names than from zip-code areas. Towns, therefore, will reflect more accurate locations of radon samples.
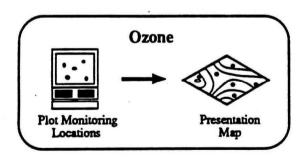
Region I believes the most beneficial contribution of the radon GIS project is that information can be given to the states, which can then focus resources on their largest and most critical radon areas. By comparing low-income areas with radon data, areas that may need government assistance to correct radon problems may be identified.

Quincy Bay

Spatial Data → High-Quality Map

For the Water Division's Bays Program, Region I conducted a GIS mapping project for Quincy Bay, which is a small section of Boston Harbor. The Bays Program asked for a map of sample data from Quincy Bay of:
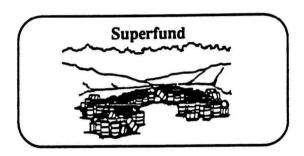
- Emergency discharge/combined sewer overflow;
- Sludge discharge;
- Effluent discharge; and
- Oyster, lobster, clam and flounder samples.

The goal of this project was to produce a high-quality 1:25,000 scale map which contained these data and could be presented at public meetings. Region I can use the map and sample data for many years and regards this information as being of great use towards future work in Boston Harbor.

Ozone

Plot Monitoring Locations → Presentation Map

Region I is just beginning a pilot project that will use GIS to plot the location of forty ozone monitoring stations located throughout the Region. The Region's managers can then use the GIS map at presentations to show the locations where ozone levels exceed the

standard set by EPA. Presently, base maps are being assembled from data provided by other sources, and the GIS staff is attempting to secure latitude/longitude data of the ozone monitoring stations.

The project is considered to be a relatively straightfoward mapping effort at the present time. There is, however, interest in using the GIS to do modeling, perhaps incorporating dynamic changes into the models.

Superfund

GIS is viewed as a tool that has great potential for assisting several Region I Superfund projects that are still in the planning stage:

(1) New Bedford Harbor Superfund Site -- Large electronic firms have dumped great quantities of PCB's into the harbor, creating a pollution problem that may require as much as $200,000,000 to clean up. Since much data has been collected by contractors to determine cleanup stratagies, GIS could be used to map this data, and lawyers could then use these GIS maps in court cases. In addition, GIS could assist in evaluating the proposed cleanup strategies, as well as do analysis when corrective action does begin.

(2) Old Southington Landfill -- This effort was conceived as an EPA GIS demonstration project that addressed such issues as:

- Site characterization;
- Potential routes of contaminant migration; and

- Populations and environments
  potentially affected.

Region I's Superfund staff are now interested in using GIS as a day-to-day tool for the Old Southington Landfill Project. However, due to the demonstration nature of the project, necessary sections of the data base (i.e., ground water monitoring information) were never developed. Region I believes that if these sections of the data base are developed it will provide important information for Superfund site management and decision-making.

(3) The Waste Division believes GIS could be used internally to plan and prioritize enforcement activities for Superfund and RCRA sites.

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Implementation Issues

Management/ Communications

Three important factors have contributed to the successful implementation of GIS at Region I:

(1) The support of program management in some areas (i.e., Water Division) has been instrumental in implementing GIS. Their support was developed through the continual efforts of IMB management, who saw the usefulness of GIS as a decision-making tool.

(2) Region I was able to utilize USGS GIS expertise for its first GIS project. USGS guidance in CCAMP provided Region I the opportunity to gain valuable GIS experience.

(3) GIS and ARC/INFO are successfully used by the Region I states, and there is an active ARC/INFO users group in New England. These were factors in creating support for the acquisition of ARC/INFO at Region I, as well as providing Region I with expertise helpful in getting started with GIS.
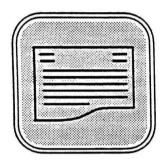
GIS is perceived by Region I's IMB to be a powerful communications tool. With its ability to visualize information, GIS makes tasks such as site prioritization much easier to accomplish than by working with tabular representation of the data alone. Moreover, applications such as the Ground Water Mapping Project and the Quincy Bay Project demonstrate how basic mapping products prepared with the GIS can effectively be used as presentation products, readily accessible by local officials for their decision-making purposes.

Region I expressed concern about the user's perception of GIS maps. Program staff believe that some users might think of the maps as highly accurate, authoritative sources of information. Without knowledge of the accuracy of the data from which the maps were compiled, there is a possibility of inadvertently circulating inaccurate data. Region I program staff recommend that this potential problem can be minimized by verifying the accuracy of the data as it is input into the database.

Region I's IMB also expressed concern about the expense of operating a GIS. Although Region I management generally regards GIS as a useful communications tool, and is beginning to recognize the analytical value of GIS, it is, however, an expensive technology and there are concerns as to whether it can be afforded.

A project management factor crucial to the success of a GIS project is focusing on the goals and objectives of that project. In Region I's experience, scientists may want to obtain all possible data related to their project. If project objectives are not clearly defined, the time-consuming data collection phase may extend longer than necessary. By focusing on clearly-stated project goals, efforts can be directed towards collecting the data needed to meet those goals.

Region I's IMB believes that the key to future GIS success at Region I is sustaining interest in GIS. If a sustaining project was found that could provide enough resources to keep the GIS staff funded, then this would give the staff a solid basis on which to grow, during which time the Region's GIS expertise could be built up.

 Data

Region I obtains much of its data through informal data sharing arrangements. The fact that ARC/INFO is used extensively throughout Region I's states enables the Region and states to share data easily. Although informal data sharing has worked much better than formal arrangements would, the states may be reluctant to continue informal data sharing in the future as they fund the development of expensive data bases.

Data sets acquired by Region I include:

POINT COVERAGES
- Underground storage tanks
- Regulated facilities
- Public water-supply wells
- Hazardous waste disposal sites
- Municipal sewage disposal discharge
- Road salt piles
- Public water-supply test sites
- Spills and leaks (SPOT)
- Geographic names

LINE COVERAGES
- Primary transportation routes
- Water-table contours
- Ground water flow paths
- Town boundaries
- Hydrography (ponds, wetlands)
- 'DRASTIC' contours

POLYGON COVERAGES
- Barnstable zone of contribution (ZOC)
- Landuse, aggregated parcel level or better
- Zoning from Cape Cod Planning and Economic Development Commission
- Public water-supply service areas
- Planned growth zones (proposed changes)
- Planned water-supply ZOC's
- Known contamination plumes in aquifer
- Sewered service areas
- Seasonal-use areas

Region I staff expressed dismay that locational data in EPA data bases are often non-existent or of such poor quality that the information cannot be used with any reliability. Since the effectiveness of GIS requires comprehensive locational data to be included in a data base, EPA's poor locational data are regarded as the biggest constraint to Region I's GIS implementation.

Region I would like to devote more time to data base quality assurance/quality control. Documentation is considered an important part of data base development work, and documenting the quality of data bases is a top priority. Furthermore, Region I believes that data standards and quality control will only become meaningful and operational by working with real GIS applications.

CCAMP pointed out the difficulties of working with large-scale parcel maps. The quality of data collected by different assessors varied considerably, and Region I had no knowledge of the standards employed by each assessor. Consequently, work at such a large scale of analysis with numerous sources of parcel data requires more work in verifying the quality of data.

Staffing

The core GIS team in Region I consists of five individuals, each performing a specific GIS function. The Regional GIS Application Manager supplies hardware and software tools to GIS users, helps users to apply GIS technology to specific site problems, and conducts file management activities. The Region's Technical Manager is the team's graphics expert and manages the PRIME Computer. The CSC contractors consist of an Operations Manager who conducts internal data processing activities, while the other two contractors are responsible for data research, overseeing cartographic work, applying standards to digital and cartographic plots, and conducting CAD/CAM activities. Region I considers the systems and graphics expertise of this team to be a critical success factor in the implementation of its GIS.
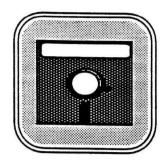
GIS staff and environmental scientists at Region I have distinct, separate roles. ARC/INFO is considered too complicated, with its four hundred commands, for the environmental scientists to become experts in its use. ARC/INFO requires constant use to develop expertise, and environmental scientists are much too busy with other responsibilities. Providing such expertise is the function of Region I's GIS staff. Moreover, a "lesson-learned" in Region I from pilot projects is that "dabbling" in GIS does not prove successful. Two commitments are necessary:

(1) The GIS staff must work with GIS daily, not just on an occasional basis, to acquire the necessary expertise to support the technology.

(2) Program staff working with GIS projects must be able to commit at least one third of their time to a GIS project.

The technology transfer required between the GIS staff and the environmental scientists is an issue Region I is presently evaluating. Environmental scientists need to know GIS and ARC/INFO as well as EPA regulatory programs. An example of this need for technology transfer occurred during Region I's Ground Water Mapping Project. Environmental scientists did not understand the complexities and effort involved in changing GIS base coverages for the Branch River Basin, RI, so they requested that its boundaries be changed several times. This created extra work that may have been avoided if the scientists had known earlier in the project the implications of such changes and the importance of getting accurate base coverages.

Region I's IMB management expressed the opinion that EPA may be evolving in its use of data -- from managing systems that collect and maintain data to a more active role by program staff in their use of the data. As program staff become more involved in working with data to support their activities and make decisions, the following resources will be required:

(1) Environmental scientists that know enough about GIS to use tools, such as macros, developed for their benefit.

(2) Technology transfer (training) for environmental scientists.

(3) Sufficient staff resources so environmental scientists working with GIS have enough time to devote to their projects. A workable staffing arrangement for a GIS project requires that at least one third of the scientist's time be spent on the project.

(4) Sufficient GIS staff to write macros, user-friendly interfaces, and provide support so environmental scientists can work with the data.

Software

ARC/INFO was installed at Region I in December, 1987 and is viewed as a successful GIS package. Presently, Region I is writing ARC/INFO macros to help the GIS operations staff perform various GIS activities (i.e., plotting, editing). The macros help the operations staff perform the tasks more efficiently, and reduce the chances of tying up the system due to errors incurred while performing these operations.

The program staff expressed interest in using macros as well. They desire the GIS to be more user-friendly so that they may be able to experiment with the system more often. Region I hopes to develop macros for the program staff in the near future.

All of ARC/INFO's modules are utilized by the GIS team with the exception of NETWORK and COGO. The only constraint they have experienced with ARC/INFO is that map display may occasionally be time-consuming (i.e., 10 - 15 minutes per display), depending on how many people are using the PRIME computer. This slowness may be a combination of ARC/INFO and the PRIME 2755, and modifications to the hardware are expected to improve this condition.

The GIS staff has had much success using ARC/INFO's LIBRARY function (which allows for efficient data maintenance and organization) in their small scale DLG applications. They have great regard for LIBRARY's ability to pull out various pieces of the data base, as well as analyze and map these pieces individually.

Hardware

As shown in Figure 1, Region I's current hardware configuration consists of a PRIME 2755 CPU, Tektronix graphics terminals, a Calcomp digitizer and electrostatic plotter, and other supporting peripherals.

The PRIME slows down considerably when it simultaneously supports four GIS users. The Calcomp electrostatic plotter produces high-quality maps and is much faster than a pen plotter.
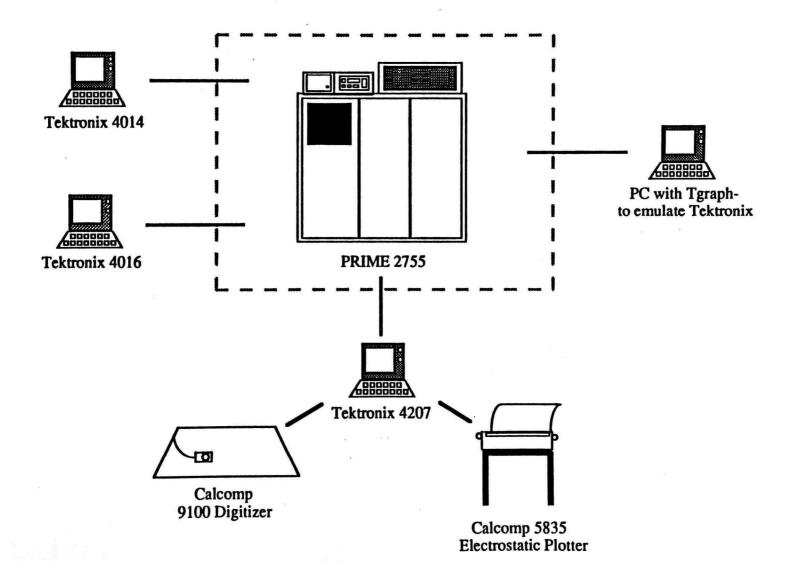
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Constraints

Several constraints are seen as impacting future GIS work in Region I:

(1) **Locational data in EPA data bases are often poor:** A major benefit of GIS is providing maps of various sites of interest (i.e., wells, hazardous waste sites, etc.) to EPA programs and showing the relative location of these various sites to each other. However, the lack of locational data (or the poor quality of much existing data) constrain this effort. Poor or missing locational data is considered the biggest barrier to Region I's GIS implementation. Acquiring the accurate locational data will require an extensive, time-consuming effort, but will be a worthwhile one for the future.

(2) **Need to sustain interest in GIS:** Region I's IMB needs to find a *sustainable* GIS project that could fully secure upper management support, even through transition years or budget cutbacks. This project would create a stable base upon which Region I's GIS expertise could be built.

(3) **Need for additional GIS staff to support program staff:** Program staff do not have much ARC/INFO expertise and must rely on the GIS staff to support their programs. The program staff, however, believe the GIS team lacks the manpower to handle all of their requests for processing data. For instance, several program staff members have a long list of GIS tasks they would like to have accomplished, but since they regard the GIS staff as being too busy with current assignments, only a fraction of the GIS tasks are requested.

(4) **Need for recurrent training of GIS staff:** Region I's IMB would like to see resources become available to support the continued development of the GIS staff. It is recommended that for the training program to be successful, it must be accomplished on-site for a brief period (2-3 days) and only cost several hundred dollars per session.
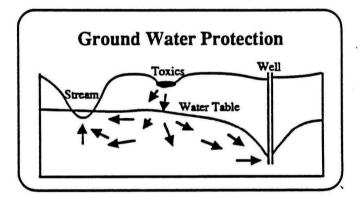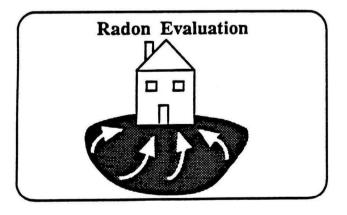
Conclusion

GIS at Region I has been successfully implemented in several pilot projects. This success has been due to the continual efforts of Region I's IMB in communicating the usefulness of GIS, and the resulting support of Region I's program management. Other important factors include a talented GIS team with system and graphics expertise, USGS guidance in Region I's initial GIS project, and the help of Region I's states in terms of their ARC/INFO expertise and data sharing. The continued evolution of GIS from pilot stage to production, however, will require better locational data in EPA data bases and more resources/manpower for Region I's GIS staff.

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Figure 1
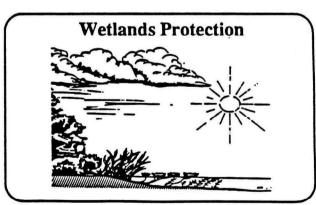
Overview of Region I GIS and Related Computer Systems

Tektronix 4014

Tektronix 4016

PRIME 2755

PC with Tgraph-
to emulate Tektronix

Tektronix 4207

Calcomp
9100 Digitizer

Calcomp 5835
Electrostatic Plotter

GIS Pilot Projects at Region III

Ground Water Protection

Radon Evaluation

Wetlands Protection

EXECUTIVE SUMMARY

Although Region III is in the pilot stage of GIS implementation, the region's GIS work to date has been successful and has the potential of becoming an integral part of program activities. Efforts in late 1987 and early 1988 were directed towards acquiring GIS hardware and software and hiring a GIS staff. With the planned completion of a pilot project in ground water protection in the fall of 1988, the first steps have been taken towards using GIS as a tool to support management decisions in ground water protection. The successful completion of projects in other divisions is required to incorporate GIS into the decision-making process of those divisions.

The following GIS pilot projects are being conducted or planned at Region III:

GROUND WATER PROTECTION -- For New Castle County, Delaware, GIS is being used to identify potential sources of ground water contamination and to delineate wellhead protection areas. Future work will assist in prioritizing inspection and enforcement actions to protect ground water. A second ground water project, which is a cooperative effort with Temple University, is utilizing GIS to identify and prioritize "hotspots" in the Region with the greatest ground water contamination risks.

RADON EVALUATION -- A planned pilot project will identify and prioritize high-risk radon areas and will investigate relationships for predicting high-risk areas.

WETLANDS PROTECTION -- GIS will support the evaluation of permits for filling or dredging wetlands in a planned pilot.

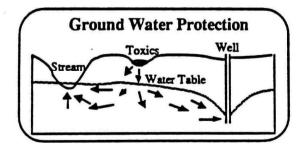Region III's GIS work has depended upon the following key factors:

o   Support of upper management and program management

o   Environmental scientists with an understanding of GIS who can devote sufficient time to GIS projects

GIS at Region III

During the past year GIS has been implemented at the pilot level in Region III. Initial activities have included the installation of hardware and software and the formation of a GIS support team. The first pilot project, which was scheduled for completion in the fall of 1988, has demonstrated the feasibility of using GIS as a tool to make management decisions related to ground water protection. Other pilot projects on radon and wetlands protection are in the planning stage.

Region III's entry into GIS occurred with delivery of its PRIME 2755 and ARC/INFO in December, 1987. Since that time additional peripherals, including graphics terminals, a digitizer, and plotters have been acquired. A GIS staff, which originally consisted of three Computer Science Corporation contractors, was formed in the Information Resources Management Branch. In October, 1988, an EPA staff member joined the GIS group to complete its initial staffing level. ARC/INFO training for all four staff members occurred during the spring of 1988.

Region III's GIS pilot projects are described in the following sections.

Ground Water Protection

The Ground Water Protection Section has initiated two GIS pilot projects to demonstrate how GIS could be used as a tool to support management decision-making for ground water protection. The first project has used New Castle County, Delaware, as a case study area, whereas the second project is being conducted as a cooperative effort with Temple University.

New Castle County Pilot Project

The New Castle County Pilot has shown the utility of using GIS in the area of ground water protection. Examples of decisions that may be supported by the pilot and by further analyses of data collected during the project include the following:

(1) Delineate boundaries of wellhead protection areas, and assist New Castle County in developing a management plan for wellhead protection.

(2) Assist the Underground Storage Tank Section in prioritizing inspection and enforcement actions for underground storage tanks (USTs).

(3) Identify other "environmental hotspots", and target these sites for enforcement actions (e.g., Superfund sites near wellhead protection or recharge protection areas).

The possibility of using GIS as a tool for geographic targeting of sites for enforcement action has generated much interest in the Ground Water Protection and Underground Storage Tank Sections. By using GIS to prioritize inspection and enforcement actions, limited resources could be applied to the most critical problems.

The New Castle County pilot was begun in May, 1988, and was scheduled for completion during the fall of 1988. A contributing factor in selecting New Castle County as a pilot site was that the county had already collected 77 data layers in its ARIES GIS. However, only one of these data layers was used for the pilot project. Approximately two man-months were required to convert the ARIES data to an ARC/INFO format.

The first two months of the pilot were spent obtaining data from New Castle County and other agencies, such as USGS, and converting data into ARC/INFO coverages. Types of data gathered or to be obtained later include:

> Locations of CERCLA and RCRA sites
> Locations of NPDES major dischargers
> Locations of high-risk USTs
> Location of Public Water Supply (PWS) wells
> Locations of PWS surface water intakes
> Recharge areas
> Aquifers
> Hydrology
> Land use
> Soils
> Slope
> Political boundaries

Tasks to be completed for the pilot that will be of immediate benefit to New Castle County are as follows:

(1) Identify sources of ground water contamination relative to receptors. This has been accomplished by mapping recharge protection areas, PWS wells, CERCLA and RCRA sites, NPDES major dischargers, and USTs which are fifteen or more years old. Preliminary wellhead protection areas were identified as two-mile buffers around PWS wells. For mapping the UST locations, Region III used the NETWORK module of ARC/INFO to match UST addresses to the road network from the 1980 Census DIME file.

(2) Identify the potential vulnerability of county areas to ground water contamination. This will involve looking at both the vulnerability of wells to contamination and the relative degree of hazard of sources of contamination. The DRASTIC index, which is a ground water vulnerability index, will be used with this task.

(3) Select the highest third of the DRASTIC values, and identify which areas have the selected level of ground water vulnerability.

These tasks will lead to the identification and prioritization of PWS areas with the greatest risk for contamination.

The New Castle County pilot project will serve as the springboard for much additional work in the area of ground water protection. Specific efforts for New Castle County will be based on the extensive ARC/INFO data base for the county that is being created as part of the pilot project. Since the number of potential tasks is very large, the following tasks are listed as only a few examples of projected future work:

(1) As stated above, Region III will assist New Castle County in developing a management plan for wellhead protection. Various ground water models will be used to delineate wellhead protection areas. This modeling task is projected to begin following completion of the pilot.

(2) The locations of high-risk USTs may be mapped with GIS for other areas in Region III. Automating the mapping of UST locations would save months of effort.

(3) GIS can be used to target and prioritize sites for inspection, enforcement, and cleanup efforts. An example of this involves the requirement to prioritize these efforts for underground storage tanks in the next three years. With GIS, all high-risk tanks within a quarter mile of wellhead protection

areas could be identified. These sites would be prioritized for inspection and enforcement actions.

(4) The work with New Castle County has already been used to demonstrate to Delaware and to other states in Region III the utility of GIS in establishing wellhead protection plans. Delaware will be able to use the New Castle County work as a basis for developing a state-wide management plan for wellhead protection. Projects similar to the New Castle County work are planned for Anne Arundel County, Maryland, and Jefferson County, West Virginia. Both of these projects will be cooperative efforts involving Region III and state and local agencies. With GIS, Region III will be able to provide assistance to the states in developing wellhead protection plans.

(5) The states are required to develop management plans for protecting ground water from pesticides. Region III will also be able to assist the states in this effort by using GIS to identify both areas with high potential for ground water contamination from pesticides and populations at risk from pesticides in drinking water.

Temple University Cooperative Project

The Ground Water Protection Section at Region III and the Laboratory for Geographic Information Systems, College of Engineering and Computer Science, Temple University are conducting a cooperative GIS project with the following objectives:

(1) Identify areas in Region III that are most susceptible to ground water contamination.

(2) Identify the Region's major sources of ground water contamination.

(3) Prioritize the Region's ground water supplies in terms of vulnerability to contamination and risk to affected users.

Through this work, Region III plans to prioritize ground water problems and obtain a broad view of ground water contamination "hotspots" throughout the Region. The Region's resources can then be allocated to the highest priority areas for more detailed subregional analyses.

In addition to providing grant funds to meet the project's costs, Region III's responsibilities in the cooperative project are to formulate research objectives, work with the Temple University GIS Lab to design a research procedure, provide data, assist the GIS Lab in using constructed GIS programs, and evaluate project results. The Temple University GIS Lab will design the research procedure with Region III's assistance, build the GIS data base, and construct and run the GIS programs needed to address the project's objectives. Temple University's ARC/INFO system will be used for building the GIS. At the completion of the project, the GIS data base and programs will transferred to Region III.

The types of data required for the Temple University project are similar to the types used in the New Castle County project. The data that Region III plans to provide to Temple University include:

Locations of CERCLA and RCRA sites
Locations of NPDES major dischargers
Number of USTs per county
Locations of PWS wells and surface water intakes
Identification of PWSs using ground water that violates maximum contaminant levels
Hydrology
Political boundaries
Land use and land cover
Number of ground water contamination incidents per county
Per county DRASTIC evaluations
Population dependency on ground water per county

The Temple University project will also benefit from the experience of the New Castle County project in mapping UST locations with the address matching capabilities of ARC/INFO's NETWORK module. Because this process was so successful for the New Castle County effort, a similar procedure may be done to map USTs in major metropolitan areas throughout Region III.

The Temple University project is a good example of a cooperative effort between an EPA Region and a university in which both parties gain from a joint project. The cooperative effort has provided to Region III the external manpower needed for another GIS project. Temple University has benefited from the grant that provides financial support and experience with a real-world GIS application for its students.

Radon Evaluation

The Special Programs Section of the Air Programs Branch is in the planning stage of a GIS pilot project to identify and rank potential high-risk radon areas. The Special Programs Section has previously undertaken other radon studies in which house samples of radon levels have been mapped. The pilot project will go beyond mapping radon sample values by investigating the relationships between several variables and exploring possibilities for predicting potential high-risk radon areas. It is anticipated that the pilot will focus on areas in Maryland first, followed by Virginia.

Data to be collected for the pilot project include:

Digital National Uranium Radiometric Evaluation (NURE) data available from USGS
House radon samples
Private well-water samples
Digitized base maps with topographic, geologic, and hydrologic data
Digitized political boundaries
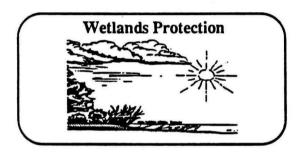Census tract population data
News media listener/viewer/reader areas

House radon sample data for the Section's previous work have been obtained through arrangements in which commercial radon monitoring firms have given copies of their data to Region III. One set of such data was obtained through a home radon testing program initiated by WJLA TV of Washington, D.C. As more home tests are conducted, the data will be given to Region III.

Analyses for the pilot will address several project objectives, including those listed below:

(1) Compare NURE, geologic, indoor radon, and private well-water data to determine the extent of correlation of radon values with other variables.

(2) Determine if NURE and/or geologic data are useful for predicting potential high-risk radon areas.

(3) Prioritize geologic units in counties on the potential of a high radon risk, and determine if erosion has produced sediment deposits that result in high radon areas.

(4) Prioritize high-risk radon areas based on population and radon data.

(5) Identify rural areas with high and low radon risks.

(6) Identify possible areas where private well-water may be contaminated by high radon levels.

(7) Explore whether occurrences of radon in private well-water can be predicted by well depth and location.

In addition to the research and risk identification orientation of these pilot objectives, the Special Programs Section is also concerned about effectively communicating the results of this work to the public. GIS-produced maps will be one means by which the results will be communicated. With the incorporation of news viewer/listener/reader areas in the ARC/INFO data base, analyses can be done to determine the best media for reaching various populations at risk in high radon areas.

Wetlands Protection

The Wetlands and Marine Policy Section views GIS as a tool that has great potential for assisting in wetlands protection work. A primary use of GIS would be for evaluating permits related to wetlands, such as permits for filling or dredging. By using GIS to assist in making recommendations on wetlands permits, GIS would be incorporated into the decision-making process for wetlands protection.

Linking GIS and expert systems in the permit evaluation process has also been considered. Expert systems technology would be used to guide an analyst through questions asked in evaluating a permit, while the GIS would store data and perform spatial analyses based on questions that were asked.

In addition to permit evaluation, GIS could be used in the cumulative assessment and advanced identification of wetlands. Trends of wetlands loss in a watershed over time could be studied and assessments made of the impacts of such losses.

The biggest barrier to these GIS applications is collecting the large amount of data required for wetlands analysis. Types of data that should be part of a wetlands data base include:

Hydrology
Ground water
Aquifers
Wells
Recharge areas
Watershed boundaries
Wetlands locations, size, classification
Topography
Land use
Soils
Parks
Historical sites
Critical areas

Furthermore, the data need to be collected is at a very large scale for some wetlands analyses, perhaps at 1:6,000 or larger. The largest scale readily available for much data is 1:24,000.

To avoid a large data collection effort for a pilot project, the Wetlands and Marine Protection Section would like to identify a pilot area where data have already been collected. A potential candidate area is the Elizabeth River watershed, for which USGS has developed an extensive data base for a joint USGS/EPA project. Region III may select a sub-watershed within this area for a pilot project on evaluation of wetlands permits. Although the scale of some of the data collected for the Elizabeth River watershed may not be as large as desired, the data may be adequate for a pilot project.
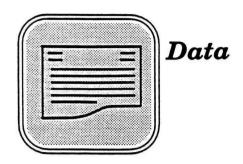
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Implementation Issues

Management/ Communications

Both the GIS staff and program staff in Region III emphasized the need for upper management support if GIS is to be fully implemented in the region in support of agency programs. To date, GIS has received support that should continue if the pilot projects are successful and demonstrate that GIS can save time and money vis-a-vis the enhanced analytical capabilities that it provides. Successful pilot projects will also prove the utility of GIS to the program divisions and will be crucial in getting more staff and resources to support a larger GIS operation in the future.

An important factor in ensuring the success of a pilot project is to have a management plan that clearly states the pilot's objectives, the data required, and analyses to be done. Such a plan helps to focus the time and resources invested in the pilot. The Ground Water Protection Section assessed the relative costs and benefits of GIS to various management decisions and applications, an activity which helped to focus the direction of the New Castle County pilot. A detailed action plan, which addressed the tasks of every stage of the pilot, was then constructed and served as a guide throughout the project.

A general understanding of GIS throughout the Ground Water Protection Section has aided the program staff working on the New Castle County pilot. Because the pilot occasionally has required the assistance of staff who are not assigned to the project, cooperation among the section staff has been important to the pilot's success. The high level of cooperation that has been demonstrated has been attributed to the general level of understanding, interest, and excitement about GIS in the section.

Concern about communication among EPA headquarters, regions, states, and counties involved with GIS was expressed. There is a need for staff at these various levels to know what others are doing with GIS and especially to know what data are available through other offices. Program staff, as well as the GIS staff, emphasized this need for communication. Program staff also were concerned that some information from EPA headquarters regarding GIS may not filter down to them.

Data

The biggest challenge encountered by program staff for the region's pilot projects is finding high-quality digitized data. In many cases either data are not available at required scales, or the quality of available data is questionable. A contributing factor in selecting New Castle County as the study area for the ground water protection pilot was the existence of a digital data base. The largest constraint for the radon pilot is that geological data being digitized by USGS will not be available for one or two years. The wetlands protection pilot requires many types of data at relatively large scales. Although a data base for the Elizabeth River watershed may be used for a pilot, evaluating wetlands permits with GIS will require data at a larger scale than is normally available.

A common theme expressed by Region III staff was that many federal, state, and county agencies are collecting much data and may be duplicating efforts. A great amount of time can be spent in determining who has data that may be useful for a project. The need for a clearinghouse that would include information on digital data collected at all levels of government was emphasized.

Even after data are found that may be used for a project, the quality of the data may be poor, or the data may not have been collected with a common spatial reference that allows the data to be used easily. It was stated that the locational accuracy of EPA data historically has been poor. When ARC/INFO was used to compare the locations of the same hazardous waste sites obtained from EPA and from New Castle County data bases, large discrepancies occurred. The New Castle County locations were generally correct. Even if the GIS staff corrected the EPA locations in the GIS data, they presently have no mechanism for making the corrections in the original EPA data bases. Since the locations of hazardous waste sites is vital information that must be accurate, the issue of correcting this locational data must be addressed.

At the present time the data quality control functions performed by the GIS staff involve ensuring that data added to a GIS data base for the region are reproduced accurately from the source of the data. The program staff are relied upon to determine whether the quality of the data is adequate for their purposes. It is felt that EPA headquarters and the Environmental Monitoring Systems Laboratory in Las Vegas should take the lead in providing guidance to all EPA offices on data standards and quality assurance/control issues. This is especially critical to guarantee that data are collected with a common spatial reference and therefore can be shared.

Some data that are available are too obsolete. The most critical of these data sets is the 1973 land use/cover data obtained from USGS. More frequent updates to land use/cover data are required for many analyses, such as those related to ground water protection.

Because the data capture and quality assurance/control stages of a project can be so time-consuming, it was suggested that it may be necessary to be more selective in terms of how much

data are collected for a GIS data base. By devoting sufficient time to planning a GIS project and especially the data capture stage, a balance might be achieved between obtaining enough quality data and the time required for data capture. Questionable data could be flagged in the data base until time is available to assess the data's quality, rather than delay a project. Long-term goals that require additional data must also be kept in mind when planning the amount of data to collect.

Even if quality data are available, getting the data may be a slow process. Although USGS data was praised for its quality, it generally took two months for Region III to get data from USGS. If EPA headquarters obtained base coverages from USGS, it was felt that the regions would have faster access to these coverages.

As more GIS data bases are developed in the region, the GIS staff stated that guidelines and procedures for archiving data will be needed. To date, development of archive procedures has not been necessary for Region III.
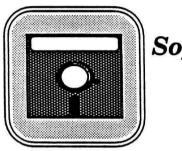
Staffing

Two key types of personnel have been essential to GIS pilot projects in Region III: (1) a member of the GIS staff and (2) an environmental scientist with an understanding of GIS. For the pilot projects, the GIS staff member is responsible for all GIS tasks involving use of ARC/INFO and other software. These tasks include digitizing, writing data conversion programs in other languages, creating ARC/INFO coverages, analyzing data with ARC/INFO as directed by the environmental scientist, and producing maps. The environmental scientist is responsible for deciding what data are needed and where to obtain the data, assessing the quality of the data, determining the analyses to be performed, and evaluating the results of the analyses. Both GIS staff members, environmental scientists, and program section chiefs stated that having talented people in both roles is vital to the success of GIS projects. Cooperation and a good working relationship between the GIS staff member and the environmental scientist are also essential.

The GIS staff emphasized the importance of having an environmental scientist on a GIS project that can devote sufficient time to the project. If a scientist could perform some analyses in ARC/INFO, a project could be expedited by saving time required for back-and-forth communications between the GIS analyst and the scientist. Although program staff agreed that GIS projects required large time commitments from environmental scientists, concern was expressed by some sections that the workloads of their scientists are already too great, making it difficult to devote much time to GIS. ARC/INFO is viewed as a very complex package that takes a year to become proficient in its use. For future GIS projects, the Environmental Planning Section may hire a contractor with environmental expertise who also knows GIS to provide the day-to-day environmental expertise needed for GIS projects.

The need for staff at a lower level to perform many routine tasks for GIS projects was also mentioned. By having other individuals do digitizing and handle some data collection responsibilities, such as making numerous phone calls to locate data, the highly-trained GIS staff and environmental scientists can devote more of their time to the creative and analytical tasks of GIS projects.

The size of the GIS staff is sufficient to handle the GIS work currently being done at Region III. As more GIS projects are initiated, the staff may need to be larger. The staff may also play a more active role in identification of data sources in the future, especially as Region III builds up its GIS data bases.

Software

Although ARC/INFO is viewed as a successful GIS package at Region III, INFO may not be the best language for numerical data processing that will be required for some projects. Region III may write models and other programs that perform extensive mathematical calculations in FORTRAN or another language. Outputs from the models would be imported to an INFO data base, and maps could then be generated with ARC.

As GIS becomes more widely used, common procedures for reading data from tapes, creating ARC/INFO coverages, and archiving data will be needed. Region III is acquiring a ground water workstation for site-specific work with RCRA and Superfund sites. Routines to convert data from formats used by models running on the ground water workstation to a format easily imported into ARC/INFO may be required to support the use of GIS with some applications.

Hardware

The PRIME 2755 and associated hardware that support GIS in Region III (Figure 2) are adequate for the current number of GIS projects. Although some ARC/INFO functions are rather slow, such as selecting arcs from a data base or drawing maps, the slowness may be a combination of ARC/INFO, the PRIME 2755, and the use of 9600 baud lines.

As the use of GIS increases in Region III, hardware upgrades will probably be required. Supporting dial-up access to ARC/INFO for the states was mentioned as an option that some states in Region III may desire. Dial-up access to ARC/INFO would also require hardware upgrades, since the present hardware capacity and user support facilities of Region III are not adequate to support remote state users.

Region III has attempted to get a Tektronix 4958 digitizer to work with ARC/INFO. Although ESRI has said that there is a device driver that should work with the digitizer, Region III has not been able to resolve problems with the driver and stated that EPA headquarters has had the same problem. A Calcomp digitizer has been ordered to replace the Tektronix 4958.

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Figure 2

Overview of Region III GIS and Related Computer Systems

Hardcopy Unit

Tektronix 4106

Tektronix 4692 Color Printer

Tektronix 4207

Tektronix 4958 Digitizer

Epson Equity III

PRIME 2755

Calcomp 1043 Plotter

(3) Line Printers

On Order

Electrostatic Plotter

Calcomp Digitizer

Constraints

Although the ground water pilot projects have been successful to date, three constraints are seen as impacting future GIS work in Region III.

(1) **Lack of program staff time to support GIS:** The GIS staff has emphasized the necessity of having an environmental scientist associated with a GIS project who can devote sufficient time to the project. As questions regarding data or analyses arise, the GIS analyst needs prompt responses so that work can proceed. The time and effort spent by ground water staff on the New Castle County pilot project are one major reason for the success of that pilot. The lack of program staff time contributed to delays in starting a wetlands protection pilot and a multimedia pilot involving comparative risk management.

As stated above, the program sections also recognize the need to commit sufficient time to GIS projects, but existing large workloads have in some cases prevented such time commitments. For continued success in implementing GIS, resources must be provided so that the staff time needed for GIS projects will be available.

(2) **Lack of high-quality locational data:** As discussed in the *Data* section, the lack of high-quality locational data is a major problem for much GIS work. Even if digitized data are available, the data may not be at the scale needed for a particular project, or the data may be obsolete. Of special concern is the lack of current land use/cover data that is updated on a regular basis. The need to have all agencies collect data with a common spatial reference is also a requirement for sharing data among agencies.

(3) **Costly duplication of effort:** The lack of information on who is collecting what data has raised concerns about costly duplication of effort. Because the data capture stage of a GIS project is generally the most costly and time-consuming, there is a need for a clearinghouse to know what data have been collected at all levels of government.

Duplication of technology is also an issue that may impact future GIS work. Workstations obtained for ground water work in the area of hazardous wastes may duplicate some of the capabilities that GIS has to offer. Without an easy method to convert data used by the workstations to an ARC/INFO format, additional analyses that could be performed with ARC/INFO may not be done.
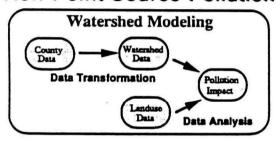
Conclusion

GIS at Region III has been successful to date in its pilot stage of implementation. The ground water protection pilot for New Castle County has been successful because the pilot has had upper management support and the commitment of sufficient GIS staff and program staff time. The pilots for evaluation of potential high-risk radon areas and for wetlands protection also require these key factors.

The completion of successful pilots that demonstrate the utility of GIS in supporting management decisions, as has been done by the New Castle County project, will promote the expanded use of GIS in Region III. Greater use of GIS in the region will require that adequate staff time and other resources be made available to support the work.

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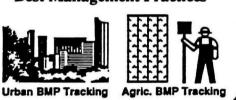Chesapeake Bay Program and GIS: The Shift From Bay to Land

EXECUTIVE SUMMARY

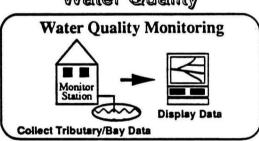The Chesapeake Bay Program (CBP) completed its initial research phase in 1983 and moved into a second major phase of activity directed towards improving and protecting the quality of the Bay. During this implementation phase, the CBP's activities have been focused on land conditions that impact the Bay. GIS has supported this shift in the CBP's focus to the land surrounding the Bay by providing an effective tool for the analysis and display of spatially-distributed land and Bay data. For the CBP, GIS is no longer an emerging technology with a separate budgetary line item but is a useful tool that has been incorporated within program budgets.

GIS supports ongoing CBP activities through its use with many small tasks that are often completed in several days or weeks, rather than through large GIS projects requiring months to finish. These ongoing programs and activities include:

NON-POINT SOURCE POLLUTION -- Work is directed toward watershed modeling and analysis of urban and agricultural best management practices.

LIVING RESOURCES -- The distributions of water quality indicators and the habitats of living resources are mapped to identify the impacts of water quality on habitats.

WATER QUALITY MONITORING -- Data from the Bay and tributary monitoring programs are converted to a common format that can be displayed efficiently by the GIS and used with other analyses.

DATA BASE DESIGN -- Data base design and development is supported by the common format required by GIS and by documentation and quality control/assurance activities.

CBP experience has highlighted key factors needed for implementing a GIS:

o Management commitment of necessary resources required for an extended start-up period.
o The support of upper management and mid-level program managers.
o Effective communication between program managers and GIS implementors.
o Mechanisms for information transfer of data, GIS techniques, and GIS experiences within EPA and with other organizations.
o Development of and compliance with good data management practices, including documentation and quality control/assurance.
o A multi-disciplinary core staff with expertise in GIS.

GIS at the Chesapeake Bay Program

The Chesapeake Bay Program (CBP) is a cooperative program involving the EPA, the states of Maryland, Pennsylvania, and Virginia, the District of Columbia, and five other federal agencies: the National Oceanic and Atmosperic Administration (NOAA), the Army Corps of Engineers (COE), the Fish and Wildlife Service (FWS), the Geological Survey (USGS), and the Soil Conservation Service (SCS). The CBP was commissioned by Congress in 1975. During the following year, the CBP, in cooperation with other federal, state, and private organizations, began studying primary sources of Bay pollution. This scientific research phase ended in 1983, and the CBP began to focus on implementation efforts to improve the quality of the Bay.

In December 1983, chief executives from Maryland, Pennsylvania, Virginia, the District of Columbia, and EPA signed the Chesapeake Bay Agreement, which called for implementation of coordinated plans to improve and protect the quality of the Bay. Memoranda of Understanding also have been signed between EPA and the other federal agencies with environmental responsibility for the Bay to create joint ventures that more efficiently use public funds and other resources committed to the Bay programs.

The earliest GIS tasks at the CBP used the MOSS GIS software on the CBP's VAX 780. ARC/INFO was installed on the VAX in November 1987 and was later installed on the CBP's new VAX 8600. All MOSS GIS files were converted to the ARC/INFO format.

At the CBP, GIS provides support for ongoing CBP programs and activities. Many of the GIS tasks undertaken are smaller requests that can be completed in several days or weeks, rather than large projects extending over many months. These smaller tasks often focus on using GIS as a mapping and information comparison tool. The data for these tasks are taken from the approximately 5000 files that have been developed or acquired by the CBP for use in multiple projects. Data capture and data base construction are the heart of CBP's long-term GIS task. The depth and accuracy of CBP's data base has provided CBP the ability to undertake many projects.

This integral use of GIS for many small tasks supporting ongoing work is an outgrowth of the CBP's research orientation. Rather than conducting enforcement and program management activities like EPA regions, the CBP focuses on analyses that can support the programs of the political jurisdictions and agencies with responsibility for the Bay and its watersheds.
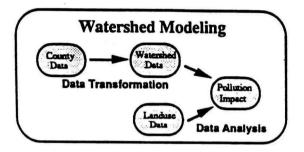
The following four major activities of the CBP are supported by GIS and are described below:
(1) Non-point source pollution
(2) Living resources
(3) Water quality
(4) Data base design and implementation
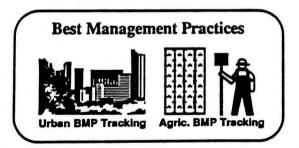
Non-Point Source Pollution

Addressing the problems of non-point source pollution is a major focus of the CBP's implementation phase. Seventy-five percent of CBP program funds are to be directed towards activities concerned with non-point source pollution. GIS has or will assist CBP

in this work through watershed modeling and the analysis and implementation of best management practices.

Watershed Modeling

Most soil and agricultural data needed to develop and verify watershed models are collected by political units, such as counties, rather than by watersheds. With the tools provided by a GIS, data collected by county can be transformed into data by watershed for use with watershed models.

The CBP plans to use data transformation techniques of GIS in its development of watershed models for the Bay. The results of these models will be displayed with the GIS. After the watershed models are refined, the GIS will be used to combine landuse data with the results of the watershed models to examine the impacts on Bay pollution of various land uses.

Best Management Practices

To support its work with non-point source pollution, the CBP has examined how GIS may be used to identify areas for best management practices (BMPs) and to analyze the effectiveness of BMPs. BMPs may be implemented to control both urban and agricultural pollution.
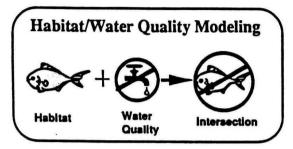
In urban areas BMPs may help to control the runoff problem from sources such as lawns and gutters. The runoff's high concentration of nutrients and toxic materials are not treated by the sewage treatment plants but reach the Bay directly. The CBP wanted to find areas which could be easily constructed for the containment and treatment of these nutrients and toxics before they reached the Bay.

In a demonstration project the CBP used ARC/INFO to map land use and stream segments in the Baltimore area from USGS land use/land cover files. By locating areas where streams intersected with highway cloverleafs, the Stemmer's Run area near the Baltimore beltway was identified as a potential BMP area that could easily be transformed into dry/wet ponds for impounding urban runoff. This type of urban BMP would trap oil, greases, and other elements that runoff from paved surfaces, such as highways.

In agricultural areas the effectiveness of various BMP practices, such as no-till farming, may be analyzed with a GIS. In general, agricultural BMPs have been tracked only by the dollars that have been spent on such programs, rather than by the effectiveness of such measures in non-point source pollution control. A project vested with the Virginia Department of Soil and Water Conservation has been using VIRGIS with the Universal Soil Loss Equation to target county conservation districts for implementation of BMPs. VIRGIS is a custom grid-based GIS developed at Virginia Tech.

Living Resources

Habitat/Water Quality Modeling
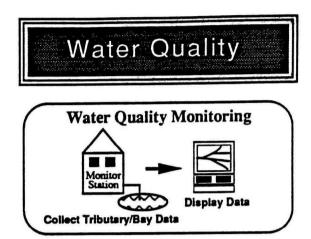

Habitat + Water Quality → Intersection

The CBP has implemented several projects that have examined the relationships between habitats required for living resources and the Bay's water quality. In separate studies of oysters and striped bass, the distribution of potential habitats was overlaid with water quality monitoring data. By looking at the spatial distribution of dissolved oxygen, temperature, and depth, the impact of water quality on potential habitats could be examined. In a project with the Maryland Department of Natural Resources, the CBP will combine historic oyster bar location data with data on shipping channels, bathymetry, and dissolved oxygen to identify areas that satisfy basic habitat requirements for oyster spat sites. With this information, artificial reefs may be constructed in areas that have a high probability of success.

The GIS has also been used to digitize detailed maps of submerged aquatic vegetation at scales of 1:12,000 or 1:24,000. The GIS has provided an effective tool for processing data on submerged aquatic vegetation. This time-consuming and detailed activity will contribute important data files for future analyses on living resources.

In another project on living resources, the CBP is working closely with the U.S. Fish and Wildlife Service to produce species distribution maps for the Habitat Use Report of the CBP's Living Resources Subcommittee. The GIS-produced maps show relative distribution of waterfowl, submerged aquatic vegetation, anadromous fish, wetlands, and oysters for the entire Bay and tributaries.

Water Quality

Water Quality Monitoring

Collect Tributary/Bay Data → Display Data

During the initial research phase of the CBP, which extended from 1976 to 1983, large quantities of Bay data were collected. The Bay monitoring effort begun then has continued through the collection of data on water quality from a series of monitoring stations in the Bay and its tributaries. The CBP is responsible for collecting and processing data from stations in the Bay. Tributary data are collected and processed by the states in which the tributaries are located. The states in turn submit their data to the CBP, which converts the data into a format usable by ARC/INFO when needed.

The display capabilities of ARC/INFO permit the water quality data to be displayed easily and in common formats that facilitate comparison between data. In addition, once the water quality data have been converted to the ARC/INFO format, the data can be incorporated into other GIS analyses, such as those described above for living resources and non-point sources of pollution.

Data Base Design

- ARC/INFO
- Documentation
- Quality Control/ Quality Assurance

A major effort by the CBP has been the development of a data base for use with GIS. Development of this data base is an integral part of other CBP GIS activities and is crucial to performing analyses on the quality of the Bay.

During the time that CBP was using the MOSS GIS software, numerous files on political boundaries, land use/land cover, and other data had been either digitized using MOSS or purchased in a grid-cell format compatible with MOSS. After acquiring ARC/INFO, CBP wrote a series of programs to convert the MOSS files into ARC/INFO coverage files. These programs are used regularly to create ARC/INFO coverages of point data from flat files in the MOSS format, since entry of a MOSS data file with a text editor and running the conversion programs are relatively easy processes.

As part of its data base activities, the CBP has developed a documentation format for its data base files. The documentation form, which includes information on the content, source, purpose, and quality of the data, must be completed for each new file added to the CBP's data base. This documentation has been done for the CBP's 5000+ data base files and is accessible on-line. The data quality information maintained for each of these files is an invaluable resource for all work involved with planning and designing projects analyzing the Bay.

Other Projects

Other GIS projects being conducted by the CBP include the following:

- The CBP has produced a "Monitoring Atlas", which is a series of 200+ maps showing monitoring station locations for all types of programs, ranging from water quality to breeding birds, for the entire Chesapeake Bay Drainage Basin.

- The CBP does much general mapping on a daily basis to support staff at the Chesapeake Bay Liaison Office and various state offices.

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Implementation Issues

Management/ Communications

One of the biggest initial challenges encountered by the CBP has been selling GIS to upper and mid-level management. Upper level management needed to understand how GIS could be used as a tool to support EPA's missions. Moreover, mid-level managers had to be shown that GIS could be applied specifically towards their programs. Since the CBP director became convinced of the problem solving capability of GIS, he has emphasized the need to utilize GIS to its fullest capabilities to *manage* the problems his programs are addressing. As a result, GIS at the CBP has evolved from being an emerging technology requiring a separate budgetary line item into being a fully integrated tool used in support of CBP programs.
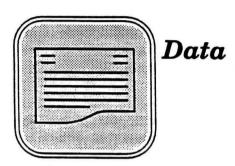
The efforts to convince CBP management of the usefulness of GIS would have been aided by a formal GIS policy statement from EPA Headquarters establishing a GIS implementation mechanism. It is hoped that the recent EPA policy statement will increase management's awareness of GIS throughout EPA and show that it can be a useful tool in the decision-making process.

The CBP has also been successful in getting state agencies to cooperate in terms of data validation and data standards. State agencies have realized the necessity of this cooperation and therefore insure the validity of their data by signing off on its quality as it is sent to the CBP. The CBP recommends that similar procedures be applied to all GIS data obtained from other agencies.

There is a need for information transfer between EPA Headquarters, Regions, and state offices. Managers must be aware of what information concerning data sources and techniques is available to them, and there must be a method which facilitates ease of communication between users. For instance, the CBP developed utilities to convert data sets built by MOSS software into an ARC/INFO format. However, it had no method for communicating this information to EPA managers who might need this data or who might be interested in its MOSS to ARC/INFO conversion routines. Another example concerns the fact that basic data sets developed by other government agencies take care of 90% of EPA's data needs. EPA managers must be made aware of data available for their use.

The CBP has found that management needs to be told upfront what to expect from GIS. There must be realistic expectations on resources required (i.e., staff, time, dollars) before any results can be achieved. Since much time is required to develop a GIS data base, management is faced with the constraint between the development of future GIS applications, and the need to

produce immediate results. It has been the CBP's experience that during the time the data base is being developed, the GIS can be used immediately to produce improved graphic displays (i.e., maps) very quickly. For example, the quick production of a Superfund site map convinced the CBP that the GIS was extremely useful as a map-making tool and able to provide results when management needed them.

Data

The CBP has been acquiring Chesapeake Bay data since its inception. This has resulted in an environmental data base that contains over 100 million data points. The data covers the entire 64,000 square mile Chesapeake Bay basin, and dates back as far as the early 1900's.

Much of the data base is geo-referenced with associated latitude and longitude, hydrologic unit, or some other spatial parameter. Since 1986, the CBP has used this as the basis for building a more specific and integrated GIS data base. Its GIS data base includes the following data files:

- Land use/land cover
- Hydrology by watershed
- Agricultural practice
- Pesticide application
- Timber survey
- Shellfish, finfish
- Waterfowl
- Bathymetry
- Political boundaries
- Shoreline
- Topography
- RCRA/CERCLA
- Transportation

A factor critical to the success of CBP's GIS implementation is its commitment to good data base management practices. This is illustrated by the fact that a data base design was implemented prior to the creation of an ARC/INFO data base. As the CBP considers complete documentation of the data files an integral part of the data base, it created and tested the documentation format to ensure that it was useful and could be implemented. Furthermore, CBP's coordination of other agencies' data validation/standards assurances has permitted quality control to become a major factor in the management of their data base.

The CBP successfully implemented a GIS data base conversion from MOSS to ARC/INFO. The MOSS GIS data base included land use/land cover, state, county, city, watershed, and other significant GIS data files. However, the MOSS GIS program had several

limitations which affected storage, analysis, and presentation of the data. The CBP wrote a series of programs which converted the MOSS files into the ARC/INFO format and retained the attribute data of the original MOSS files. The resulting ARC/INFO applications can now map data which were originally in MOSS GIS data bases. The CBP recommends that the EPA issue a policy stating that all data should be collected in formats compatible with ARC/INFO to minimize future data integration problems.

In addition to collection of data in an ARC/INFO-compatible format, the CBP has found that data integration problems can also be eliminated by the purchase of only high quality data. This is considered the best method for data acquisition when large quantities of data are needed. The CBP recommends in-house digitization as a cost-effective alternative when quality data are unavailable elsewhere and large quantities of data are not needed.

Various land use/cover data collected by EPA are generally obsolete and somewhat inconsistent with one another. Timely and accurate land use/cover information is critical to CBP's GIS applications. The CBP recommends that EPA Headquarters purchase a land use/cover data base every five years. This data base should be provided by the federal government, who should also maintain it. Through this mechanism, EPA Headquarters could provide base coverages for use by all EPA Regions and offices.
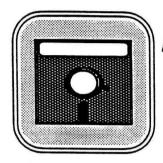
 Staffing

All GIS technical work at the CBP is done by Computer Sciences Corporation contractors, as opposed to EPA or other governmental staff. The CBP considers its staff to be its most valuable resource. Several key positions have been identified as being crucial to its GIS implementation. The CBP stressed that a successful GIS team must consist of a core of ARC/INFO experts with a multi-disciplinary background (i.e., geographers, geologists, hydrologists, biologists). They must also be familiar with EPA programs. Furthermore, all supporting personnel (i.e., digitizers) must be very skilled.

In addition to this multi-disciplinary team, the CBP has found the need for a manager who, in addition to understanding EPA policy and programs, has a strong knowledge of GIS. The CBP believes that this person can greatly facilitate the use of GIS with management's decision-making process through his/her ability to understand how GIS may be integrated with the overall EPA program.

The CBP recommends that the most useful ARC/INFO training will be gained by sending a staff member to a functioning ARC/INFO site for approximately three months. At this site, the staff member will receive practical, hands-on experience which will enable him/her to clearly understand the many factors involved with implementing GIS.

The CBP also sees the need for a full-time staff member to perform hardware/software support, such as routine maintenance, backups, and similar tasks. These support responsibilities should be handled by computer operators rather than by GIS staff.

Software

Because MOSS could not adequately handle the large data sets needed for the Bay Program's analyses and had some inherent inadequacies in its basic algorithms, the CBP purchased ARC/INFO and converted its MOSS data to the ARC/INFO format. This conversion has proven to be very successful for the CBP. ARC/INFO has much greater functionality on the VAX computer than MOSS and has been very reliable. MOSS nevertheless proved to be a convenient format for creating geo-based data sets, ultimately to be converted to a more successful format at a later point in time.

The CBP encountered a limitation with ARC/INFO when it utilized the TIN module to perform 3-D volumetric modeling of the Chesapeake Bay. It was found that TIN could only perform 3-D modeling of the Bay's surface, not 3-D volumetric modeling.

Previously classified as a secondary site in terms of access to ESRI's ARC/INFO user support, the CBP was limited in the amount of assistance it could receive from ESRI. A secondary site must coordinate its requests for support through a designated primary site, rather than contact ESRI directly. This procedure often resulted in delayed answers for CBP questions needing prompt answers. The CBP is now a primary site, and this has proven to be useful in obtaining rapid response to problems. Based on the CBP's experience, careful consideration should be given to whether all major GIS programs in EPA should have primary site licenses.

Hardware

As shown in Figure 3, the CBP's current hardware configuration consists of a VAX 8600 computer, Tektronix graphics terminals and printers, Calcomp and Nicolet pen plotters, and

Figure 3

Overview of Chesapeake Bay Program
GIS and Related Computer Systems

Anticipated Purchase

(2) Macintosh IIs

Nicolet 836
Zeta Plotter

DEC VT241

Tektronix 4695
Ink-Jet Printer

Calcomp 1012
Plotter

Tektronix 4111

Altek Digitizer

VAX 8600

(2) 1200 lines/min. printers
(1) 600 lines/min. printer

Tektronix 4696
Ink-Jet Printer

Tektronix 4106

Altek Digitizer

(36) DEC
VT220s

(11) DEC
VT241s

(3) Macintosh

(4) IBM PC
compatibles

other supporting peripherals. The CBP plans to order two Macintosh IIs to increase its number of graphics terminals. On the average, 30 online users access the VAX 8600 at any given time . However, the VAX is capable of handling up to 100 possible users.

The CBP currently is creating more maps than can be plotted on the pen plotters. The demand for high quality, fine resolution plots in color necessitates the acquisition of a high resolution electrostatic plotter. Several options for obtaining a new plotter are being considered.

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Constraints

Two major constraints on the success of GIS at the CBP were eliminated during the past year with the installation of both the VAX 8600 and ARC/INFO. Without this increased hardware capacity and better software that could handle the CBP's large data sets, GIS work at the CBP would have been constrained by inadequate tools to perform necessary tasks.

Management support for GIS was essential for the acquisition of new hardware and software. It is vital that such support continue as the CBP further develops data bases required for subsequent analyses. As demonstrated by the CBP experience, the necessity of management support and availability of adequate resources during the data base development stage of GIS analyses are crucial to any GIS implementation.

The CBP's secondary site license for ARC/INFO was a limiting factor in its implementation of ARC/INFO. The secondary license required CBP to go through a designated primary site for ESRI support, which resulted in delays to resolving problems. The CBP has since acquired a primary site license, which has eliminated this former constraint. The issue of primary site licensing for regions and other major GIS programs needs to be addressed very carefully. Although a secondary site license may be appropriate for a site with PC ARC/INFO, major programs may need the support that only a primary site license provides.
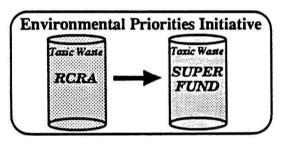
The major constraint on continued GIS success at the CBP is the **lack of high-quality, timely land use/cover data.** The land use/cover data available to the CBP is generally obsolete. With the focus of the CBP on non-point sources of pollution, the necessity of acquiring updated land use/cover data for the Bay's watersheds at five-year intervals is important to addressing the problems of non-point source pollution. The CBP hopes to obtain more recent land use/cover data by acquiring Landsat data. The CBP is working with OIRM on its initiative to obtain better GIS data sets in support of EPA programs.
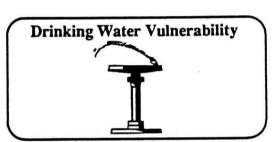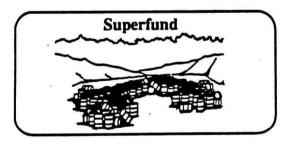
Conclusion

The CBP has successfully implemented GIS as a useful tool applied to the CBP's ongoing activities. ARC/INFO is perceived as a tool to be used daily, not unlike word processing and spreadsheet software, in support of the CBP's analysis and research work. This success has been based on extensive efforts that obtained both management's support for GIS and the required hardware and software. The CBP's commitment to good data base management practices and its ability to produce useful graphical outputs while building data bases have also been essential to the success of GIS.
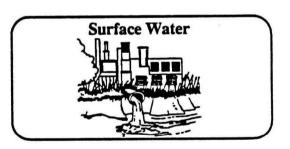
Future applications at the CBP will focus on using GIS to combine output from water quality and land use models with other data layers, such as living resources. Other work will involve living resource and water quality trend analyses. The CBP hopes to incorporate dynamic changes into its Bay models. These analyses will permit further study of land/Bay interactions and of those practices that may be used to improve the quality of the Bay.

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GIS at Region IV: A Tool for Regional Program Support

Environmental Priorities Initiative

Drinking Water Vulnerability

Superfund

Surface Water

RCRA

Air Program

EXECUTIVE SUMMARY

Region IV's approach to GIS is part of a regional data integration initiative designed to provide better methods of managing environmental programs. GIS staff at Region IV's Office of Inte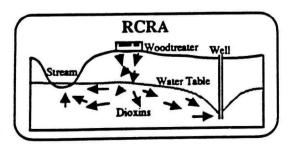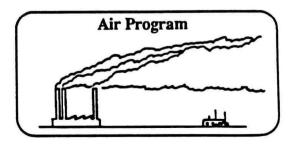grated Environmental Analysis (OIEA) are supporting this approach to decision-making by developing region-wide data bases that provide separate EPA programs access to the same data. To relate programs to improvements in environmental quality, OIEA is implementing a Results/Risk Analysis and Management System (RAMS) which will utilize GIS as a tool to tie data and monitoring efforts to regulatory programs. This will enable managers to target regulatory activities based on problems and risks and to determine if programs are effective. As an EPA Center of Excellence for GIS, Region IV is helping other Regions to get started with similar practical regional GIS applications.

RAMS and GIS currently support, or are planned to support, the following programs:

ENVIRONMENTAL PRIORITIES INITIATIVE -- GIS has been used to identify and rank which RCRA sites should be assigned to the National Priority List as Superfund sites.

DRINKING WATER VULNERABILITY ANALYSIS -- A planned project will utilize GIS to reduce sampling requirements of well water by analyzing relationships between well data and Superfund/RCRA sites.

SUPERFUND -- GIS has helped to identify and evaluate Superfund sites for the National Priority List by integrating well data with Superfund data and the Hazard Ranking System (HRS).

SURFACE WATER -- In this planned project, the relationship between surface water quality and construction grants will be evaluated with GIS.

RCRA -- GIS is being used to identify potential areas of ground water contamination from dioxins produced by woodtreaters, prioritize enforcement actions, and facilitate site management.

AIR PROGRAM -- GIS will be applied as a tool for integrating air quality data and analyzing air quality trends.

Region IV's GIS work has depended upon several key factors:

o   Support of upper management and program management;

o   OIEA as a service organization that supports programs;

o   OIEA staffed by environmental experts with EPA program experience and computer technology expertise; and

o   Development of common data bases needed by many programs.

GIS at Region IV

Region IV has adopted a regional approach to GIS which focuses on developing region-wide data bases, rather than conducting pilot projects for small areas. This is based on the fact that Region IV's primary purpose for using GIS is to help regional managers to effectively manage their programs. The regional approach allows the GIS staff to work on individual applications while simultaneously developing methodologies that can be applied in other situations.

To support the regional managers, a Results/Risk Analysis and Management System (RAMS) is being implemented. This is a management system based on risk reduction and environmental improvements. For all media (surface water, ground water, air), the objectives of RAMS are to:

(1) Identify and prioritize problems and risks.

(2) Relate problems/risks to needed regulatory controls.

(3) Track environmental trends, improvements, and risk reductions.

(4) Relate trends to regulatory controls.

Region IV regards GIS as a tool to implement RAMS.

The Office of Integrated Environmental Analysis (OIEA) was established by Region IV and is responsible for the development of advanced technology and information management tools required to support effective Regional environmental decision-making. GIS is one of the tools supported by OIEA and is used in *response* to programs. OIEA staff:
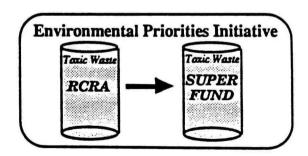
- supports projects developed by program management

- integrates data

- technically analyzes data

- reduces data to a useful form for decision-making based on risks

- develops management systems after the RAMS model

As part of this work, OIEA has produced products for management demonstrating how GIS will help in policy setting, program management, and resource allocation.

Region IV installed ARC/INFO on a PRIME 2655 in November of 1986. Since that time the PRIME has been upgraded to two 2755s, and additional peripherals, including graphics terminals, digitizers, and plotters, have been acquired.

The six major programs of Region IV that are either currently supported by GIS or will be supported by GIS in the future are described in the following sections. It is important to note that several of these programs utilize the same data and will therefore benefit by regional data base development.

Environmental Priorities Initiative

As part of the Environmental Priorities Initiative, Region IV is using GIS to identify and rank which RCRA sites should be

assigned to the National Priority List (NPL) as Superfund sites. Region IV will assign these sites to the states by October 1st, 1988.

Utilizing the DRASTIC index as well as other data, Region IV is identifying aquifer vulnerability to pesticides for developing pesticides strategies. This work has enabled drinking water vulnerability data to be used as input to the ranking of sites and to determine monitoring requirements.
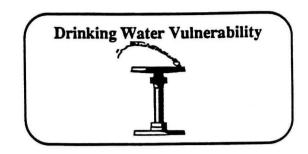
Among the GIS maps which Region IV produced in order to identify and prioritize RCRA ground water problems are:

- Geology of Georgia
- Population density of Georgia
- RCRA/Superfund sites with municipal withdrawls
- Depth to top of aquifer
- Soils
- Major aquifer outcrop and recharge areas
- Other DRASTIC vulnerability components
- RCRA land disposal municipal withdrawls

To relate problems to needed RCRA regulatory activities, Region IV generated GIS maps showing data such as:

- RCRA land disposal sites with 5000 and 10,000 meter buffer zones and municipal withdrawls
- Municipal withdrawls on potentiometric surface map
- Municipal withdrawls with potentiometric surface map, wetlands, and low permeability soils
- RCRA sites and withdrawls on potentiometric surface map

This use of GIS allows Region IV to be proactive, not reactive, in identifying and prioritizing environmental problems, and enables the region to go beyond statutory requirements and look at facilities that are problems.

Drinking Water Vulnerability
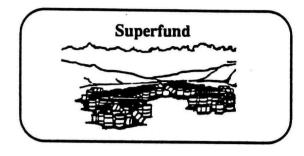
Region IV is in the planning stage of a project which will examine drinking water vulnerability. The states are unable to inspect every well site and would like to use GIS to allocate resources so only key sites are inspected.

Presently, the states in Region IV are required to sample every well site four times per year. It is estimated that approximately 100,000 samples would be needed to satisfy these requirements. However, at $400 - $2500 per sample, the minimum cost would be $40,000,000.

The states only need to sample one time per year rather than four times per year provided:
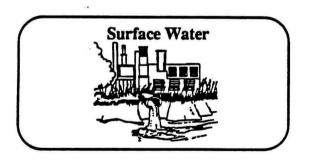
(1) A well is acceptable after the first sample in a year.

(2) No potential sources of contamination are nearby.

GIS could be used to identify wells near potential sources of contamination by overlaying well data, drinking water data, Superfund and RCRA sites. Region IV believes that GIS can save up to $15,000,000 per year by reducing sampling requirements.

Superfund

Region IV has used GIS to help identify and evaluate Superfund sites for the National Priority List (NPL). GIS has been utilized as a tool to map the locations of public and private wells. This data was then combined with Superfund site data and the Hazard Ranking System to identify and rank new sites for the NPL.

By providing Region IV with the ability to see information in graphical form instead of tabular form, GIS helped reduce the project time to eight weeks, which would have required three to six months to finish otherwise. While GIS in this case was used only to show geographical locations of wells, it demonstrated that maps help communicate information much better than text. In a similar manner, this screening process for ranking sites with GIS has been used to assign highest priority projects to the FIT contractor.
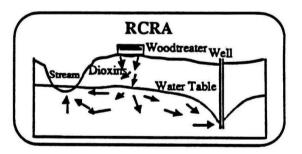
Surface Water

Region IV sees great potential in using GIS to help determine the relationship between surface water quality and construction grants for waste water treatment plants. By mapping out this relationship, managers can get a quick picture for determining:

(1) If grants and loans are actually going to the areas where there are problems.
(2) If the waste water treatment plants have made any difference in water quality.

By overlaying data on industrial discharges, municipal discharges, water quality monitors (i.e., STORET stations), permit violations, and grant information, managers can easily determine if the grants/loans and problem areas match.
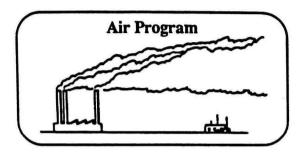
Region IV believes this GIS application has much potential, but sees the high cost necessary to clean up the existing locational data as a barrier to the success of this program. However, if initial costs can be met, Region IV estimates maintenance costs will be minimal.

RCRA

GIS is supporting the RCRA program in Region IV through identification of potential areas of ground water problems due to dioxins produced by woodtreaters. Region IV has mapped public water supply wells within a 5-mile radius of the woodtreaters. In potential problems areas, contractors have been sent into the field for inspections. By allocating inspection resources to the areas most likely to have problems, Region IV believes it will get "more bang for the buck."

With the same procedures used for Superfund prioritization, areas for RCRA enforcement prioritization are being designated. Region IV is automating RCRA site management and analysis to produce the

analytical reports needed to be proactive in RCRA enforcement.

Air Program

Region IV views GIS as a tool that has great potential for targeting areas of emerging air quality problems by integrating various sources of air data and analyzing trends in ambient air quality. Examples of GIS activities that may support the Air Program include the following:

- Overlay air quality data and the monitoring network to determine if the network is adequate.

- Overlay monitoring and compliance data to flag sources not in compliance in priority areas.

- Overlay emissions data in noncompliance areas to determine sources of pollutants and target priority areas.

- Analyze trends for ambient air quality. Region IV would like to include demographic data, meterological parameters, and emissions data in the analysis.

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Implementation Issues

Management/ Communications

Several management and communications factors have contributed to the successful implementation of GIS at Region IV. One of these key factors has been the support of the Regional Administrator. This support has been obtained through OIEA's emphasis on using GIS as a tool to tie EPA programs to improvements in environmental quality. Rather than assessing the effectiveness of programs by improvements in environmental quality, EPA programs have traditionally been evaluated by counting numbers of permits and grants issued. However, through the Results/Risk Analysis and Management Systems (RAMS), GIS can be utilized to help tie data and monitoring efforts to regulatory programs. GIS will allow managers to target regulatory activities based on problems and risks and to see if programs are effective in environmental terms.

Region IV managed its start-up period for GIS by choosing a few areas where GIS could succeed in supporting management (i.e., resource allocation). By supporting only a few applications which could be done well, Region IV used these successes to demonstrate what GIS could do. Moreover, Region IV's focus was on applications that had national significance. Using its successful results, Region IV convinced upper management of GIS's usefulness in EPA programs and received their support. Region IV also believes that by showing these results to Regional Administrators in other regions, they might be convinced to adopt and support GIS as well.

Another important factor in ensuring the success of Region IV's regional approach to GIS has been that prior to its GIS implementation, Region IV conducted a study to find out what managers needed for their programs to succeed. Region IV's GIS program was then built around the managers' needs. The managers were then informed of how the region-wide GIS could support their programs.

Communicating the benefits and merits of using GIS effectively requires talking with both upper management and technical personnel (i.e., section chiefs and technical staff). While upper management needs to understand how GIS can be used as a tool to support EPA's missions, it is the technical personnel who really understand *how* GIS can be applied. OIEA has communicated with both groups in its efforts to apply GIS to agency programs.
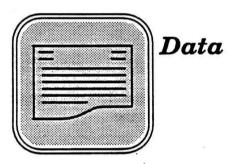
A significant factor contributing to Region IV's successful application of GIS has been that the manager of OIEA was previously a technical branch chief in three different divisions and

therefore has extensive programmatic experience. His ability to understand program needs and to communicate easily with program managers and staff has been an important factor in the development of applications that meet program needs.

A final factor in the success of GIS at Region IV is OIEA's orientation as a service organization. Since it is the program staff that decides whether OIEA's services should be used in the program, OIEA's mission is to assist programs and respond to their needs, rather than direct these programs.

OIEA does not have any ongoing operating functions except developing RAMS and providing analytical services. Region IV feels that this single objective has benefited the Region's work in building applications focused on risk reduction and environmental improvements. If OIEA was part of an existing office with other priority activities, time and energy could have been taken away from the RAMS effort.

The success of Region IV in producing practical applications, which management wants to utilize in managing environmental programs, is reflected in Region IV's role as a Center of Excellence for GIS in EPA. In this role and based on its experience, Region IV can assist other Regions in developing management applications based on the RAMS model and by providing guidance for obtaining management acceptance and support of those applications.

Data

Region IV's focus in GIS implementation is developing regional data bases. Its approach is to acquire data bases already in existence and forgo digitizing, since OIEA does not have enough staff to support time-consuming digitizing efforts. With this approach, Region IV is in a position to evaluate if more data will actually benefit a project. Data acquisition is considered the most difficult part of Region IV's data base development, since locating and acquiring the data takes much time. Data sets acquired by Region IV include:

- USGS 1:2,000,000 Digital Line Graph Data
  - Political Boundaries
  - Water Bodies
  - Rivers and Streams

- USGS Hydrologic Unit Boundaries

- EPA River Reach File

- U.S. Bureau of the Census Block Group Centroids
  - Thiesson polygons generated from centroids

- U.S. Bureau of the Census DIME Files

- U.S. Bureau of the Census Summary Tape File (STP #3)
  - Demographic and socio-economic data tied to census geography

- USGS 1:250,000 Land Use/Land Cover Data
  - Land Use/Land Cover
  - Census Tracts
  - Political Boundaries
  - Hydrologic Units
  - Federal Land Ownership

- USGS Public Water Supply Data

- U.S. EPA (derived from STORET, PCS, WHDMS, GICS)

- Soil Conservation Service MIADS Soils Data

- USGS Geographic Names File

- EPA Pesticides Data

- USGS 1:100,000 Digital Line Graphs

Region IV is developing common data bases needed for all programs dealing with ground water (i.e., Superfund and Drinking Water Vulnerability Analysis). Data include:

(1) Sources of contamination and their locations (Superfund and RCRA sites).

(2) Water supplies, populations using these water supplies, and their locations.

(3) Vulnerability of water supplies to contaminants - how easily can contaminants move from their sources to water supplies?

By focusing on development of regional data bases, many programs will benefit. For example, the Environmental Priorities Initiative, Superfund prioritization, drinking water vulnerability analysis, pesticide strategies analysis, and RCRA enforcement prioritization programs all need the same data, even though each views the data from different perspectives for analysis. With a regional data base, applications such as prioritization of Superfund and RCRA sites for the entire region will be possible.

Region IV has obtained much of its data through cooperation with other federal agencies and states. States are willing to provide data after they see that Region IV's work can assist the

states. Formal Memoranda of Understanding (MOU) are not used by Region IV for data acquisition since MOU's are regarded as an extremely time-consuming and restrictive process. Instead, Region IV has developed person-to-person contacts in which both parties benefit from borrowing or "bartering" for data.

GIS is being used as a quality assurance/control device at Region IV. By plotting incoming data, staff are able to more easily identify errors and therefore verify accuracy of data coverages. Because its focus is at a regional level, Region IV is willing to accept data of lesser quality than would be required for projects dealing with a smaller area. Moreover, Region IV may have several coverages of the same type of data at different scales, and will mix different scales of data in the same analysis. Because the program offices want GIS applications to be developed, the programs have begun very significant efforts to clean up data.

Region IV has encountered problems with the National Pollutant Discharge Elimination System (NPDES) discharge data. There is no locational data available for the minor dischargers. Moreover, the form for minor dischargers lacks a latitude/longitude section. Latitude and longitude are not required for the Permit Compliance System (PCS) as well. Less than 50% of its sites have latitude/longitude coordinates. Without locational data, Region IV regards GIS as being useless for regulatory work.

Staffing

Region IV's Office of Integrated Environmental Analysis (OIEA) was formed to develop advanced technology and information management tools required to support effective regional and state environmental decision-making. OIEA's responsibilities include:

- Develop integrated environmental analysis techniques using the latest technology (including but not limited to GIS).

- Provide leadership and act as a catalyst for development of analytical tools to support multimedia decision making.

- Maintain liaison with Headquarters' integrated information management developments.

- Develop analysis and report techniques for assessing environmental results.

- Assemble a high quality staff with programmatic and ADP technology capabilities.

- Provide leadership and serve as a catalyst for joint data integration projects with other federal agencies.

- Develop a management system (RAMS) based on risks and environmental improvements.

- Coordinate data collection activities by the Region.

- Liaison with states in the Region.

OIEA is staffed by environmental experts who have both experience with EPA programs and expertise with computer technology. The staff has a high degree of technical expertise in areas such as environmental engineering, chemical engineering, geology, and air and water programs. In addition, the OIEA staff works directly with ARC/INFO.

OIEA stressed the fact that the GIS staff needs to have expertise in program areas. As a result, Region IV does not want to have contractors as key GIS staff. The work requires close contact with the program staff, and Region IV believes it would be difficult to develop an iterative process with a contractor.

OIEA has emphasized the importance for a technical program person to work closely with OIEA staff on GIS work supporting that program. This person should have environmental science expertise and an understanding of how GIS may be applied to the program. Without this program person, OIEA believes GIS work will not be successful at Region IV.

There is a need to have on staff an expert for each technical discipline related to the environmental problems on which OIEA is working. These experts would come from areas such as epidemology, meterology, and water quality.

To augment its staff, OIEA has initiated a personnel rotation plan in which individuals from other agencies and divisions spend three months at OIEA. The benefits of this plan are:

(1) OIEA gains the expertise of the rotated staff.

(2) These individuals learn about GIS and bring this knowledge back to their agencies.

This rotation plan has been successful for OIEA, and it has expressed a strong interest to continue the program.
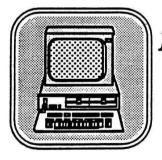
Software

ARC/INFO is viewed as a successful GIS package at Region IV, and the OIEA staff has become very proficient in its use. They utilize INFO to do all their analysis and "number crunching". In addition, OIEA plans to use AML to develop user-friendly, menu-driven applications for managers.

OIEA uses map libraries (which allow for efficient data maintenance and organization) in ARC/INFO extensively and recommends their use for regional coverages. They caution, however, that if a region deals exclusively with site specific projects, a map library may not be appropriate. There are also certain rules which must be followed if the map library is to be successful. For instance, while data collected at different scales may be mixed in the library, static and dynamic data may not.

Ground water workstations are being acquired by Region IV (as well as other Regions) so that site specific work utilizing ground water site data (i.e., RCRA and Superfund sites) may be done. To access this data for regional GIS purposes, OIEA needs procedures to convert the ground water workstation data into ARC/INFO coverages. However, there is a constraint on this conversion as the workstation data does not contain latitude/longitude coordinates, but is instead based on the cartesian coordinate system (i.e., 0,0).

Hardware

As shown in Figure 4, Region IV's current hardware configuration consists of two PRIME 2755 CPUs; Tektronix graphics terminals, printers and digitizers; Hewlett Packard and Calcomp pen plotters; a Calcomp digitizer; and other supporting peripherals.

As the use of GIS increases in Region IV, hardware upgrades will be required. There is presently a need for a larger CPU as well as more data storage capacity.

Figure 4

Overview of Region IV GIS and Related Computer Systems

Tektronix 4956 Digitizer

Tektronix 4106

Tektronix Ink-Jet Printer

Calcomp 1044 8-Pen Plotter

Tektronix 4125

Calcomp 9100 Digitizer

(2) PRIME 2755s

Tektronix 4207

Tektronix Ink-Jet Printer

12 PCs with Tgraph-to emulate Tektronix

Tektronix Ink-Jet Printer

On Order

Electrostatic Plotter

Houston Instrument Plotter

Tektronix 4125

Tektronix 4958 Digitizer

Constraints

Although Region IV's service-based, regional approach to GIS has been successful to date, three constraints are seen as impacting future GIS work:

(1)   **Key national data bases lack locational data:** OIEA has expressed concern that location is not a required field for several key data bases. This is seen as a major problem for GIS applications which utilize the locationally deficient PCS and NPDES data bases. Moreover, where latitude/longitude does exist in the PCS data base, its accuracy is questionable. Without locational data, GIS would not be useful for regulatory work.

The conversion of ground water workstation data into an ARC/INFO format is another area where locational data poses a constraint on future GIS work in Region IV. The cartesian-coordinate based data of the workstations are completely incompatible with the geo-based data (i.e., latitude/longitude, UTM, etc.) necessary for GIS work.
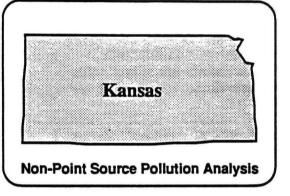
(2)   **Lack of staff:** OIEA does not have enough staff to meet the increasing need for GIS support in Region IV. They emphasized the necessity of acquiring more people with GIS and environmental expertise. Without this additional help, the existing staff has reached its limit in terms of GIS work that can be supported. Currently, a backlog of GIS projects is growing.

(3)   **Need for improved hardware:** Region IV is approaching its limit as well in terms of the hardware necessary to support its GIS applications. OIEA staff recommends that the two PRIME CPUs be upgraded to a larger mainframe. There is also a need for more data storage capacity.

Conclusion
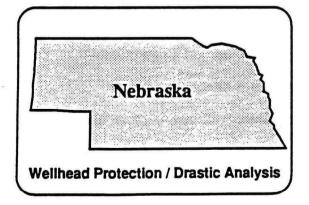
Region IV has successfully implemented GIS as a useful management-decision tool in several of its projects and has thus generated widespread interest at all levels in its use of GIS. This success has been due to upper management support, a region-wide approach to data base development, and the ability to act as a service organization for the support of programs. Because of its success, Region IV has been designated as an EPA national Center of Excellence for GIS.
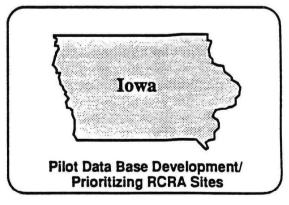
Plans are underway to incorporate GIS in several more projects. Greater use of GIS in the region, however, will require that the data, staff, and hardware constraints be eliminated.

❑

Region VIII

GIS at Region VII: Cooperative Pilot Projects with States

Kansas

Non-Point Source Pollution Analysis

Missouri

Emergency Response Development

Nebraska

Wellhead Protection / Drastic Analysis

Iowa

Pilot Data Base Development/ Prioritizing RCRA Sites

EXECUTIVE SUMMARY

Region VII has adopted a GIS strategy based on cooperative efforts with the Region's states and involvement of the regional program offices. GIS pilot projects have been initiated with each of the Region's four states. These pilots, which have been funded by grants from Region VII to the states, are true cooperative efforts in which Region VII and the states share project responsibilities and work. Regional program staff members were involved in the initiation of these projects and actively serve on the project teams. Region VII's support and expertise for GIS reside in the Office of Integrated Environmental Analysis.

Region VII's GIS pilot projects being conducted with the states are as follows:

KANSAS -- NON-POINT SOURCE POLLUTION ANALYSIS: GIS is being used to generate input parameters for the Agricultural Non-point Source model from a GIS data base and to map model outputs. From this work, scenarios of different land management practices will be analyzed.

MISSOURI -- EMERGENCY RESPONSE DEVELOPMENT: An emergency response management plan for hazardous spills will be developed by examining various scenarios with GIS.

NEBRASKA -- WELLHEAD PROTECTION / DRASTIC ANALYSIS: A state-wide wellhead protection plan will be developed using a DRASTIC ground water vulnerability analysis and GIS.

IOWA -- PILOT DATA BASE DEVELOPMENT / PRIORITIZING RCRA SITES: Data from a pilot GIS data base will be utilized in prioritizing RCRA sites based on indices of environmental hazard and environmental quality.

Region VII is also conducting the initial planning for a GIS pilot related to wetlands permits.

Key factors in the implementation of GIS at Region VII have been:

o Excellent start-up support for GIS from upper management;

o High level of program office interest and involvement with initial GIS efforts.

GIS at Region VII

Region VII has adopted a GIS strategy based on cooperative efforts with the Region's states and involvement of the regional program offices. This strategy, which follows an overall emphasis by Region VII on working with its states, is being implemented through joint GIS pilot projects between Region VII and each of its four states. The pilot projects are true cooperative efforts in which both parties share responsibilities and work for the projects. Formal cooperative agreements in the form of grants from Region VII to the states are funding the pilot projects.

Region VII's pilot projects have been designed to involve the EPA regional program offices as well as the states. Both states and regional program staff were asked for proposals for GIS projects. The pilot projects have been developed from both the state and program proposals and have been designed to produce work that is meaningful to regional program objectives. Program staff members are part of the pilot project teams.

GIS support and expertise at Region VII reside in the Office of Integrated Environmental Analysis (OIEA), which is part of the Office of Policy and Management, Environmental Review Branch. OIEA was formed during the first half of 1988 to provide automated, multimedia analytical support to the Region's programs. Through developing applications that use state-of-the-art information management technologies, OIEA's goal is to support decision-making by program managers. GIS is the core technology around which OIEA is developing applications for EPA programs.

At the time that this report was written, OIEA's GIS staff consisted of one EPA employee and one Computer Sciences Corporation contractor. OIEA was in the process of hiring two additional EPA employees. When fully staffed, OIEA's GIS staff will consist of five FTE's, which may be met by a combination of EPA staff and contractors.

OIEA acquired ARC/INFO and its PRIME 2755 from EPA's Office of Information Resources Management in February, 1988. The Region's states are also in the process of acquiring either ARC/INFO or PC ARC/INFO. As described in the summaries of the pilot projects given below, both the Region's and the states' systems are being utilized for some of the pilots.

Region VII's four pilot projects are listed below and are described in the following pages:

- Kansas -- Non-pont source pollution analysis
- Missouri -- Emergency response development
- Nebraska -- Wellhead protection / DRASTIC analysis
- Iowa -- Pilot data base development / Prioritizing RCRA sites

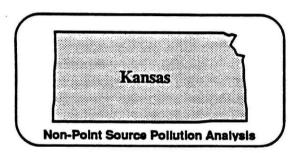Completion of all four pilots is scheduled for FY 89. Another planned GIS project involving wetlands permits is described below.

Region VII also has a cooperative agreement with the Kansas Applied Remote Sensing (KARS) program at the University of Kansas. Two research projects that are being funded by this cooperative agreement are:

- Development of a methodology to derive input parameters to a

non-point source pollution model from remote sensing data

- Development of a methodology for an environmental quality index

The results of these two KARS projects will be used in conjunction with work being done with the Kansas and Iowa pilot projects, respectively. The KARS projects are described in more detail below as part of the summaries for the Kansas and Iowa pilots.

Non-Point Source Pollution Analysis

Region VII is using GIS for an analysis of non-point source pollution in an 8000 acre watershed in Kansas. This project, which is the regional GIS pilot for Region VII, is being done in association with the Kansas Department of Health and Environment, the Kansas Water Board, the U.S. Soil Conservation Service, and Region VII's Drinking Water Branch.

GIS is being utilized to generate inputs to the Agricultural Non-point Source (AGNPS) model and to map model outputs. AGNPS is a grid-cell model that requires numerous parameters related to slope, aspect, soil, and other variables. OIEA is automating procedures to generate these input parameters from data in an ARC/INFO data base. AGNPS outputs will then be mapped with ARC/INFO and overlaid with land use and land cover data. From this work, scenarios involving different land management practices will be developed to determine the best land management practices for the area that

minimize runoff. These results will be presented to local farmers, who are the individuals responsible for land management practices.

After completion of the Kansas pilot project, state agencies would like to apply the AGNPS model and GIS to the entire state. Although field surveys were used to collect and verify data for the Kansas pilot project, field surveys would be far too time-consuming for a state-wide project. To alleviate this problem, the KARS program is conducting research on a methodology to derive twenty-one input parameters to the AGNPS model from remote sensing and other data sources. This research is being funded by a grant from Region VII.

Emergency Response Development

Region VII and the Missouri Department of Natural Resources are developing an emergency response management plan for hazardous spills that may contaminate water supplies. A GIS data base is being built that contains data on soils, geology, landfills, RCRA sites, and other data within a one-mile radius of all public water supplies in Missouri. From this information and data on public water supplies, a state-wide wellhead protection plan will be developed.
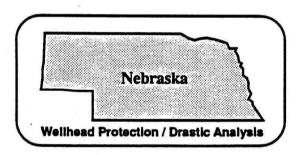
Using the NETWORK module of ARC/INFO, various scenarios for hazardous spills will be examined to determine the following information:

- Length of time for spills to contaminate water supplies;

• Which water supplies would be affected by spills;

• Alternative water supplies for towns with contaminated water supplies; and

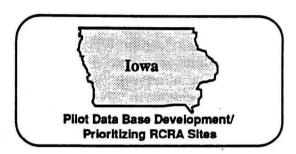• Economic impacts of using alternative water supplies.

A detailed study will be conducted in St. Charles County, where a data base for the entire county is being built for examining emergency response scenarios.

Much of the data needed for the GIS data bases for this project is in paper files. Missouri is responsible for data extraction work and for construction of the data base. Region VII will be involved with generating and running scenarios for hazardous waste spills.

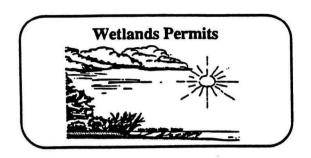**Wellhead Protection / Drastic Analysis**

Region VII and the Nebraska Department of Environmental Control (NDEC) are conducting a ground water vulnerability analysis for the state of Nebraska using the DRASTIC index. This analysis will be combined with public water supply data to develop a state-wide wellhead protection plan. GIS will be utilized in the project to map the results of the DRASTIC analysis, to examine spatial relationships between data, and to assist in buffer zone analyses around wellheads. From the results of this project, the most vulnerable wells could be identified and prioritized for increased monitoring and protection activities. The project is being conducted at a scale of 1:250,000.

In conjunction with this project, Region VII and NDEC will implement and test a facility to transmit data between Nebraska's ERDAS and PC ARC/INFO system and Region VII's PRIME ARC/INFO system. This facility will then be used to transmit data layers comprising the DRASTIC index from Nebraska to Region VII.

Pilot Data Base Development/ Prioritizing RCRA Sites

With the assistance of Region VII, the Iowa Department of Natural Resources is developing a pilot GIS data base to be used with its PC ARC/INFO system. Region VII will then use this data base to prioritize RCRA sites in Iowa.

Prioritization of Iowa's RCRA sites will be based on indices of environmental hazard and environmental quality being developed by Region VII and the KARS program. RCRA sites have already been ranked on a manual environmental hazard index that gives a relative measure of the hazard associated with a site. The KARS program is being funded by Region VII to develop a methodology for an environmental quality index. This research is investigating methods for using GIS and remote sensing technologies with the index. Region VII plans to pilot test the index with the Iowa RCRA sites. Region VII also hopes to automate the manual environmental hazard index.

Wetlands Permits

Region VII is in the initial planning stages for a GIS pilot project related to wetlands permits. Approximately three hundred to five hundred wetlands permits must be evaluated per year by two Region VII staff members. Many of these requests for permits are submitted after an activity requiring a permit has already occurred. The lack of public awareness about the law and the lack of strong environmental groups in the Midwest contribute to this situation.

GIS could be used to assist the wetlands permit process in a several ways. A GIS data base would allow consolidation of data on permits and provide a means of identifying areas with many permits or with permits granted after unauthorized activities occurred. This information could be used in turn to concentrate inspection efforts in critical areas. A baseline for current wetlands could be established from a GIS data base. This would assist in prioritizing wetlands for protection. Areas where fill and excavation activities would be permitted or restricted could be identified in advance, which would assist in the permit review process. Finally, GIS-produced maps could be used to increase public awareness of the need to preserve wetlands.

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Implementation Issues

Management/ Communications

The development of a GIS program at Region VII has been the result of much careful thought and planning. Before establishing a GIS program, Region VII met with key individuals at other GIS installations in EPA (e.g., Region IV, EMSL-LV) to learn from the experiences of these other sites. An ad hoc group of Region VII's senior managers and staff interested in GIS was established to assist in the formation of the Office of Integrated Environmental Analysis (OIEA), which is the regional office responsible for GIS. Because GIS is viewed as a management tool and service that must be available to all program divisions and the states, it was decided that OIEA should reside within the Office of Policy and Management, as opposed to one of the other programmatic divisions.

In its implementation of GIS, OIEA stresses serving program offices and involving programs and states in the use of GIS. OIEA's service orientation is not that of a service bureau which runs user applications. Rather, OIEA plans to design and develop applications that will serve the needs of programs. These applications will then be turned over to the programs for their day-to-day use.

To involve the programs in the implementation of GIS, OIEA sent a questionnaire on information needs to all regional section and branch chiefs. The questionnaire asked what types of information were needed to accomplish the goals of their programs, what sources of data were used, and what types of outputs were required for program operations. Based on replies to the questionnaire, follow-up interviews were conducted with the managers to identify ways in which GIS might help managers in meeting their programs' goals and in the decision-making process. From this work, forty-nine applications for GIS and the major data layers required for those applications were identified. Through this input from program managers, OIEA has acquired invaluable information to use in focusing its GIS resources on serving the needs of Region VII's programs.

Another mechanism through which OIEA receives input from regional programs is through two advisory groups of program staff. The first group, which consists of program senior managers, serves as a GIS "board of directors" by approving GIS projects. The second group is an advisory task group of technical staff that assists in proposing and implementing GIS applications. This technical group helps OIEA to identify program sources of information for GIS projects. Program staff may use the task group to obtain information on how GIS may be applied to their programs.

As stated above, OIEA has taken an approach to GIS that has involved the Region's states as well as the EPA program offices. Proposals from both the states and the programs offices were considered in designing the Region's GIS pilot projects. The pilots had to be of interest and use to both the states and the regional programs. By taking an approach that has involved the states as full partners in the pilot projects, OIEA has been able to bring the states along in their use of GIS at the same time that OIEA is acquiring GIS expertise. This approach has been successful in that the GIS seed money provided by Region VII's cooperative agreements with the states has resulted in additional funds being allocated to GIS by the state legislatures.

The cooperative agreements between Region VII and the states for the pilot projects are formal written agreements that include approved project work plans. The project responsibilities for both Region VII and the states are specified in the agreements.

The involvement of the states and regional programs has been a major factor in the successful implementation of GIS to date at Region VII. Another key factor has been the support of upper management at Region VII. The Deputy Regional Administrator and the Assistant Regional Administrator have been very supportive of establishing a GIS program, and as a result, Region VII has had excellent start-up resources for GIS. Enthusiam for GIS extends to the program staff, who see GIS as a tool for assisting them in their work. While some division directors are also supportive of using GIS, other division directors are more tentative in their enthusiam and are waiting to see actual products from GIS before fully supporting its use.
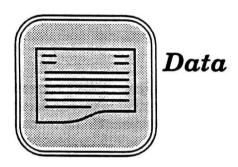
To sustain interest and support during the life of a GIS project, Region VII plans to identify and produce useful interim products from a project. Although these interim products, which may be various types of maps, would not be the end goals of a project, they would provide useful information to program offices supporting the project and would serve to sustain project support. Region VII also plans to keep GIS projects relatively simple whenever possible. Although GIS is a complex technology, every application does not have to be complex to be useful to EPA programs.

Region VII expressed the need to communicate with the states, other EPA Regions, and academia about developments in the use of GIS. With the explosion of interest and use of GIS, it has become difficult to keep up with the work of others. To assist in this need for sharing information and technology transfer, Region VII holds an annual coordination meeting with its states. This forum is one mechanism of enabling all states in the Region to know what the other states are doing with GIS.

As another method of fostering communication about GIS, Region VII plans to write complete documentation for its GIS pilot projects. The documentation will include detailed steps of the methods and procedures used in the projects, the results of the projects, and the impacts of applying the project results. This documentation will enable Region VII to share the findings of its pilot projects with others.

Region VII's concern for GIS communications extends to its interest in communicating project results to the public, since most efforts at improving environmental quality require public support. When a community relationship component of a project is known at the beginning of the project, a community relationship plan will be incorporated as part of the overall project plan. This has occurred for some of the cooperative agreements that are supporting the GIS pilot projects.

The long-term support required to maintain a GIS program is an issue that Region VII believes will need careful attention. Efforts to share project and data acquisition costs need to be explored. Cooperative agreements coordinated by EPA Headquarters that would provide for free data sharing with other federal agencies could reduce project costs. Other possibilities that should be investigated include sharing project costs and work responsibilities with the states and close cooperation with program offices in securing funding. All of these efforts require advanced planning that would identify the resources needed for future projects. With its role of developing common data bases, OIEA could coordinate common data requirements for GIS projects in such pre-planning efforts.

Data

OIEA has developed a conceptual framework for a regional GIS data base for Region VII. This framework has been based on results from the questionnaire on information needs sent by OIEA to section and branch chiefs. Responses to the questionnaire identified fifty-six major data layers needed for proposed GIS applications. These data layers have been prioritized into high, medium, and low categories for acquisition. Although the total number of data layers for applications could be several hundred, the fifty-six layers represent most of the high and medium priority data required for the Region's potential GIS applications. Key data layers required by many of the applications include the following:

- Base map layers, including hydrography, political boundaries, transportation, and elevation
- Soils
- Water quality
- Public water supply locations
- Air quality
- Geology and hydrogeology
- RCRA and Superfund sites

To implement its conceptual framework for a regional data base, OIEA has set up ARC/INFO map libraries for each of Region VII's four states. As data are acquired for specific projects, the data will be incorporated into the libraries. In general, OIEA will concentrate on obtaining data needed for specific projects and will use that data to build a regional data base over time, as opposed to developing all data layers for a regional data base immediately. As an exception to this plan, some key layers, such as the base map layers listed above, may be obtained for the entire region even if parts of the layers are not needed immediately by a project. Whenever possible, data will be acquired at a scale of 1:24,000.

Region VII staff stated that data acquisition is the most time-consuming task of a GIS project. Determining who has what types of data is often a long process. After data sources have been identified, much time and money may be spent in acquiring the data and preparing the data for use in a GIS. For Region VII, the time and cost of acquiring data are constraints on the immediate development of a regional data base. By taking a project-specific approach to data acquisition, the problem of waiting for results from a GIS while large data bases are being developed is minimized.

Region VII's approach of working closely with its states for GIS implementation has aided the Region in acquiring data. Although some federal and state agencies have been reluctant to share data, both the personal contacts developed between OIEA and individuals in states agencies and the general good relationships between Region VII and its states have made sharing state data much easier. Because states and local governments generate much data needed for environmental analysis, contacts with the states are important for obtaining data for many projects.

Since data acquisition is such a major cost for GIS projects, Region VII is interested in agreements that may be established with states or other federal agencies that permit sharing data for free or sharing the costs of acquiring data. As stated in the *Management/Communications* section, OIEA could play an important role in data sharing at Region VII by coordinating projects that need common data. GIS greatly facilititates such data integration efforts, and OIEA would like to utilize GIS to meet data coordination goals.

Much of the state and local data that may be needed by Region VII is based on the section/township/range locational reference system. To use this data in the Region's GIS will require converting the data to latitude/longitude coordinates. As the states develop their own ARC/INFO data bases, they also will need to convert such data to latitude/longitude coordinates.

Region VII has expressed concern about data quality issues for GIS. Both the quality of locational data and the need to measure the accuracy of source data and outputs from a GIS are pressing problems that must be addressed. Region VII has found that much of the locational information in EPA's data files is poor. For some RCRA and Superfund sites, the mailing address for a company associated with a site is found in the files, as opposed to the location of the site itself. Region VII also stated that methods must be developed to measure the accuracy of GIS maps. An error measure is needed not only for source maps but also for cumulative errors on GIS-produced maps that are the result of combining different types of data with different levels of accuracy. This type of error measurement is vital for legal actions that may be based on results of GIS analyses.

To begin to address data quality issues, Region VII has taken initial actions to verify locations in the field and to conduct a study on data quality assurance and control (QA/QC) in a GIS. Region VII has purchased five portable Loran C units that may be checked out by program and state personnel performing field inspections. These units will enable field inspectors to verify latitude and longitude coordinates for RCRA, Superfund, and other sites that receive on-site inspections.

Region VII has also begun work on GIS QA/QC issues, with the goal of identifying a quality indicator that could be used throughout a GIS application. OIEA would like to conduct a
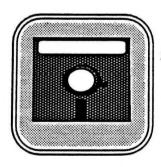
review of all literature on error tracking and measurement for spatial data. A pilot project may also be conducted to track errors throughout the process of utilizing a GIS. Region VII plans to coordinate its QA/QC efforts with work being done by the Environmental Monitoring Systems Laboratory at Las Vegas.

Staffing

At the time that this report was written, OIEA's GIS staff consisted of one EPA employee and one Computer Sciences Corporation contractor, who is also the PRIME systems administrator. OIEA was in the process of hiring two additional EPA employees. The ideal candidates will have expertise in environmental management, since OIEA believes that it is easier to teach ARC/INFO and computer skills to someone with expertise in environmental management than to teach environmental management to a computer scientist.

Project teams that have been formed for GIS projects at Region VII consist of an OIEA staff member, representatives from each state agency involved in the project, and a regional EPA staff member from the associated program. Having a program staff person on a project team has been important to the successful planning and implementation of the projects. The program staffer is involved with all meetings that are convened for the project.

Software

Region VII acquired all modules of ARC/INFO in February, 1988. After initial difficulties were encountered in getting a Tektronix digitizer to work with ARC/INFO, ESRI wrote a driver for the digitizer that permitted the digitizer to be connected directly to the PRIME computer, rather than through a terminal. In general, Region VII has been satisfied with ESRI's support and responsiveness for resolving ARC/INFO problems.

INFO is viewed as a limited data base management system. Although INFO is easy to use for simple tasks, complex tasks are awkward to program in INFO. Programs requiring multiple files are cumbersome to write, especially if the files cannot be related by a common key.

As OIEA acquires more staff and develops a broader base of expertise in ARC/INFO, OIEA would like to develop user-friendly ARC/INFO macros for program users. These macros would be part of OIEA's development of applications for program offices, who would then use the macros and applications on a daily basis.

All of the states in Region VII have or will be acquiring a version of ARC/INFO. Missouri currently has ARC/INFO installed on a PRIME computer, whereas Kansas has ARC/INFO and a PRIME on order. Both Nebraska and Iowa have purchased PC ARC/INFO. With all the states in Region VII having the same GIS, exchange of common routines and ARC/INFO data bases will be greatly facilitated.

Hardware

As shown in Figure 5, Region VII's current hardware configuration for GIS consists of a PRIME 2755 and supporting peripherals. A Calcomp electrostatic plotter has been ordered. Region VII's hardware is adequate to meet its current processing requirements for GIS.

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Figure 5

Overview of Region VII GIS and Related Computer Systems

On Order

Calcomp
8-pen Plotter

Calcomp
Electrostatic Plotter

(2) Tektronix 4207s

PRIME 2755

Epson PC

Tektronix 4325
Workstation

Tektronix Digitizer

Constraints

The main constraints on GIS work at Region VII are **data availability, data acquisition, and data quality.** As described in the *Data* section above, determining who has what types of data is often a lengthy process. Some governmental agencies that may have useful data are reluctant to share their data. After data that are available have been identified, acquiring that data may be time-consuming and expensive. The data may be in paper files that have to be searched, compiled, and automated. If no data of a specific type are available, expensive field survey work may have to be done. These expensive procedures greatly increase the cost and time required for a GIS project. Even after data are obtained and automated as part of a GIS data base, the quality of that data may cast doubt on the accuracy and reliability of GIS analyses that used the data. Consequently, Region VII views these data problems to be the major constraints on its GIS work.
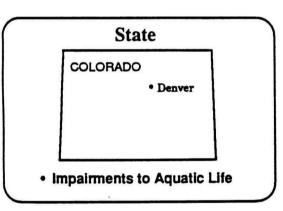
The issues of data quality are especially of great concern to Region VII, particularly for GIS work that may lead to legal actions. Region VII staff stated that they have a responsiblity to know the limits of accuracy of their GIS products and analyses and to convey those limits to others, so that information from GIS analyses is not misused. Without good quality assurance measurements for GIS, it is difficult to fulfill that responsibility.
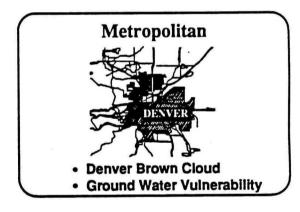
Conclusion
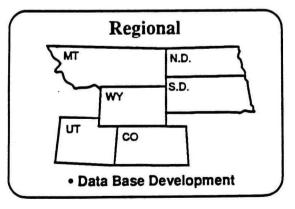
Region VII has involved both the regional program offices and the Region's states in the implementation of GIS. The pilot projects selected for the Region were chosen to be of interest and use to both the programs and the states. The pilot projects are being conducted as joint cooperative efforts between Region VII and the states, and program staff are also part of the project teams. This approach by Region VII has been successful in gaining much interest and support for GIS from both program staff and the states. Upper management has also provided excellent start-up support for GIS, which has been a major factor in initiating the GIS program at Region VII.
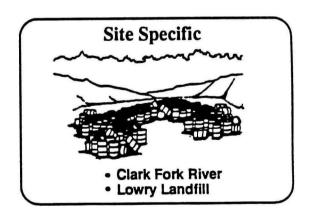
The small size of the Region's GIS staff has limited the amount of GIS work that could be done. With the planned increase in staff size, additional GIS applications beyond the pilot projects may be undertaken.

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Region VIII

GIS at Region VIII: Multi-Scale Implementation at the Pilot Level

State

COLORADO
• Denver

- **Impairments to Aquatic Life**

Metropolitan

DENVER

- **Denver Brown Cloud**
- **Ground Water Vulnerability**

Regional

MT
N.D.
S.D.
WY
UT
CO

- **Data Base Development**

Site Specific

- **Clark Fork River**
- **Lowry Landfill**

EXECUTIVE SUMMARY

GIS at Region VIII has been implemented successfully in support of several pilot projects and has the potential of becoming an integral part of program activities. The Region is approaching GIS program development and GIS pilot projects from a wide range of geographic levels of analysis. The successful application of GIS in Region VIII's state and metropolitan pilot projects has demonstrated that GIS is a useful tool in the Region's decision-making process.

The following programs are being conducted or planned at Region VIII:

STATE -- GIS has been used to map ecoregions in Colorado as well as help identify patterns of impairments to aquatic life from metals, sediments, salinity, and nutrients.

METROPOLITAN -- As part of the Denver Brown Cloud project, GIS is being integrated with LIDAR (a laser-based air particle monitoring device) to help scientists determine the fate and transport of the Denver Brown Cloud. In addition, GIS will assist in the analysis of ground-based air quality monitor placement.

GIS is also being used to visualize ground water environmental characteristics and contamination sources to help identify the potential vulnerability of northwest Denver to ground water contamination.

REGIONAL -- A regional GIS data base is being developed for the application of region-wide analyses as well as to provide separate EPA programs access to the same data.

SITE-SPECIFIC -- As part of Montana's Clark Fork River NPL Site project, GIS is being used in macro site analysis and as a support for monitoring activity. Region VIII's advisory role provides for quality assurance in the project.

In a planned project, GIS will be used to develop scenarios that will aid in the evaluation of a Superfund site in southeast Denver.

Region VIII's GIS work has depended upon several key factors:

o Program staff that understands the value of GIS as a communications tool;

o Program staff *initiating* a collaborative effort with the GIS team; and

o A GIS team staffed by environmental experts with EPA program experience and computer technology expertise.

GIS at Region VIII

During the past year GIS has been implemented at the pilot level in Region VIII. Initial activities have included the acquisition of software, hardware, and telecommunication equipment and the formation of a GIS support team. The Region has focused on implementing pilot projects at four different scales -- Regional, State, Metropolitan, and Site Specific. The projects have concentrated on surface/ground water quality assessments and air quality monitoring assessments.

Region VIII began its work with GIS in the Spring of 1988 by remotely accessing Research Triangle Park's (RTP) ARC/INFO system in North Carolina. Region VIII plans to install an on-site system in 1989. A GIS team that consists of three EPA staff members was formed in the Environmental Monitoring and Assessment Section of Region VIII's Environmental Surveillance Branch. The GIS team is augmented by another EPA staff member who devotes fifty percent of his time towards GIS applications. ARC/INFO training for the GIS team occurred during March, 1988. Region VIII senior management's decision to commit additional personnel to the GIS program will eventually bring the GIS team's FTE total to five.

Using GIS, Region VIII plans to accomplish the following objectives:

1) Significantly enhance the use and analysis of environmental data in Region VIII;

2) Integrate regional geographic data into one framework;

3) Achieve better usage, control and display of regional data:
   a. across EPA data sets
   b. across agencies; and

4) Incorporate more spatial analysis in regional problems, programs, and projects.

Six pilot projects are described in the following sections:

STATE
- Impairments to Aquatic Life in Colorado

METROPOLITAN
- Denver Brown Cloud
- Denver Ground Water Vulnerability
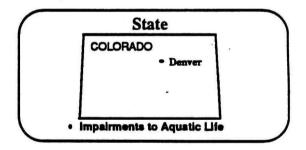
REGIONAL
- Data Base Development

SITE SPECIFIC
- Clark Fork River NPL Site
- Lowry Landfill

In a cooperative effort with the Environmental Research Laboratory at Corvallis (ERL-C), Region VIII's Water Management Division is conducting a demonstration study that focuses on assessment of surface water quality in Colorado. The goal of the study is to demonstrate the value of using GIS and an ecoregion approach for water monitoring and assessment, and to identify patterns of impairment to aquatic life. Region VIII suggests that ecoregions provide an appropriate framework for monitoring and evaluating natural patterns in water resource

quality, and help to determine regionally attainable quantitative, chemical, and biological goals of water quality.

ERL-C is a leader in ecoregion research and has provided much assistance to Region VIII by supplying ecoregion data as well as sending an environmental scientist to work with the Region VIII staff on data base development for one year. The demonstration study is scheduled for completion in June, 1989.

Tasks completed or scheduled to be completed for the project are as follows:

(1) Map ecoregions and sub-ecoregions in Colorado. With data provided by ERL-C as well as other sources (i.e., Petroleum Information Data Base), Colorado has been divided into ecoregions and sub-ecoregions, and a draft map displaying this information has been completed. The map has been digitized and sample maps compiled at a 1;500,000 scale have been printed. With ARC/INFO, the ecoregion and sub-ecoregion data can be combined with stream trace data to display areas within which stream quality is expected to be relatively similar when compared with the quality of other areas, and to identify candidate reference sites to assess attainable stream quality.

(2) Use statistical analyses of available chemical and biological data (i.e., STORET data) to demonstrate the process of assessing present and attainable quality of aquatic ecosystems. This requires:

 a. selecting sites by location (e.g., latitude/longitude, county, or hydrologic units);

 b. selecting sites by station type (e.g., lake, ambient stream, etc.).

This information has been converted into an ARC/INFO format through a series of computer programs.

(3) Demonstrate the use of GIS for storage, retrieval, and analysis of data. Among the

tasks Region VIII has accomplished are:

 a. Created a River Reach File that divides each of Colorado's streams into segments and identifies each segment with an 11 digit identifier, the reach number. Region VIII's ARC/INFO data bases can be accessed using the River Reach Number.

 b. Integrated hydrography data (i.e., streams, lakes and reservoir traces) from Petroleum Information Data Base into ecoregion and sub-ecoregion data.

 c. Culled small streams for use in low-level resolution maps.

(4) Produce Aquatic Life Use Maps and Aquatic Life Use Impairment Maps. With ARC/INFO, aquatic life use data has been combined with stream trace data to produce a composite map that displays the spatial distribution of aquatic life use classes. Aquatic life uses are mapped as the categories Cold Water Classes I and II and Warm Water Classes I and II.
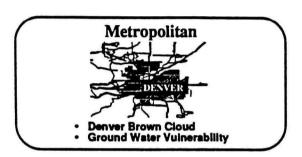
ARC/INFO has also been used to display aquatic life use impairment data. For example, maps are created to display waterbodies that are impaired by any combination of metals, sediments, salinity and nutrients. The maps indicate that in many cases, streams within ecoregions have impairments more similar to each other than to streams in other ecoregions.

The Aquatic Life Use Maps and Aquatic Life Use Impairment Maps are still in the draft stage due to the continuing quality control/quality assurance analysis that must be performed on the data.

(5) The only task remaining is to complete both the draft and final reports that address the issues of ecoregion rationale, documentation of methodology, recommendations regarding the use of GIS, as well as other issues.

Region VIII views GIS as a promising tool

for implementing and benefiting from the ecoregion approach. The maps produced with GIS help water quality managers see how the information fits together geographically and can assist in the setting of priorities for water quality control.

Metropolitan
- Denver Brown Cloud
- Ground Water Vulnerability

There are two pilot projects currently taking place at the metropolitan scale. The first project is assisting in the evaluation of the Denver Brown Cloud, while the second project is assisting in the evaluation of Denver's ground water vulnerability.

Region VIII's Denver Brown Cloud project assesses air pollution exposure among the metropolitan area's residents. The project is currently using GIS to help in:

(1) Determining if the ground-based air quality monitors are in the optimal location for the collection of data. Health risks of the population may more accurately be determined from the improved placement of the monitors.

(2) Determining the fate and transport of the Denver Brown Cloud.

A data base has been developed that includes:

- air quality data
- soils data
- cultural features
- hydrography
- roads
- census tracts
- population data

GIS can help in determining more accurate placements of the air quality monitors by enabling scientists to visualize characteristics of the pollution, population, and other parameters. In addition, the GIS results can be used as a quality control device whereby scientists can compare the GIS results to those of other air quality models to determine their accuracy.

Region VIII has also been integrating LIDAR data with GIS. LIDAR, which refers to Light Detection and Ranging, uses light waves to detect and range (measure the distance to) airborne particles. For air pollution monitoring, a very short burst of laser light is beamed through a smokestack plume or through the air above Denver. Back scatter is then recorded from the particles or other substances reflected in the laser beam. The scatter is subsequently converted into a "picture" of the air contaminants the beam has encountered.

Region VIII has obtained LIDAR data from the Environmental Monitoring Systems Laboratory at Las Vegas (EMSL-LV) in an ARC/INFO format, and is using LIDAR and GIS as tools to help determine the fate and transport of the Denver Brown Cloud. Analyses for the pilot will address several project objectives, including those listed below:

(1) Determine the extent to which the air mass has aged.

(2) Determine the extent of the air mass's movement.

(3) Determine the source of pollutants that compose the cloud.

LIDAR has been of great use in helping the Region VIII staff determine the source of pollutants that compose the cloud. For example, a Denver Brown Cloud study was done previously by a private consortium at the government's request. Without the aid of LIDAR, the consortium determined that smokestacks in the Denver metropolitan area

were not a primary contributor to the cloud. LIDAR, however, can collect data over a much more extensive area than was previously done and has enabled Region VIII's Brown Cloud study to determine that the smokestacks are a contributing source to the Denver Brown Cloud.

The staff regards GIS as an important tool in the interpretation of LIDAR data. For instance, the ability of GIS to accurately map the information contained in the LIDAR data has enabled Region VIII to pinpoint a distant smokestack that contributes to the Brown Cloud. GIS makes LIDAR data more comprehensible.

The LIDAR/GIS Denver Brown Cloud project is regarded by the Region VIII staff as being an influential study. It can help the EPA scientists more accurately locate sources of air pollutants, as well as help them understand the Brown Cloud's air flow pattern.

Region VIII is also using the metropolitan scale approach in a pilot project that will help identify the potential vulnerability of northwest Denver to ground water contamination. The Region is working in cooperation with the USGS, and is using the DRASTIC index to assess the ground water vulnerability of the area. The pilot will demonstrate how GIS can be used as a tool to make management decisions related to ground water protection. Examples of decisions that may be supported by the use of GIS include the following:
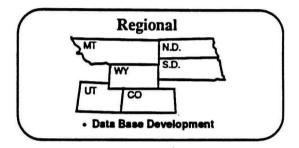
(1) Delineate boundaries of wellhead protection areas; and

(2) Identify the location of underground storage tanks (USTs).

Extensive data sets have been collected for this effort, including:

- locations of Public Water Supply wells
- roads

- counties
- streams
- elevations
- census data
- ground water vulnerability data
- geology
- aquifers

Region VIII intends to utilize these base data sets for other projects in addition to the DRASTIC study.

Region VIII has begun the development of a regional level GIS data base that will integrate point (and to a lesser degree, non-point) data from EPA's National Data Bases as well as from other sources of data.

The data base consists of:

- STORET data
- air quality monitoring data
- locations of NPDES major discharges
- locations of CERCLA sites
- locations of RCRA sites
- hydrography data
- point sources of air and water pollution
- non-point sources (i.e., feedlots, mining areas)

The development of the data base has been in operation since March, 1988 and will use GIS to support several goals:

(1) Create base maps so the location of the pollution sources may be easily identified.

(2) Perform analysis on a regional basis. For instance, GIS could be used as a tool to help officials prioritize Region VIII's RCRA sites.

(3) Stimulate upper management interest in GIS. By demonstrating to senior management the value of GIS in the Region's decision-making process, it is hoped that they will more actively support the Region's GIS development.

(4) Provide an effective means of communicating information to the public.

Site Specific

• Clark Fork River
• Lowry Landfill

The Clark Fork River NPL site in Montana, which actually consists of four NPL sites, is one of the largest NPL areas in the country. With its 150 river miles and over 100 years of copper mining, the site will require massive investigative and cleanup efforts. The site involves numerous environmental problems, many of which are related to contaminant migration of heavy metals.

The project was initiated by EPA's Montana Operations Office in Helena. Staff at this office felt that GIS may be a useful technology to apply to the Clark Fork River site but had no knowledge about how to apply the technology. The Montana office sought EMSL-LV's help in formulating a work plan and in designing and building a GIS data base.

Region VIII has an advisory role in the project. Montana had little knowledge of GIS at the start of the project in the summer of 1987, and Region VIII played a major role in helping the state identify and more effectively utilize available resources (i.e., data, GIS knowledge, etc.). In addition, data must meet Region VIII's high-quality standards before it is recommended for use by the state.

The focus of the project involves using GIS in macro site analysis and as a support to monitoring activity. For the longer term GIS will be used as a tool to augment the remedial investigation/feasibility study (RI/FS) process for the site. Because the site has so many environmental problems that overlap spatially, GIS is viewed as the best method to characterize the nature and extent of these problems in a remedial investigation. It is anticipated that the data base that is being built may be used for twenty years in support of a broad range of activities at the site.

In addition to its work at the Clark Fork River NPL site, Region VIII is also in the planning stage of a GIS pilot project that will help evaluate southeast Denver's Lowry Landfill Superfund site. The Lowry Landfill is a small (one-half square mile) NPL site that Region VIII would like to use for GIS test applications. With data provided from fifty-four test wells as well as from other sources (i.e., chemistry data from waste ponds), Region VIII plans to develop a data base with extensive locational information for this site. Ground water analysis will then be performed with the GIS with the hope that Region VIII can characterize the nature and extent of the problems involved.

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Implementation Issues

Management/ Communications

Three important factors have contributed to the successful implementation of GIS at Region VIII:

(1) The program staff in some areas (i.e., Water Management Division) sought the assistance of the GIS staff for help in their programs. This initiation on the part of the program staff towards a collaborative effort with the GIS team has demonstrated their interest in GIS and has been instrumental in the application of GIS in Region VIII.

(2) Program managers view GIS as a useful communications tool. The capability of GIS to analyze and display large amounts of data enables program managers to more clearly determine where their efforts should be focused.

(3) The program staff also helped to turn around initial resistance to GIS, as well as develop priorities for determining where GIS was needed most (i.e., water quality and air quality applications).

Region VIII's GIS team emphasized the need for upper management support if GIS is to be fully implemented in the Region in support of agency programs. The GIS team believes that successful pilot projects will prove the utility of GIS to upper management and will be a critical factor in getting upper management's support. The GIS team also emphasized the need to have program staff support GIS applications.

The GIS team considers the communication of GIS *experiences* with other Regions and States as being very important, and as something that should be done now. If communication of experiences is done at a later time (i.e., 1 - 2 years) in a more documented form, decision-makers will be more set in their ways and tend to resist any changes suggested by these experiences. Providing information now will influence GIS decisions later.
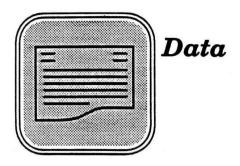
The GIS team also expressed concern that Region VIII's GIS projects are not addressing enforcement and regulatory concepts, but instead are taking a planning agency approach to GIS applications. The GIS staff suggests that this issue needs to be resolved for GIS to continue to be successful in EPA.

Region VIII considers support from EPA Headquarters (Office of Information Resources Management) to be a major factor in the successful implementation of Regional GIS. OIRM involvement would be of benefit in the following areas:

(1) OIRM should enhance communication between Regions. For example, Region VIII needs to know what Region VI or Region III has been doing with GIS. It is recommended that OIRM:

  a. act as a conduit to other agencies and get key people to share information;

  b. recommend quarterly meetings and conference calls; and

  c. advocate more thorough documentation of Regional GIS work.

(2) Headquarters should organize responsibilities for the Regions and research laboratories. For example, the GIS staff at Region VIII wants the Environmental Monitoring Systems Laboratory at Las Vegas (EMSL-LV) to develop AML macros for common applications so that a possible duplication of effort will not take place at another Region. It is believed that OIRM should take responsibility for coordinating efforts such as this.

(3) Headquarters needs to provide resources for the Regions. National support should be provided for FTEs and contract dollars, as the Regions have limited control in these matters.

(4) Headquarters should take responsibility for setting data standards. For instance, the GIS team expressed interest in having ARC/INFO's shade files standardized.

Region VIII believes that a key factor in ensuring the success of a pilot project is to have a management plan that clearly states the pilot's objectives, the data required, and analyses to be done. Without having a specific end product in sight, program management will find it hard to justify the commitment of resources towards the long term development of GIS.

The GIS team is concerned that CERCLA administrators do not view the usefulness of GIS the same way as they do. While Region VIII is studying GIS applications from a scientific approach in determining the role of GIS in the EPA, the management at CERCLA is driven by the legal process and is more concerned with administrative requirements than the analytical capabilities of GIS. The CERCLA administrators find it hard to see the value in GIS since it does not affect their job responsibilities.

Data

Region VIII's programs require the collection of surface water quality data and air quality data. Much of this data is obtained through informal data sharing arrangements. The approach is to either exchange or buy data bases already in existence and minimize digitizing, since the GIS staff does not have enough manpower to support time-consuming digitizing efforts.

Data sets acquired by Region VIII include:

- STORET data
- Petroleum Information Data Base:
    o Land net (describes congressional townships)
    o Hydrography data (stream, lake, and reservoir traces)
    o Roads
    o Political boundaries
- Air quality data
- Ecoregion boundaries
- State and County boundaries
- USGS Hydrologic Cataloging Units
- Geology
- Ground water vulnerability
- Location of CERCLA/RCRA sites

A factor critical to the success of Region VIII's demonstration study of impairments to aquatic life in Colorado has been the commitment to developing and acquiring high quality documentation. Region VIII's thorough documentation of data sources acquired (i.e., STORET data and Petroleum Information Data Base) as well as map products developed (i.e., Aquatic Life Use Map) has permitted the study's objectives to be more easily understood and analyzed.

It was mentioned by both Region VIII's program and GIS staff that the quality of the locational data Region VIII has acquired varies from acceptable to poor. Only after the data has been plotted out can the staff verify the locational accuracy of the data. Since the effectiveness of GIS requires accurate locational information to be included in a data base, the issue of correcting this data must be addressed.

GIS is used as a quality control/assurance device at Region VIII. Staff are able to download data from the VAX, make any necessary corrections, and return it to the VAX in a more improved version. It was suggested that QC/QA of this type could be best utilized during the lengthy time the data base is being developed for GIS analysis.

There is a wide disparity of time and costs between the collection/preparation of the data and the actual analysis of the data. Region VIII estimates that ten times more money is spent

collecting data than analyzing it. The preparation (i.e., cleanup) of the data is considered the most time-consuming element of Region VIII's data base development.

Region VIII is acquiring data from sources such as the Soil Conservation Service, the Bureau of Land Management and the Forest Service. The program staff has expressed concern over the resource commitment necessary from Region VIII to keep this data current. Moreover, the GIS team recommends taking a regional approach towards data collection. They desire to acquire data that can be used for more than one project.

Staffing

The core GIS team at Region VIII consists of three environmental experts who have both experience with EPA programs and expertise with computer technology. The staff has a high degree of technical expertise in areas such as engineering and statistics. In addition, the team is augmented by another EPA staff member who devotes fifty percent of his time towards GIS applications.

Due to Region VIII upper management's decision to commit additional FTEs to the GIS program, the GIS team will eventually consist of five ARC/INFO experts who will work with ARC/INFO on a full-time basis. The GIS team stressed that these additional positions will be filled by either Environmental Scientists or Geographers with GIS skills, since their knowledge of program areas is crucial to GIS application development. The GIS team believes it is much easier for an Environmental Scientist to develop expertise in ARC/INFO than it is for an ADP expert to develop expertise in EPA program areas.

Region VIII has found great use for a GIS manager who, in addition to understanding EPA policy and programs, has a strong knowledge of GIS. This individual has greatly facilitated the use of GIS with program management's decision-making process through his ability to understand how GIS may be integrated with the overall EPA program.

The GIS team has expressed interest in initiating a personnel rotation plan in which individuals from other divisions (i.e., Water Division, Air Division) will spend several months with the GIS staff. The benefits of this plan are:
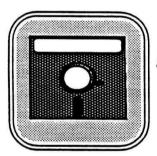
1) The GIS team will gain the expertise of the rotated staff.

2) These individuals will learn about GIS and ARC/INFO and bring this knowledge back to their divisions.

Interest has also been expressed in developing a personnel rotation plan with several Region VIII states that are working with GIS. The benefits the GIS team hopes to gain by this collaboration are:

1) The possibility of developing GIS projects with the states.

2) The chance of a more extensive data sharing network.

The GIS team also sees a need for a staff cartographer. They believe that while information on a GIS map will be correct, the complexity of the information might tend to confuse the viewer. A cartographer's skills could be utilized to arrange the map's information in a more presentable form.

The need to acquire staff at a lower level to perform many routine tasks for GIS projects, or to contract out the lower level jobs, was also mentioned. By having other individuals do digitizing and handle some data collection responsibilities, the GIS staff can devote more of their time to the creative and analytical tasks of GIS projects.

 Software

Both the program and GIS staff at Region VIII view ARC/INFO as a successful GIS package. Region VIII has been using ARC/INFO since the Spring of 1988 through remote access to RTP in North Carolina, and plans to acquire from OIRM an on-site system in FY89.

Region VIII still has a great deal more to learn about ARC/INFO and is getting much support from RTP. The GIS team is generally pleased with the quality of support they are getting from RTP. However, due to the relative unfamiliarity of GIS among program staff at Region VIII, ARC/INFO is still in the process of finding its "niche" among the different EPA programs.

The GIS team is utilizing all ARC/INFO modules except NETWORK. They also desire to have EMSL-LV develop user-friendly, menu-driven applications for Region VIII's managers through the use of AML.

Converting data bases from different sources (i.e., River Reach File, Petroleum Information Data Base, etc.) into the ARC/INFO format has been a relatively straightforward process, with the only constraint being the occasionally lengthy amount of time required for such conversions. The GIS team also sees the need for EPA Headquarters to standardize ARC/INFO's shade files so that the different EPA Regions will be consistent in their selection of thematic shading.

Region VIII has used ARC/INFO's LIBRARY function (which allows for efficient data maintenance and organization) in the development of its data base. Through this function, the state of Colorado data base, for example, can be retrieved by County, by ecoregion, or by hydrographic basin. These parts of the data base can be analyzed and mapped as well. Region VIII considers the LIBRARY feature to be an integral part of its data base development.

Hardware
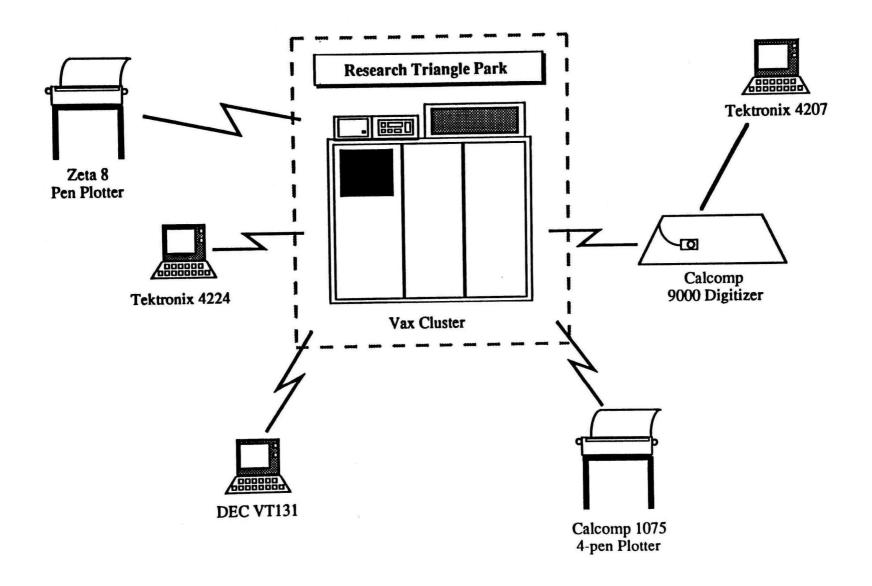
As shown in Figure 6, Region VIII's current hardware configuration consists of Tektronix graphics terminals, a Calcomp digitizer, Zeta 8 and Calcomp pen plotters, and other supporting peripherals connected via telecommunications to RTP's VAX cluster.

When Region VIII installs ARC/INFO on-site in FY89, its use of GIS will increase and hardware upgrades will be required. There is presently a need for an electrostatic plotter as well as Tektronix emulation boards so that staff may utilize PCs for ARC/INFO applications.

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Figure 6

Overview of Region VIII GIS and Related Computer Systems

Research Triangle Park

Vax Cluster

Zeta 8
Pen Plotter

Tektronix 4224

DEC VT131

Tektronix 4207

Calcomp
9000 Digitizer

Calcomp 1075
4-pen Plotter

Constraints

Several constraints are seen as impacting future GIS work in Region VIII:

(1) **GIS projects have not addressed enforcement and regulatory concepts:** Region VIII believes that its current GIS applications are not being developed from a regulatory point of view, but instead are being developed from a planning agency point of view. Without developing GIS applications that are uniquely representative of EPA, Region VIII believes that successful GIS applications will be limited at EPA.

(2) **Need for upper management support:** Insufficient resources have been a major constraint for the GIS team. However, upper management's recent decision to commit additional FTEs for GIS has demonstrated the growing management support for GIS at Region VIII. Upper management support and the availability of adequate resources are essential during the data base development stage in which Region VIII is involved.

(3) **EPA Headquarters should take a more supportive role in Regional GIS implementation:** OIRM should provide support for such GIS issues as:

    a. Organizing Regional communications;
    b. Organizing responsibilities between Regions and EPA's research laboratories at Las Vegas and Corvallis;
    c. Providing resources for Regions in terms of FTEs and contract dollars; and
    d. Setting data standards on a national scale.

(4) **Quality of acquired locational data varies:** Both the program and GIS staff have expressed concern that the quality of the locational data they have acquired varies from acceptable to poor. In most cases, the accuracy of the data can only be verified after the data has been plotted. Poor or missing locational data prevents GIS from being useful for regulatory work, and acquiring these accurate locations requires a time-consuming, but necessary, effort.
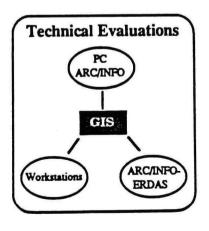
Conclusion

GIS at Region VIII has been implemented successfully in several pilot projects. This success has been due to Region VIII's program staff *initiating* a collaborative effort with the GIS team, and the program staff's ability to see GIS as a useful communications tool. Other important factors include a core GIS team with experience in EPA programs and expertise in computer technology, and a GIS manager who has both an understanding of EPA policy and programs as well as a strong knowledge of GIS. The evolution of GIS from pilot stage to production, however, will require GIS projects with more focus on enforcement and regulatory concepts, continued support from upper management and EPA Headquarters, and better locational data in EPA data bases.

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EMSL-LV: EPA's GIS Center of Excellence

Demonstration Projects

Macro Site Analysis

Clark Fork River NPL Site

Ground Water Modeling and Human Exposure Assessment

San Gabriel NPL Site

Contaminant Pathway Analysis

Commencement Bay NPL Site

Air Quality Analysis

Denver Brown Cloud

- GIS Data Base Development
- Integrating Other Technologies With GIS
- Developing Techniques for Applying GIS

Regional Support

Technical Evaluations

PC ARC/INFO

GIS

Workstations

ARC/INFO-ERDAS

GIS Technical Memoranda

EXECUTIVE SUMMARY

The Spatial Analysis Laboratory of the Environmental Monitoring Systems Laboratory at Las Vegas (EMSL-LV) is EPA's GIS Center of Excellence. EMSL-LV conducts geographical research, performs environmental analyses, and develops advanced geoprocessing techniques and technologies for the benefit of Agency research initiatives and regulatory programs. EMSL-LV transfers this knowledge and expertise to EPA Regions and programs through demonstration projects, technical assistance, and technical memoranda.

EMSL-LV conducts a wide range of projects and other activities, which include but are not limited to the following examples:

GIS DATA BASES FOR NPL SITES: EMSL-LV is building GIS data bases for several NPL sites that will be used for many years for remedial and cleanup work.

INTEGRATING OTHER TECHNOLOGIES WITH GIS: Several of EMSL-LV's projects are integrating GIS with data obtained from other technologies, such as remote sensing, photogrammetry, and LIDAR (a type of laser that measures back scatter from particulates in the air).

DEVELOPING TECHNIQUES FOR APPLYING GIS: Examples of work for which EMSL-LV is developing GIS techniques are contaminant pathway analysis and air pollutant exposure assessment.

REGIONAL SUPPORT: EMSL-LV has provided technical support to EPA Regions I, III, and VII for their GIS projects.

TECHNICAL EVALUATIONS: EMSL-LV is performing technical evaluations of PC ARC/INFO, GIS workstations, and data transfer algorithms between ARC/INFO and ERDAS.

GIS TECHNICAL MEMORANDA: EMSL-LV has produced a technical memorandum on "GIS Project Planning and Data Set Selection" and has other memoranda in draft on Digital Line Graph processing, ARC/INFO one-to-many relationships, population enumeration methods, TIC reference system standards, and global positioning systems.

EMSL-LV's success to date has been based on the skills and expertise of its staff. EMSL-LV's ability to fulfill its mission as use of GIS spreads throughout EPA depends on two key factors:

o Base funding for GIS research that is not tied to specific programs; and

o More EPA FTEs that are trained in GIS and ARC/INFO.

GIS at EMSL-LV

As part of EPA's Office of Research and Development, the Environmental Monitoring Systems Laboratory at Las Vegas (EMSL-LV) is EPA's GIS Center of Excellence. The Spatial Analysis Laboratory (SAL), which is under EMSL-LV's Remote and Air Monitoring Branch, is the organizational unit where GIS research is conducted. SAL's primary purpose is to investigate, develop, and integrate spatial information systems into the mission of EPA. At the present time, SAL is conducting research into both remote sensing and GIS.

SAL's mission includes the following tasks:

- Advance GIS and remote sensing research to meet EPA needs;

- Provide advice to EPA Headquarters on GIS policy;

- Provide technical support to the ten EPA Regions; and

- Provide technical support to EPA programs such as CERCLA, RCRA, Water, EMAP, etc.

Much of SAL's work is done through demonstration projects for specific sites. Because these projects are a major vehicle for SAL's GIS research, the benefits of SAL's site-specific approach extend beyond the immediate benefits to a particular site. The GIS knowledge gained by SAL through demonstration projects, as well as from its other research activities, is transmitted to the rest of EPA through technical memoranda, recommended standards and procedures, and advice and support provided to EPA Headquarters, Regions, and programs. The

Regions for which SAL is conducting demonstration projects also receive much informal GIS training and technology transfer through these projects.

GIS work at EMSL-LV uses ARC/INFO, which resides on a VAX 11/785 and was originally installed in 1985. SAL GIS staff consist of one EPA employee, who is the manager of SAL, and ten contractors from Lockheed Engineering and Sciences Corporation.
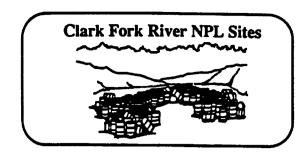
Because the GIS work conducted by SAL at EMSL-LV is quite extensive, four projects have been selected to be described in detail. These projects, which have been chosen as representative of EMSL-LV's work, are as follows:

- Clark Fork River NPL sites
- San Gabriel NPL site
- Commencement Bay NPL site
- Denver Brown Cloud

For these projects, EMSL-LV is either building GIS data bases for NPL sites, integrating other technologies with GIS, and/or developing techniques for applying GIS.

After describing the four projects, a brief summary is given of other GIS activities at EMSL-LV that are being done by SAL. These are grouped into four categories:

- Other projects
- Regional support
- Technical evaluations
- GIS technical memoranda

Clark Fork River NPL Sites

The Clark Fork River NPL site in Montana, which actually consists of four NPL sites, is one of the largest NPL areas in the country. With its 150 river miles and over 100 years of copper mining, the site will require massive investigative and cleanup efforts. The site involves numerous environmental problems, many of which are related to contaminant migration of heavy metals.

The project was initiated by EPA's Montana Operations Office in Helena. Staff at this office felt that GIS may be a useful technology to apply to the Clark Fork River site but had no knowledge about how to apply the technology. The Montana office sought EMSL-LV's help in formulating a work plan and in designing and building a GIS data base.

The project soon became a joint effort involving EMSL-LV, EPA's Helena office, the Montana State Health Department, the Montana State Library, and the Montana Governor's Office. EPA's Region VIII office also has an advisory role in the project. With this many offices involved, as well as four NPL site officers, the project has required much coordination among the various parties. Because real clients are being served by the project, EMSL-LV considers its work on the Clark Fork River site as a production project, as opposed to a demonstration project.

The project began in the summer of 1987 with the first work plan being developed in November, 1987. Because the various Montana offices had little knowledge of GIS, EMSL-LV played a major role in educating these offices in how GIS could be applied to

the Clark Fork River site. As these offices became more knowledgeable about GIS through EMSL-LV's efforts, they began to modify the project objectives. To accommodate these changing requirements, EMSL-LV initiated a second round of scoping meetings for the project, beginning in September, 1988.
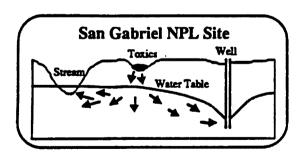
The focus of the project involves using GIS in macro site analysis and as a support to monitoring activity. For the longer term, GIS will be used as a tool to augment the remedial investigation/feasibility study (RI/FS) process for the site. Because the site has so many environmental problems that overlap spatially, GIS is viewed as the best method to characterize the nature and extent of these problems in a remedial investigation. It is anticipated that the data base that is being built may be used for twenty years in support of a broad range of activities at the site.

EMSL-LV's role in the project has been one of educating other offices in the application of GIS, assisting these offices in formulating a work plan, and designing and developing a GIS data base. Because the other offices had no prior GIS experience, EMSL-LV took the lead in the operational component of the project as the offices learned about the technology. As part of its data base development work, EMSL-LV has digitized coverages for the data base. The GIS data base that is being developed and the copy of ARC/INFO being used for the project reside on the Montana State Library's PRIME computer.

EMSL-LV anticipates that its role in the project will continue for three to five years. After the data base has been completely developed, the data base will be turned over to the state of Montana for ongoing use with the Clark Fork River site.

EMSL-LV has taken questions that have arisen from the Clark Fork River project and has used other research funding to expand its

GIS knowledge. Useful benefits from EMSL-LV's research will accrue in the following areas:

• The Clark Fork River project has necessitated the development of efficient production routines for batch processing of Digital Line Graphs. With another source of funding, EMSL-LV is translating this knowledge and experience into a technical memorandum for EPA.

• The project is increasing EMSL-LV's understanding of how to apply GIS to the RI/FS process for Superfund sites. This understanding will help EMSL-LV to develop models and data processing techniques that may be used at other Superfund sites.

• With numerous operable units involved in the project, the project is a challenge for developing methods for charging for the costs of data base development. Methods that are designed to handle charging may be applicable to other projects with multiple chargeable units.

• The project is a good test arena for developing EPA/state relationships for joint projects.

San Gabriel NPL Site

The San Gabriel Basin project is EMSL-LV's first and most mature GIS project and is closer to being used for remedial work than any other EMSL-LV project. The work was originally undertaken as a demonstration project at the request of EPA's Office of Emergency and Remedial Response and Region IX. Because the demonstration phase was successful, the work has evolved into a project for technology transfer of a GIS data base to Region IX and CH2M-Hill, a contractor for Superfund work at the site.
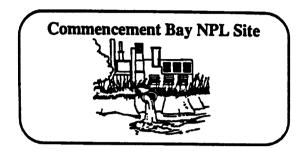
The purpose of the original demonstration project was to investigate the utility of GIS in support of regulations for environmental monitoring and recovery. This was done by examining the use of GIS in risk assessment and by interfacing GIS with a ground-water flow model. A GIS data base was developed from existing data provided by Region IX and its contractors. By overlaying water districts with contaminated wells and population, an assessment could be made of potential risks from contaminated wells.

The GIS also was used to prepare aquifer data for input to a ground water flow model. The model estimated flow pathlines from contaminant sink to potential source. Model outputs were also mapped with the GIS.

With the successful completion of this demonstration phase, work has begun on development of a detailed data base for the San Gabriel site. EMSL-LV is playing a major role in this effort, which is scheduled for completion in FY 89. A copy of the data base will be transferred to CH2M-Hill, who will use the data base for three-dimensional ground water modelling. Over the long term the GIS data base will be incorporated with a management information system to track cleanup efforts at the San Gabriel site.

EMSL-LV's work in developing the San Gabriel data base will feed directly into its work to use the data base for quality assurance research for GIS. By being involved in the data base development, EMSL-LV will have much better information on the quality of data that comprises the data base. It is anticipated that the quality assurance work will continue well beyond FY 89, since little work has been done in EPA in addressing the critical issue of

quality assurance for GIS. EMSL-LV plans to produce an EPA GIS quality assurance document from its work with the San Gabriel data base.

EMSL-LV's work with the Commencement Bay NPL Site is an example of a demonstration project that has become a useful Superfund site application. This transition has occurred because the demonstration project has shown to the Superfund site manager the utility of GIS. The site manager already understood the advantages of using a relational data base management system for analysis. EMSL-LV's work demonstrated the power of combining a relational data base with a GIS that could produce high-quality maps.

The demonstration project was initiated by EMSL-LV in early 1988. Commencement Bay is a NPL site near Tacoma, Washington. Tetra Tech, a Superfund contractor, had developed a Knowledgeman data base of attribute data for the site. With the assistance of the Superfund site manager, EMSL-LV obtained the Knowledgeman data base from Tetra Tech and also acquired data on potential sources of contamination and fish and water samples. EMSL-LV used this data, in addition to data purchased or digitized by EMSL-LV, to build an ARC/INFO data base.

EMSL-LV originally intended to do some simple overlays of drainage, suspected waste sites, and population to provide a general view of population at risk in the Commencement Bay area. This work expanded when EMSL-LV obtained a map of drainage pipelines and open channels near the Bay's shore from the Tacoma - Pierce County Health Department. By using ARC/INFO's NETWORK module, the segments of the drainage network contributing to an outfall in the Bay were identified. A map of selected outfalls and the associated drainage network was produced.

A digital parcel data set was also obtained from the city of Tacoma and was incorporated into the GIS data base. By examining concentrations of contaminants at outfalls and the associated drainage, parcels that contribute to that drainage could be identified. The data for these parcels could in turn be used to identify potential contributors of contaminants.

EMSL-LV plans to share data from this project with Tacoma and to provide both Tetra Tech and other EPA offices with maps of parcels relative to the drainge system. The Superfund site manager has also expressed interest in obtaining a copy of the GIS data base for subsequent use.

Although EMSL-LV's role in the project will end with the completion of maps and sharing of data, the project has demonstrated the power of GIS in contaminant pathway analysis. Because the project was originally designed as a demonstration project, minimal time was spent on quality assurance for the data. EMSL-LV hopes that detailed site monitoring will be done to obtain better quality data related to potential polluters identified through the project. Better quality data would be required for legal actions against the polluters.

The image of Denver Brown Cloud map is an image.

Denver Brown Cloud

EMSL-LV and Region VIII initiated the Denver Brown Cloud project to examine the feasibility of integrating LIDAR data with GIS. LIDAR, which refers to Light Detection and Ranging, is a laser technology which records as a digital signal the back scatter from particles or other substances reflecting a laser beam. Locational coordinates for the laser are also recorded for the LIDAR measurements.

Because the back scatter from LIDAR may be due to factors besides particulates in the air, the Denver Brown Cloud project will attempt to correlate LIDAR values with particulate values as measured by ground monitoring stations. For the correlations, the particulate measurements from the ground monitoring stations will be regarded as "truth." If correlations indicate that LIDAR values are hightly correlated with ground monitoring station values, then LIDAR and GIS may be used as a technique to model atmospheric particulates. The "Brown Cloud" over Denver is being as the test area for this project.

The project was begun in May, 1988. LIDAR data have been obtained from transects flown at various altitudes. EMSL-LV has mapped and contoured LIDAR values with ARC/INFO. The ARC/INFO TIN module has been used to create surfaces of LIDAR data. The efforts to correlate LIDAR with ground monitoring data should be completed in FY 89.

A second major effort of the Denver Brown Cloud project involves the development of a methodology for air pollutant exposure assessment. As part of an initial effort, LIDAR values from thirty meters elevation over Denver were grouped into nine ranges. The spatial distribution of these ranges was then mapped. Census tracts were digitized from 1:24,000 maps, and population data by census tract and age/sex categories were obtained. The numbers of persons for specific age/sex categories were then overlaid with the ranges of LIDAR data as a preliminary assessment of populations at risk from particulate pollution. If LIDAR is validated as being a good measure of particulate pollution, LIDAR readings taken at various elevations could be overlaid through GIS with a variety of population and health statistics to assess health risks from particulate pollution. At a minimum, the techniques developed are directly applicable to future studies with calibrated LIDAR systems.

Other Projects

In addition to the four projects described in the preceding pages, EMSL-LV is conducting or has completed several other projects, which are summarized below.
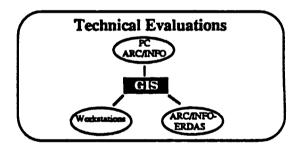
• EMSL-LV will assist Region VI with a pilot GIS project involving the Pearl River Basin in Louisiana. The work for this project, which is in the preliminary stages, will be done at EMSL-LV.

• For Region VIII, EMSL-LV will map point and nonpoint pollution sources for Lake Pend Oreille. This work will be part of a management information system built to monitor nutrient contributions to the lake's pollution problems over the long-term. Watershed models may be integrated with the GIS. At the present time, this project is in the

scoping stage, with a work plan to be developed next.

• For Region IX, EMSL-LV is developing maps of aquifer vulnerability for Fresno County, California, using the DRASTIC index. These maps will identify values of relative ground water pollution potential for Fresno County. From this work, wellhead protection areas may be defined.

• EMSL-LV will integrate remote sensing data with GIS in development of a management information system for Puget Sound. This project, which is being done for Region X, will focus on intertidal habitat analysis and habitat exposure assessment.

• EMSL-LV used photogrammetric data in developing a data base for the Old Southington Landfill NPL site in Region I. This project, which was conducted as a pilot for the Office of Solid Waste and Emergency Response, was designed to demonstrate the feasibility of using GIS with photogrammetric data for micro site analysis of a Superfund site. The project also used GIS to assess risk from exposure to landfill contaminants.

• For the Office of Toxic Substances, EMSL-LV developed the Environmental Methods Testing Site (EMTS) data base for the Chattanooga area. EMSL-LV hopes to use this data base in its work with population enumeration methods, exposure assessment models, hazard ranking automation, and design of GIS data bases and users interfaces. The EMTS data base has already been used as a training data base for ARC/INFO courses taught to EPA.

Regional Support
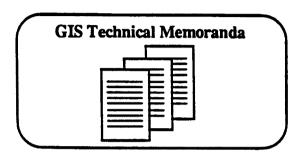
In addition to the projects for specific Regions described in the previous pages, EMSL-LV has provided GIS support to Regions I, III, and VII. This assistance has included on-site support for Regions I and VII, development of custom tools for Region I (e.g., tape management libraries, command libraries, symbol tables), review of documents on pilot projects, and assistance in designing GIS data bases. Through this work EMSL-LV assists in the integration of GIS technology throughout EPA as well as supporting regional projects.

Technical Evaluations

PC ARC/INFO

GIS

Workstations   ARC/INFO ERDAS

EMSL-LV is conducting the following technical evaluations for the Office of Information Resources Management:

• PC ARC/INFO: EMSL-LV is evaluating the usefulness of PC ARC/INFO, its utility in the Regions, and interfaces with mini-based ARC/INFO.

• Workstations: EMSL-LV is evaluating the Sun, Tek, and VAX workstations and interfaces between the workstations and mini-based ARC/INFO.

• ARC/INFO-ERDAS/ELAS: EMSL-LV is investigating data transfer algorithms between these two technologies, which would involve the combination of vector and raster data.

GIS Technical Memoranda

To disseminate the knowledge that it gains through its demonstration projects, support to EPA Regions and programs, and other research, EMSL-LV plans to publish a series of technical memoranda. To date, the topics of published and draft memoranda are:

• "GIS Project Planning and Data Set Selection", published as GIS Technical Memorandum 1-88

• "Processing Digital Line Graphs", draft

• "One-to-Many Relationships in ARC/INFO", draft

• "Methods for Population Enumeration Using a GIS", draft

• "TIC Reference System", draft

• "Global Positioning Systems", draft

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Implementation Issues

Management/ Communications

As EPA's GIS Center of Excellence, EMSL-LV is responsible for numerous areas of GIS research, including GIS data base design and data standards, spatial data processing techniques, quality assurance/control methods for GIS, interfaces between remote sensing and GIS, evaluation of GIS workstations, use of photogrammetric products, use of GIS with the remedial investigation/feasibility study process, etc. Since EMSL-LV's base funding is obtained from the CERCLA and RCRA programs, the objectives of its research must be designed to meet the specific needs of CERCLA and RCRA. Funding from EPA Regions and from other programs also must be spent in direct support of those units' needs. However, GIS is a technology that cuts across all EPA programs. Since all programs utilizing GIS benefit from the improved methods and knowledge gained by EMSL-LV's research activities, EMSL-LV needs to have a source of base funding for GIS research that is not directly tied to a specific program. Such a pool of funds would allow EMSL-LV to proceed with needed GIS research without restrictions imposed by specific program requirements.

Besides its function as a GIS research unit, EMSL-LV fulfills a GIS educational role as it provides support to EPA Regions and offices. As EMSL-LV gives advice to Regions and assists Regions with demonstration projects, informal GIS training and technology transfer occur. At the time of this writing, EMSL-LV has provided the funding that allows its staff to support Regions I, III, and VII and will continue to support all Regions.

In addition to its research and technology transfer functions, EMSL-LV views its role as being one of oversight for GIS development within EPA, not as being a production shop. EMSL-LV wants to assist offices in developing GIS data bases, which are then turned over to the offices for day-to-day analyses.

EMSL-LV has adopted a site-specific approach for its demonstration projects through which it conducts research activities related to the projects. Because many of these projects involve development of data bases that will be used for many years for site remedial investigation and cleanup work, the projects will result in long-term management decisions as opposed to immediate short-term decisions.
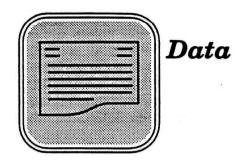
Through its role in conducting demonstration projects and supporting EPA Regions, EMSL-LV is in a unique position to learn about management and planning of GIS projects from much first-hand experience. A key factor that has been learned is the importance of planning a

GIS project. Although clients often need results immediately and do not allow enough time for proper project planning, EMSL-LV has stressed that planning is critical to the success of GIS projects. EMSL-LV has outlined a series of steps for project planning in its GIS Technical Memorandum 1-88, "GIS Project Planning and Data Set Selection."

Key points in project planning that were emphasized by EMSL-LV include the necessity of having clearly defined objectives, users, and a work plan. Those who define the objectives should also be involved in determining the data that need to be captured to satisfy those objectives. This critical step of identifying data for the project is not a task that can be done by the GIS technical staff without consultation with the project's users. A group of users who have participated in definition of the objectives must also review the project periodically. These users will give their approval to various steps of the project implementation and will ensure that work continues to be on the correct track for satisfying project objectives.

EMSL-LV stressed that clients must have a basic understanding of GIS to be able to fully participate in the planning process. As clients become more familiar with the technology and understand how GIS can be applied to their programs, they are better able to conceptualize questions to be answered by the project. At this stage, project objectives often are revised due to the clients' increased knowledge. EMSL-LV has recommended that a second scoping meeting be held approximately six months after the first scoping activity so that project objectives may be refined, if necessary, based on the clients' increased understanding of GIS.

In its project work, EMSL-LV stated that it is often difficult to get Superfund site officers to articulate their requirements or even to devote time to try to identify their needs for support. Since client involvement in project planning is critical to the success of a GIS project, it is imperative that site officers be able to devote sufficient time to working with GIS project teams that are supporting GIS efforts at Superfund sites.

Data

In its role as EPA's research unit for GIS, EMSL-LV has primary responsibility for research into GIS data standards and quality assurance/control. As discussed above, EMSL-LV requires base funding to support these responsibilities, since the results of research in these areas can be utilized by all EPA programs.

EMSL-LV is especially concerned about quality assurance and quality control (QA/QC) for GIS. To date, only modest attention in EPA has been given to GIS QA/QC issues. However, QA/QC will be extremely important when work resulting from GIS applications results in court cases against polluters. EMSL-LV is anxious to develop QA/QC methods for GIS before these methods are needed in support of legal actions.

EMSL-LV has suggested that several different levels of QA/QC may be required to cover the range of work within EPA. At the lowest level, regional demonstration projects would require a minimal amount of QA/QC, whereas legal actions would demand the highest level of QA/QC. EMSL-LV's work in this area would include assessing the appropriate QA/QC methods based on requirements for a specific type of application. Since more extensive QA/QC would presumably consume more resources, adopting the appropriate QA/QC methods based on application requirements is important in terms of obtaining sufficient data quality at acceptable costs.

EMSL-LV's research into QA/QC will include a review in late 1988 of methods that it uses for handling spatial information. As described above, EMSL-LV also plans to use the data base that it is developing for the San Gabriel NPL site for QA/QC research. From these and other efforts, EMSL-LV wants to make recommendations for QA/QC procedures that can be implemented throughout EPA. Future work may include research into statistical tools that can be used to display the accuracy of vector-based GIS maps. This work may involve research efforts with academic institutions.

EMSL-LV has expressed the need for accurate, digital locational data in EPA's data bases. Many of EPA's data bases that have been used by EMSL-LV have been found to lack high-quality locational data. Some locational data are missing, whereas other locational information that does exist is incorrect.

For EMSL-LV's project work, the following types of digital data bases with good locational data are especially needed:

- Soils at 1:24,000; EMSL-LV has indicated that the county soil surveys published by the Soil Conservation Service often are of poor quality.
- Geology
- Landsat land use / land cover data
- STORET attribute data merged with Digital Line Graphs (DLGs) at 1:100,000

Regarding its work the DLGs, EMSL-LV indicated that the coding scheme used by USGS for DLG minor codes is somewhat inadequate. The DLG codes do not include all features needed for EPA's work, and the minor codes are not sorted. To work around the problem of unsorted minor codes, EMSL-LV has written macros in ARC/INFO's ARC Macro Language to extract critical attributes needed by EPA to describe features. EMSL-LV's knowledge gained by its research work with DLGs will be released to the agency in its forthcoming GIS Technical Memorandum 2, "DLG Processing", which is currently in draft.
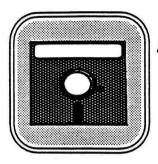
Staffing

EMSL-LV has stated that people are the key to a successful GIS program; hardware and software are secondary to GIS success. A broad mix of people with multi-disciplinary backgrounds in environmental sciences is required for a good GIS staff. Degrees in computer science are not necessary, since individuals with an appropriate background in environmental sciences can learn enough about computers to be able to work effectively with GIS.

The GIS team at EMSL-LV fits this general model in that of the eleven staff members, only two are computer scientists. The other staff members have a broad multi-disciplinary background and include geographers and environmental scientists with various areas of expertise.

As the use of GIS expands in EPA, both EMSL-LV and the Regions require more EPA FTEs for GIS. EMSL-LV wants to provide GIS training beyond the informal "training" that now occurs through its Regional support, but currently does not have a training budget. Since EMSL-LV has acquired and continues to acquire much GIS knowledge and experience through its research activities and demonstration projects, EMSL-LV has a key role to play in GIS training and technology transfer so that others might benefit from its experiences.
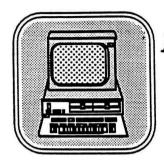
Software

EMSL-LV has used ARC/INFO since 1985 and has achieved a very high level of expertise with the software. Currently, two problem areas with ARC/INFO have been identified involving the TIN module and machine-to-machine interfaces with ARC/INFO. In the first problem area, TIN has been found to be inadequate for contouring irregularly dispersed data in an irregular shape. The contours produced by TIN do not give a good picture of the surface. EMSL-LV wants ESRI to enhance TIN to handle such surfaces better.

In the second problem area, interfaces between different types of computers running ARC/INFO are not particularly easy to use. Although macros written in AML are generally transportable between machines, binary file transfers of ARC/INFO data files are not possible. Data files must be converted to ASCII files before being transferred to another type of computer. This process makes the transfer more complicated and lengthy. Since EMSL-LV has a VAX and the EPA Regions have PRIMEs, the difficulty in machine-to-machine transfers impacts the time required for transfer of data bases developed by EMSL-LV for the Regions.

EMSL-LV needs to develop a standard set of GIS software tools for PRIME computers to augment ARC/INFO. This set of tools would be used by the Regions on their PRIMEs. The tools would include such things as tape management libraries, command libraries, symbol tables, routines for producing the EPA logo, and the like. Some of these tools have already been developed for Region I as part of EMSL-LV's support for that Region.

Development of user interfaces for GIS data bases built by EMSL-LV may be a major role for EMSL-LV in the future. For data bases that are built by EMSL-LV and then turned over to clients for day-to-day use, such as the data base for the San Gabriel NPL site, EMSL-LV may write macros that simplify users' access of the data bases.

Hardware

As shown in Figure 7, EMSL-LV's GIS resides on a VAX 11/785. The VAX, which is adequate for EMSL-LV's needs at the present time, can support a maximum of thirty-five users. Six to eight GIS users can utilize the VAX concurrently with reasonable response times. In the future, EMSL-LV may consider using the VAX as a file server for a series of workstations. No definite plans for such use of the VAX and workstations have been made.

EMSL-LV's electrostatic plotter has been a great asset to the lab's GIS work. With the combination of the expertise of its staff and the electrostatic plotter, EMSL-LV has produced an impressive variety of maps of exceptional quality.

EMSL-LV needs to develop interfaces between GIS and other hardware systems, such as the ground water workstation being used in EPA. After EPA policies are developed for such system interfaces with GIS, EMSL-LV could write appropriate software to easily convert data between these different hardware systems.

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Figure 7

Overview of EMSL-LV GIS and Related Computer Systems

Tektronix 4207 Terminals

Erdas System 2

Color Plotter

Tektronix 4125 Terminals

Tektronix 4111 Terminals

LA-100 Terminal

Decmate III Terminal

Calcomp Digitizer

Tektronix 4209 Terminal

VAX 11/785

(2) Decmate III Terminals (through modems)

Printer

Decmate III Terminals

Versatec Color Electrostatic Plotter

AeroncaVGS-300 plus System

DEC VT220

Printers

IBM PC/AT (PC ARC/INFO)

Printer

Constraints

Several constraints have been identified that affect EMSL-LV's mission as the primary GIS research unit for EPA and as a provider of GIS technical support throughout EPA. These constraints are described below.
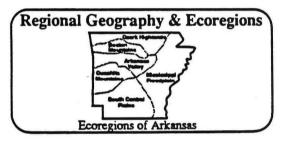
(1) **GIS research funding tied to specific programs:** As discussed under "Management/Communications Implementation Issues," EMSL-LV's base funding is obtained from the CERCLA and RCRA programs. Consequently, the objectives of EMSL-LV's research supported by this funding must be designed to meet the specific needs of CERCLA and RCRA. Since GIS research benefits many programs in EPA, a source of base funding for GIS research that is not tied to specific programs should be provided to allow EMSL-LV to proceed with a broad-based GIS research agenda.

(2) **Number of EPA FTEs supporting GIS:** As the use of GIS expands in EPA, EMSL-LV will require more trained staff to fulfill its mission of conducting GIS research, providing advice to EPA Headquarters on GIS policy, and providing technical support to the EPA Regions and programs. As recommended in Section II, staffing needs for all GIS sites in the Agency should be evaluated carefully in light of current and planned GIS work and steps taken to approve positions and hire staff when necessary.

(3) **Understanding of GIS in other parts of EPA:** A lack of understanding of GIS in other parts of EPA has increased the level of effort required in conducting site-specific projects and in supporting GIS. This situation has been apparent in the problems that Superfund site managers and others have in articulating their needs for projects conducted by EMSL-LV. EPA is taking steps to increase basic GIS knowledge in the Agency through its recent evaluation of GIS training needs. As a training program is implemented with management briefings and courses in fundamental GIS concepts, an overall awareness of GIS and of its uses and benefits should increase in the Agency, thus alleviating this constraint.

(4) **Quality of locational data in EPA data bases:** GIS is a spatially-based technology that requires accurate locational data. Some EPA data bases do not contain complete latitude/longitude data, and the accuracy of some locational data that do exist is questionable. Initial steps that EPA has taken towards addressing this problem are described in Section II. EPA should seek to provide sufficient funding for efforts to improve the quality of location data in its national data bases.
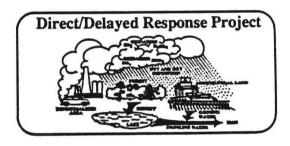
Conclusion
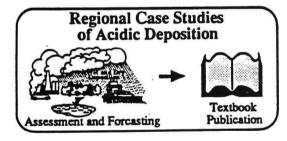
In fulfulling its mission as EPA's GIS Center of Excellence, EMSL-LV has conducted numerous GIS demonstration projects and has given GIS technical support to EPA Regions and programs. From its demonstration projects EMSL-LV has acquired knowledge on the application of GIS to EPA's needs and is transferring this knowledge to others in EPA by providing direct support to GIS users and by issuing technical memoranda.
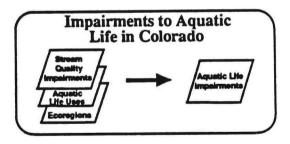
To increase its research in the application of GIS to EPA's needs, EMSL-LV requires base funding to support GIS research that cuts across programs. More staff are also needed to increase the research effort and to support a growing number of GIS users in EPA.

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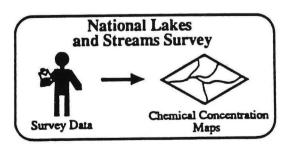
EXECUTIVE SUMMARY

The Environmental Research Laboratory at Corvallis (ERL-C) is EPA's center for atmospheric, terrestrial, and aquatic ecological research. To support its research activities, ERL-C has successfully implemented GIS as a tool for cartographic presentation. GIS-produced maps are used as more than final products from research, for they have become important tools that are an integral part of data validation, analysis, and interpretation.

ERL-C projects that have utilized GIS for cartographic presentation include the following examples:

REGIONAL GEOGRAPHY AND ECOREGIONS: Ecoregions represent an approach to much of ERL-C's research and are being studied for their use in resource management. GIS permits numerous maps to be created quickly for analysis of the spatial distributions of data.

DIRECT/DELAYED RESPONSE PROJECT: This project is examining the long-term response of surface water to continued acidic deposition. Approximately two hundred GIS maps are produced a year for this project.

REGIONAL CASE STUDIES OF ACIDIC DEPOSITION: A textbook-quality publication that assesses and forecasts acidic deposition will include approximately eighty GIS-produced maps.

IMPAIRMENTS TO AQUATIC LIFE IN COLORADO: GIS maps have been used to identify patterns of impairments to streams from metals, sediments, salinity, and nutrients.

NATIONAL LAKES AND STREAMS SURVEY: With data from this national EPA survey, GIS maps show the concentrations of chemicals in lakes and streams.

OTHER PROJECTS: GIS has been used to map Superfund and RCRA sites in relationship to aquifers, to map data from paleoecology work, and to investigate the contribution of road salt to chloride concentrations.

ERL-C's successful use of GIS has been based on the following key factors:

o A critical mass of GIS projects that have supported a sufficient number of GIS staff;

o Management support of GIS and recognition of its value as a powerful communications tool; and

o A staff that is skilled in GIS and in the analysis of spatial data.

GIS at ERL-Corvallis

The Environmental Research Laboratory at Corvallis, Oregon (ERL-C), is EPA's center for atmospheric, terrestrial, and aquatic ecological research. A major objective of much of ERL-C's work is to understand the status and extent of resources at risk from pollutants. Current areas of research are acid rain, ecoregions, tropospheric ozone, wetlands, and hazardous waste.

In conducting its research, ERL-C uses methodologies that contribute to an overall approach focused on ecoregions. These methodologies include regionalization, cartographic presentation, statistical analysis, expert systems, and spatial modeling.
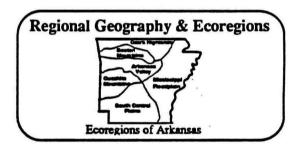
ERL-C has used GIS mostly as a tool for cartographic presentation. Much of the analytical work at ERL-C involves statistical analysis and careful interpretation of data by ERL-C scientists. In support of these efforts, GIS is used for much more than production of final maps for a report. Throughout many projects, GIS maps are produced as an integral part of data validation and analysis. GIS maps are tools that are used by scientists in their visual inspection, analysis, and interpretation of data.

The GIS software used by ERL-C is the ARC/INFO package, which was acquired in 1985 and presently resides on a VAX 8600. The GIS staff at ERL-C consists of twelve contractors from NSI Technology Services Corporation, a subsidiary of Manufacturing Technology International Corporation.

ERL-C's current or recently completed work that has utilized GIS include the following efforts, which are described below:

- Regional geography and ecoregions

- Direct/Delayed Response Project
- Regional case studies of acidic deposition
- Impairments to aquatic life in Colorado
- National Lakes and Streams Survey
- Mapping Superfund and RCRA sites in relationship to aquifers in Region 10
- Mapping paleoecology data
- Relationship between chloride concentrations and road salt

Regional Geography & Ecoregions

Ecoregions of Arkansas

ERL-C's work with regional geography and ecoregions is not just a group of projects, but encompasses an approach to the lab's research activities. A major objective behind this approach is that defining ecoregions is a method of determining homogeneous regions whose natural resources can be managed in the same way within an ecoregion. The ecoregion approach to resource management has attracted much interest, since site-specific management plans are too costly to develop for many sites. Other types of regions, such as watersheds, are often too diverse to permit the same method of resource management to be applied throughout a region.

Traditionally, regions have been defined by looking at the spatial variation of a single

variable. With the ecoregion approach, several variables are examined in defining ecoregions. In a major effort conducted by Omernik of ERL-C, ecoregions for the conterminous United States were defined by comparing the distributions of landforms, soils, land use, and potential natural vegetation. These ecoregions have been the basis of much subsequent work at ERL-C.

In one representative study, fish assemblages, physical habitat data, and water chemistry data for a sample of streams in Arkansas were compared for differences between streams grouped by ecoregions. In general, the values for these variables for streams within the same ecoregion were much more homogeneous than when comparing streams in the same hydrologic units but in different ecoregions. The implication is that other streams within an ecoregion would exhibit the same characteristics and could therefore be managed in a similar way.

For identification of ecoregions, GIS allows ERL-C staff to generate maps "an order of magnitude faster" than using other techniques. ERL-C does not identify ecoregions by putting many different variables into a GIS data base and generating numerous map overlays of those variables. Instead, ecoregion identification is a careful, analytical process that requires much interpretation of data. GIS assists greatly in this effort by enabling numerous maps to be produced that permit scientists to examine and interpret the spatial distribution of data.

ERL-C's work with ecoregions has been extended to defining sub-ecoregions at a state level. State and local resource managers have expressed interest in the GIS-produced maps of these sub-ecoregions for use in resource management. As an example of current ecoregion use, a resource manager in Michigan has used ecoregion maps in conjunction with granting NPDES permits. For lakes in ecoregions with high water quality, permits are granted in a manner that

ensures that the quality will remain high.

In other regional geography work, a map of summer total phosphorus for lakes in Minnesota, Wisconsin, and Michigan was produced with GIS. Regions of summer total phosphorus, which were shown on the map through different colors, depicted a central tendency of total phosphorus. To give a more detailed view of these regions, histograms were also drawn on the map to show frequency distributions of summer total phosphorus in the regions. With the defined regions, summer total phosphorus for areas where there were no sample data points were estimated.

Direct/Delayed Response Project

The Direct/Delayed Response Project (DDRP), which is a subprogram of the National Acidic Precipitation Assessment Project, is examining the long-term response of surface water to continued acidic deposition. This project began in 1984 and is scheduled for completion in 1990. Three areas are being studied in the project: lakes in the northeastern United States and streams in both mid-Appalachia and the southern Blue Ridge. Data from sampled lakes and streams will be statistically extrapolated to predict causes and effects of acidification.
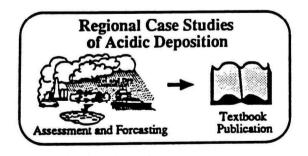
Data are being integrated from a variety of sources for the project, including the following sources:

• EPA's National Lakes and Stream Survey

• Map overlays of soils, vegetation, geology, depth-to-bedrock, and drainage from the Soil Conservation Service (SCS)

• Map overlays of land use, detailed wetlands, and drainage from Lockheed Engineering and Sciences Corporation, the contractor at EPA's Environmental Monitoring and Systems Laboratory in Las Vegas

• U.S. Geological Survey runoff maps and Digital Elevation Models
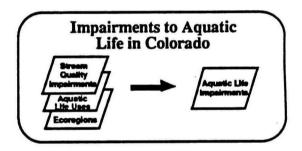
ERL-C conducts extensive quality control checks on the data before adding it to the GIS data base. Detailed comparisions are done between the map overlays obtained from SCS and Lockheed to ensure the accuracy of the data. After maps that are as accurate as possible have been obtained, ERL-C creates digitized versions of the maps with ARC/INFO.

The main use of GIS with the DDRP is for map production. As with ERL-C's ecoregion work, maps permit visual interpretation and analysis of data that supplement extensive statistical analyses. Approximately two hundred maps are produced a year for the DDRP. A wide variety of types of maps are generated, including point location maps, circle maps, contour and/or interpolated maps, and Thiessen polygon maps (i.e., polygon maps extrapolated from randomly distributed sampling points).

Regional Case Studies of Acidic Deposition

Assessment and Forcasting → Textbook Publication

The major objective of the regional case studies of acidic deposition is production of a textbook-quality publication that both assesses

the current status of and forecasts acidic deposition for twelve regions. Eleven of the regions are in the United States, and the twelfth region is in Canada. The book will also extrapolate the findings from the twelve case study regions to other areas that are sensitive to acidic deposition. Chapters for each case study region will be written by experts in acidic deposition in for each region. Most of these experts have acquired their own data sets for use in their case study.
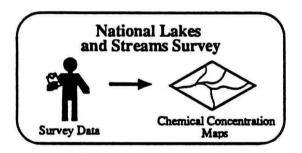
The publication, which is scheduled for completion in spring of 1989, will contain approximately eighty black-and-white maps produced with the GIS. Color maps probably will not be included because of the extra publication cost. To produce black-and white maps for this book, GIS staff at ERL-C have had to be creative in their use of ARC/INFO to compensate for the greater clarity that color adds to maps.

Impairments to Aquatic Life in Colorado

Stream Quality Impairments / Aquatic Life Uses / Ecoregions → Aquatic Life Impairments

In a cooperative effort with Region VIII, ERL-C has used an ecoregion approach and GIS to identify patterns of impairment to aquatic life in Colorado. Region VIII requested ERL-C's help with this project designed to assist in monitoring water quality and setting water quality standards throughout the Region.

Based on ecoregion work done at ERL-C, Colorado was divided into ecoregions and sub-ecoregions. Stream trace data for the state in ARC/INFO format were obtained from the Petroleum Institute in Denver. With ARC/INFO, maps of aquatic life uses and

impairments to stream quality were mapped. Aquatic life uses were mapped as the categories Cold Water Classes I and II and Warm Water Classes I and II. High quality streams were also designated. Impairments to stream quality included concentrations of metals, sediments, salinity, and nutrients. The maps indicated that in many cases, streams within ecoregions have impairments more similar to each other than to streams in other ecoregions.

For this project GIS was used as a tool in support of an ecoregion approach. The maps produced with GIS may be used by water quality managers to identify and manage water resources. Rather than following a traditional approach of managing streams by basin, managers may adopt similar management strategies for streams within the same ecoregion.

National Lakes and Streams Survey

Survey Data → Chemical Concentration Maps

EPA initiated the National Lakes and Streams Survey in 1983 for the following purposes:

- Quantify the present chemical status of surface water in the U.S.;
- Assess the temporal and spatial variablity in aquatic chemistry;
- Define the key biological resources associated with surface waters; and
- Identify temporal trends in surface water chemistry and biology.

The survey will result in lake and stream populations and data upon which long-term studies of trends in chemistry and biological resources can be based.

For this work GIS is being used to produce a variety of maps showing the concentrations of chemicals in streams and lakes. The data collected through the survey are also being used in other projects, such as the Direct/Delayed Response Project described above and studies for smaller areas. GIS is being used as a mapping tool for those projects also.

Other Projects Using GIS

Three other examples of ERL-C projects that have utilized the mapping capabilities of GIS include a project to map Superfund and RCRA sites in relationship to aquifers, paleoecology studies, and a study of the contribution of road salt to chloride concentrations.

(1) In a project to support Region 10, ERL-C produced ARC/INFO maps of Superfund and RCRA sites in relationship to ground water aquifers. Region 10 provided ERL-C with a map of ground water aquifers for the Region as well as locations of Superfund and RCRA sites. Superfund sites were categorized as sites with observed, alleged, potential, and no effects on flora and fauna.

ERL-C digitized the map of ground water aquifers and produced several ARC/INFO maps which overlaid the ground water aquifers, Superfund and RCRA sites, and ecoregions. By incorporating ecoregions into the maps, some indication of attainable surface water quality was given.

(2) In work that is just beginning, paleoecology is being used to infer chemical

concentrations in water in historical times. Initial work in this area has been done using Adirondack Park in New York as a study area. Preliminary analyses indicate that paleoecology is as good as various models in inferring historical water chemistry. GIS-produced maps are used for data display and interpretation.

(3)   To determine whether road salt was a major contributor to chloride concentrations, a study was conducted in the Catskills that used GIS as a mapping tool. Chloride concentrations were obtained from USGS, the Eastern Lake Survey, and the National Stream Survey. When chloride concentrations and the road network were mapped, many of the greatest chloride concentrations were found along major roads. The largest constraint to interpretation of the results was that the digitized road network was from a 1948 USGS base map. Major and minor roads could have changed considerably since that time.

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Implementation Issues

***Management/
Communications***

Two management/communications factors that have contributed to the successful implementation of GIS at ERL-C are:

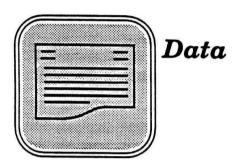(1) A critical mass of projects that has supported GIS, and
(2) Management support of GIS and recognition of its value as a powerful communications tool.

ERL-C has had a sufficient number of projects with adequate funding to support its GIS staff. Four to six persons are regarded by ERL-C as the minimum number of persons needed to have a viable GIS team. Because GIS hardware and software are expensive, support of GIS also requires larger projects with funding that can sustain and support the costs of GIS while staff are acquiring expertise in the technology. Many small projects of short duration do not provide the continuity of support needed during the start-up period of a GIS program. ERL-C has had that critical mass of projects to enable it to develop an effective GIS capability.

An equally important factor in the success of GIS at ERL-C has been management's support of GIS. This support has extended from the laboratory director down through branch chiefs and environmental scientists and has resulted in solid funding for GIS. Scientists have been receptive towards utilizing GIS in their projects where appropriate. Because GIS allows maps to be produced so much faster than by conventional cartographic methods, GIS maps have been used heavily by ERL-C for display and interpretation of data. The powerful communications tool provided by these maps has been one of the major factors that have convinced ERL-C management of the utility of GIS.

ERL-C staff stated that in a well-managed GIS project, all project team members will be included in the planning process for the project. For ERL-C projects, an environmental scientist usually will head a project team, and all staff members working on the project typically attend team meetings. By involving the GIS staff in the ongoing planning for a project, the GIS analysts have an understanding of all aspects of a project, which is important for their work in data selection, validation, and mapping. ERL-C believes that one way to ensure high-quality work is to have effective lines of communication between all persons contributing to a project, and this may be accomplished by incorporating all team members in the planning process. Lines of communication are necessary that extend from digitizers, through GIS analysts and environmental scientists, to upper managment, and down to field crews gathering data.

For some research activities, efforts to acquire funding to support ongoing ERL-C research consume large portions of time. One researcher who has utilized GIS heavily in ecoregion work indicated that he spends from half to three-fourths of his time selling people on the usefulness of an ecoregion approach to get more funds for further research. Because GIS is used as a tool in support of research at ERL-C, limitations on research funding would also impact the extent to which GIS is utilized.

Data

ERL-C has acquired and built numerous data sets as part of its research projects. Examples of some of these data sets are as follows:

- USGS Digital Line Graph data
- EPA's National Lake Survey data base
- EPA's National Stream Survey data base
- Adirondacks Lake Survey Corporation data base
- Watershed maps for 145 Northeast and 35 Southeast watersheds, which include data for: soils
    geology
    depth to bedrock
    vegetation
    land use
- EPA's East Coast emissions data
- Wet and dry East Coast deposition data
- USGS runoff data for the East
- USGS gaging station data

The GIS data bases that are built at ERL-C are project-specific. Rather than incorporating as much data as possible into a GIS data base, ERL-C staff look at the questions to be answered by a project. From those questions, the data needed to obtain answers, and therefore needed for a GIS data base, are determined.

The careful attention devoted to acquiring data extends to the data quality assurance and control (QA/QC) measures taken by ERL-C. Data acquired for a project are very carefully "combed" for errors and inconsistencies before incorporating the data into a GIS data base. It is felt that this effort saves time in the long run, as well as avoiding the problems of creating massive data bases with much unnecessary information or including questionable data in a data base. Project results are sounder by devoting sufficient time to a careful inspection of data.

The importance that ERL-C places on data QA/QC is reflected in every stage of a project. For example, the Direct/Delayed Response Project has a detailed checklist that is followed for inspecting hardcopy map overlays obtained from external sources before those overlays are digitized. For some data, overlays from two different sources are compared to determine their accuracy. The overlays are not digitized until they are as accurate as possible. The process for incorporating the digitized overlays into an ARC/INFO data base is also documented by a checklist that lists every step in the lengthy process. GIS analysts are required to initialize the checklist as each step is completed.

Another example of the effort devoted by ERL-C to data QA/QC is found in the lab's ecoregions and regional geography work. Mapped data are carefully inspected for any anomalies, which are then examined in more detail in an attempt to explain unusual data values. These efforts try to separate erroneous data from unexpected patterns in accurate data. Identifying regions is done only after much analysis and interpretation of the data, as opposed to generating one overlay of many data elements in a GIS data base.

At the same time that ERL-C's regional geography work stresses mental analysis and interpretation of data, ERL-C also recognizes that regionalization schemes must be supported by data that have some statistical basis. Efforts towards this end are another manner in which QA/QC issues are addressed by ERL-C. A very graphical representation of this work was demonstrated in a map of summer total phosphorus for lakes in Minnesota, Wisconsin, and Michigan made by ERL-C. Along with regions that were displayed in color on this GIS-produced map, the map contained numerous histograms of frequency distributions of summer phosphorus sampled from the various regions. These histograms, which also listed the total number of sites for each distribution, described the range of variation of the data and allowed one to place confidence bounds on the data and patterns displayed by the map.

Other issues of data quality that have been raised by ERL-C include the accuracy of Digital Line Graph (DLG) data and of EPA's national data bases. ERL-C has noted that some DLG's show the same density of streams on plains as in mountainous areas. Some measure of quality needs to be recorded for such data, since unequal degrees of detail in a spatial data base make statistical processing of that data difficult.

The poor locational data in some of EPA's national data bases was also cited as a problem impacting the use of GIS. For one study involving the state of Colorado, seventy percent of the locations that were accessed from the STORET data base were incorrect or missing. Such poor quality locational data adds lengthy data verification and/or additional collection tasks to a project.

ERL-C mentioned the need to have good documentation of GIS data bases. Good documentation includes some indication of the data's quality and reliability, as well as information on the data's content, source, and format.
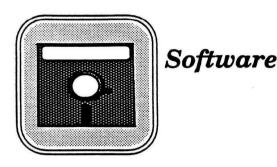
Staffing

The GIS staff at ERL-C consists of twelve contractors from NSI Technology Services Corporation. Six other NSI contractors are involved in geographic research and will be learning ARC/INFO within the next year. The staff members have acquired much expertise in the use of GIS and ARC/INFO and in the analysis of spatial data. Many of the staff are geographers, whereas none have degrees in computer science. The NSI management of the GIS staff stated that teaching geographers enough about computers to be good GIS analysts was much easier than trying to teach computer scientists about geography.

Other characteristics that are needed by a good GIS analyst and that are exhibited by the ERL-C GIS staff include an interest in the actual content of a project, not just in GIS, and a sensitivity to users, which permits GIS analysts to bridge the gap between users and computers. GIS analysts must be good problem-solvers and must be able to think spatially. Since ARC/INFO is a complex package, an analyst also must be self-motivated and be willing to immerse themselves in the package to resolve problems.

To handle its extensive amount of digitizing work, ERL-C is utilizing its geographers for both analytical and digitizing work. It is felt that by using highly trained people to perform digitizing, the quality of the digitizing work is much better. The expertise of geographers allows them to recognize errors in maps that would remain unnoticed by an individual trained only in digitizing. Also, geographers who will be analyzing data at a later stage in a project have a much greater interest in the project itself and have a vested interest in the quality of data that they are digitizing for the project. Since ERL-C has found that errors are introduced into data if an individual spends more than three or four hours a day digitizing, geographers who have many responsibilities besides digitizing are able to intersperse their digitizing tasks with other work. This eliminates data quality problems that may occur with full-time digitizers.

ERL-C staff emphasized the importance of working as a team for a project. As part of a project team, GIS analysts attend team meetings and participate in the project planning process. For GIS staff at ERL-C, functioning as part of a project team is a staffing issue important to the success of a project.

One new type of staff position that may be required to support GIS at ERL-C is an ARC/INFO systems person. This individual would be an expert in the technical issues of implementing ARC/INFO and of graphics hardware. Such a staff person would provide an effective interface with operations staff that maintain the VAX equipment on which ARC/INFO resides.

Software

ERL-C acquired the ARC/INFO software in 1985. ERL-C also has the TIN (Triangulated Irregular Network) module of ARC/INFO for the analysis and display of surface data. Although the lab has expressed interest in the NETWORK module, ERL-C has not acquired NETWORK to date.
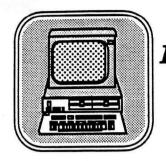
Since much of ERL-C's work involves statistical analysis, SAS is used extensively for projects that also utilize ARC/INFO. Results from regressions or other statistical analyses conducted in SAS are moved into an INFO data base, and the ARC/INFO software is then used to map the results. An automated interface between SAS and ARC/INFO would greatly facilitate this process. Because all of ERL-C's GIS funding is tied to specific projects, however, ERL-C is limited in the work that it can do to develop new tools and procedures that would be useful for many projects.

The GIS staff at ERL-C listed several criticisms of the ARC/INFO software. One of these is the lack of statistical capabilities in INFO. Although this problem has been circumvented by using SAS and importing SAS results into ARC/INFO for mapping, statistical capabilities in INFO would eliminate transferring data between SAS and ARC/INFO for those operations that could be performed easily in INFO.

Another criticism of ARC/INFO mentioned by the GIS staff is that ARC/INFO does not support point mapping nearly as well as polygon mapping. Many of ERL-C's mapping tasks involve the production of point maps that display the locations and values of several types of samples through various colors and shapes of points. To produce the variety of point symbols needed for some maps requires lengthy series of commands. For example, to generate a symbol of a colored square with a dot in the middle of the square required a sequence of eight commands repeated four times.

Because ERL-C frequently maps the results of statistical analyses, the GIS staff would like to display histograms, distribution curves of data, or other graphics on maps to provide additional information on the analyses that were performed. Incorporating these graphics on maps is extremely time-consuming in ARC/INFO, since the package does not have the commands to generate such graphics easily. On maps that ERL-C has produced that include histograms of the frequency distributions of sample data, each rectangle on a histogram had to be drawn individually with ARC/INFO commands.

ERL-C has found that the TIN module of ARC/INFO does not interpolate data well along the edges of an elongated area. The more elongated the area, the poorer the interpolation done by TIN seems to be. Artificial hills and valleys may also be inserted into the interpolated data surface.

Hardware

ERL-C's ARC/INFO originally resided on a VAX 750, which was subsequently upgraded to a VAX 8600 in late 1987 - early 1988. Figure 8 shows the current hardware configuration for GIS at ERL-C. Computer Sciences Corporation manages the ERL-C computer center.
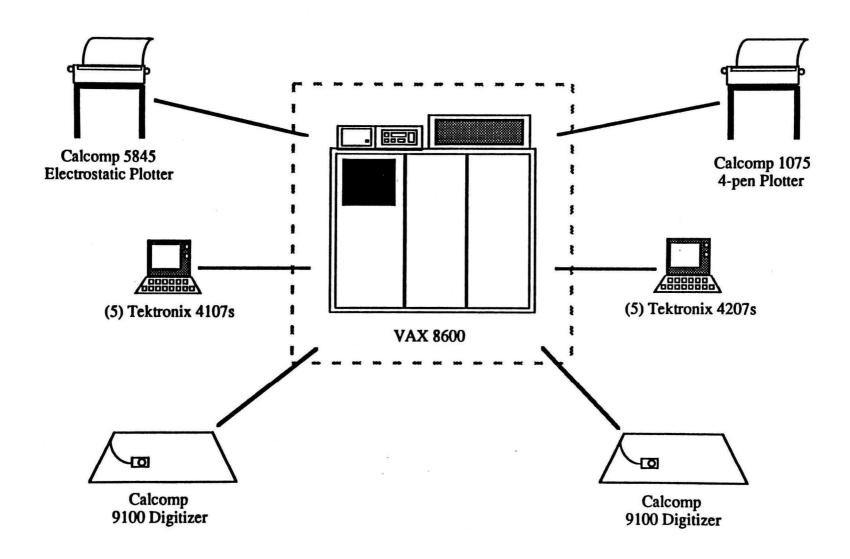
One of the biggest supports to GIS at ERL-C has been the acquisition of an electrostatic plotter. The quality of the maps that have been produced with the plotter and through the expertise of the GIS staff has done more to sell GIS at ERL-C than anything else. The GIS staff has become very proficient in generating maps with ARC/INFO and the plotter and has produced a wide variety of maps of exceptional quality.

The data processing coordinator at ERL-C stated that the hardware resources required by GIS have been consistently underestimated. The need to upgrade the VAX 8600 to a VAX 8650 in the next several months is a real possibility. The difficulty of maintaining sufficient computing capacity for GIS without being overloaded shortly after acquiring a more powerful computer was cited as an ongoing concern in supporting GIS.

For the longer term, ERL-C may need to consider the issue of keeping GIS on a mini or mainframe computer or moving to a workstation environment, in which the VAX would act as a file server. The direction that ERL-C takes on this question will be based on hardware decisions made by EPA for all EPA labs.

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Figure 8

Overview of ERL-C GIS and Related Computer Systems

Calcomp 5845
Electrostatic Plotter

Calcomp 1075
4-pen Plotter

(5) Tektronix 4107s

(5) Tektronix 4207s

VAX 8600

Calcomp
9100 Digitizer

Calcomp
9100 Digitizer

Constraints

ERL-C's GIS program is a well-functioning operation that effectively uses GIS as tool in support of research activities. As discussed in the *Management/Communications* section above, a critical mass of projects that supports a viable GIS team has been one of the major factors contributing to the success of GIS at ERL-C. Projects that have been heavy users of GIS have been well-funded. Such projects must continue to receive financial support to sustain the GIS program at ERL-C.
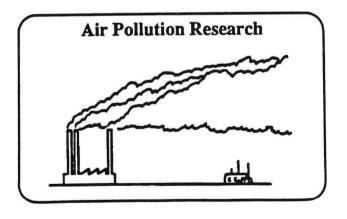
One limitation on GIS work at ERL-C is the lack of funding that can be used to develop GIS procedures and tools applicable to many projects. Because all GIS funding at ERL-C is tied to specific projects, the GIS staff is limited in the extent to which it can develop generalized routines and procedures, such as an ARC/INFO and SAS interface, which would be useful for many projects.

Conclusion

Research activities at ERL-C that utilize GIS are characterized by an emphasis on ecoregions, much attention to data QA/QC and inspection of data, and reliance on a careful, analytical and interpretative approach to regionalization. GIS has been implemented successfully as a tool in support of ERL-C's research and is used mainly as a tool for cartographic presentation. Future directions for GIS at ERL-C will include making greater use of the geographical analysis capabilities of GIS. This direction will not replace the emphasis on careful inspection, analysis, and interpretation of data, but will augment this approach with other methodologies.

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GIS at Research Triangle Park

GIS Technical Support

Air Pollution Research

EXECUTIVE SUMMARY

The National Data Processing Division (NDPD) has developed a GIS Technical Support Group based at Research Triangle Park (RTP) to aid GIS users of the Agency's VAX cluster and other GIS platforms. Four offices at RTP, the Atmospheric Research and Exposure Assessment Laboratory (AREAL), the Office of Air Quality Planning and Standards (OAQPS), the Health Effects Research Laboratory (HERL), and the Environmental Criteria and Assessment Office (ECAO), are involved in a GIS pilot project using GIS to support air pollution research.

GIS TECHNICAL SUPPORT GROUP: The GIS Technical Support Group provides the following types of aid to GIS users of the National Computer Center (NCC):

o Support uses of GIS hardware and software.
o Develop policies for the use of GIS at the NCC.
o Coordinate GIS training held at RTP for local and national users.
o Aid RTP GIS users with project and data base design and implementation.
o Assist NDPD in defining the Agency's future GIS hardware and software needs.
o Assist with GIS data acquisition and storage of national data sets and project specific data sets that will reside on the NCC.

RTP GIS AIR POLLUTION RESEARCH PILOT PROJECT: The pilot project is designed to produce a GIS application that will aid air pollution researchers in evaluating model, monitoring, meteorological, and health statistics data. The pilot project will also evaluate the effectiveness of GIS at integrating, displaying, and analyzing these data in terms of costs and benefits. The major research goals of the pilot are listed below:

o Evaluate the results of the Regional Oxidant Model (ROM).
o Review the effectiveness of control strategies for meeting National Ambient Air Quality Standards.
o Evaluate the relationship of air quality data to mortality statistics.

GIS at Research Triangle Park

GIS Technical Support

The GIS Technical Support Group at EPA's facilities at Research Triangle Park (RTP) was formed in March, 1988, under the National Data Processing Division (NDPD). NDPD also provides GIS technical support in the Washington Information Center (WIC) for GIS users of PRIME minicomputers. The work undertaken by the RTP group includes the following tasks:
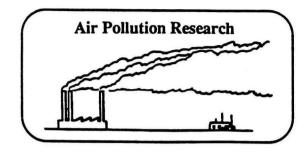
• Provide user support for GIS software and hardware. This support ranges from answering questions about how to use a command in ARC/INFO to how to connect a plotter or digitizer to the network.

• Develop policies for the use of GIS at the National Computer Center (NCC).

• Coordinate GIS training at RTP. NDPD will offer ARC/INFO training courses, as needed, on a cost-recovery basis. The NCC training facility's hardware and software are being upgraded to provide effective support of GIS training at RTP.

• Provide GIS technical expertise for problem definition, data base design, prototyping, and implementation for GIS applications at RTP.

• Assist NDPD in defining the Agency's future GIS hardware and software needs. The GIS Technical Support Group has completed a Scientific and GIS Workstation Evaluation.

• Assist with GIS data acquisition for pilot projects and national data sets that will be stored at the NCC.

GIS work at the NCC uses the ARC/INFO software product, which resides on a VAX 8650 system (VAXB) of the VAX cluster. This software was installed in February, 1988. At the present time, the GIS Technical Support Group consists of two specialists at RTP and one specialist at the WIC supplied by the Unisys Corporation.

RTP's GIS Technical Support Group has provided assistance to Region VIII with its GIS pilot projects, which have utilized the NCC's VAX cluster at RTP. From the NDPD perspective, the pilots were undertaken to evaluate the effectiveness of remote geoprocessing (Denver - RTP). The pilot projects are described as part of the Region VIII case study. The Technical Support Group has also played a major role in a GIS pilot project being conducted by several offices at RTP. The following section describes this RTP pilot.

Air Pollution Research

Four offices at RTP are conducting a joint GIS pilot project to support air pollution research, with particular emphasis on ozone pollution. The four offices participating in the pilot are as follows:

- Atmospheric Research and Exposure Assessment Laboratory (AREAL);
- Office of Air Quality Planning and Standards (OAQPS);
- Health Effects Research Laboratory (HERL); and
- Environmental Criteria and Assessment Office (ECAO).

Staff members and contractors representing these offices have formed a pilot group for conducting the project. The GIS Technical Support Group is also playing a major role in the project by providing assistance to the pilot group throughout the project.

The broad goals of the pilot project are determined by the offices involved with the pilot. AREAL hopes to conduct quality assurance analyses by comparing outputs from the Regional Oxidant Model (ROM) with air quality and emissions data from monitoring stations. These comparisons will be used in evaluating the ROM model. OAQPS plans to assess ozone air quality status in support of the review of National Ambient Air Quality Standards (NAAQS), including analysis of the results of various emissions control strategies. HERL's interests are in examining the relationships of health statistics and pollutants. Both AREAL and OAQPS would like to examine ROM outputs in relationship to population, crop yield, and land use to

determine if air quality controls have made a difference and what future controls may be needed.

The pilot began during the spring of 1988 and is scheduled for completion during late spring of 1989. The initial phase of the pilot study involved defining the scope of the project and reducing the amount of source data considered for use in the pilot. The need for the data reduction phase occurred because of the vast amount of air monitoring, modeling, and emissions data and the limited scope of the pilot project. The geographic extent of the pilot was restricted to the northeastern United States between latitudes 38 and 45 degrees north and longitudes 69 and 84 degrees west. Temporally, the pilot study was limited to a fifteen-day period from July 12 to July 26, 1980.

The second phase of the pilot involved detailed project design. A draft design document has been completed, and the pilot group is currently involved in coding the application and in prototyping.

Nine types of data files will be included in the system. These include:

- ROM predicted data
- Point emissions data
- Area emissions data
- Biogenic hydrocarbon emissions data
- Reactive hydrocarbon emissions data
- Air quality data
- Population and census data (1980)
- Land use data
- Meteorological data

The completed air pollution research system will contain three major software modules. The first module is a data management and retrieval system that will use a data control file to record all data that have been loaded into the system. Users will query this data base to identify what data are currently available. A staff person has been assigned to act as data base manager. She will

manage the data control file and coordinate the loading of new data into the pilot data base. Because model runs produce hourly results, the data control file will encompass a large number of data sets.

The second software module is a series of interfaces to the data bases and model output files that generate data sets and update the data control file. Loading new data into the system requires significant batch processing on both the IBM and VAX systems at the NCC.

The third software module is the user interface. This menu-driven interface will provide researchers with the ability to:

- List available data sets
- Request that new data sets be loaded
- Generate reports and queries
- Generate map displays
- Perform geographic analyses

The interface has been designed for use by researchers who have no training in the use of ARC/INFO and minimal training in using the pilot project's air pollution research system.

The GIS-related objectives of the pilot project include the following:

- Evaluating the effectiveness of the Triangulated Irregular Network (TIN) software for the surface modeling of air pollution data;
- Evaluating the cost/benefit of GIS for air pollution research;
- Developing inter-lab/office communications and data exchange;
- Developing existing staff's GIS skills; and
- Refining procedures used in GIS project design.

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Implementation Issues
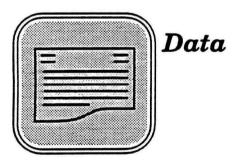
Management/ Communications

Two major factors have contributed to the successful implementation of GIS at RTP:

(1) The development of a GIS Technical Support Group at the NCC has provided a central focus for training and technical consultation for the offices and laboratories at RTP.

(2) Many of the offices and laboratories at RTP are engaged in applications and research that are spatial in nature and benefit from the introduction of GIS technology.

The RTP GIS Pilot Group was formed to introduce interested offices and laboratories to GIS technology. The pilot project has proven to be an effective tool for promoting communications among groups, developing in-house GIS expertise, and evaluating the effectiveness of GIS for each program.

Data

The GIS data sets that are stored at the NCC include data used for both the RTP GIS pilot project and the Region VIII pilot. Additionally, some base map information has been stored at the NCC. Refer to the Region VIII case study and to the description of the RTP pilot above for summaries of data used by these pilots.

The NCC will be acting as a repository for GIS data for EPA. These data will be available to GIS users of the NCC. Current plans call for the storage of a PRIME version of these base

data at the WIC and a VAX version of these data on the VAX cluster at RTP. At present, these nationwide data sets, not listed previously, include:
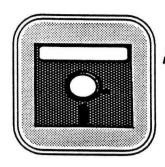
> 1:2,000,000 national, state and county boundaries (DLG composite)
> National ZIP code boundary files

Much additional work is needed to determine which data sets should be available through the NCC. An Agency standard data dictionary for GIS coverages must be developed Additionally, edge matching and quality assurance criteria for each data layer and data scale must be developed.

Staffing

The GIS Technical Support Group consists of two contractors at RTP and one contractor at the WIC from the Unisys Corporation. The RTP GIS pilot project staff includes the following EPA employees and contractors from the offices involved with the pilot: two EPA and one Computer Sciences Corporation (CSC) contract employee from AREAL, two EPA and two CSC contract employees from OAQPS, two EPA employees from HERL, and one EPA employee from ECAO. Most of these employees are involved with the project on a part-time basis.
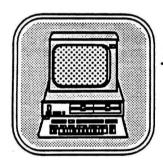
Software

NDPD acquired ARC/INFO and the NETWORK module for the VAXB in February, 1988. ESRI, the vendor of ARC/INFO, did not provide a working copy of the TIN module to the NCC until late in June, 1988. The GRID and Coordinate Geometry (COGO) modules were added in late October, 1988. The batch driver was modified to accommodate the NCC's account codes. ESRI's plot driver for CalComp's 58XX and 59XX plotters has also been installed.

The GIS Technical Support Group is developing ARC Macro Language (AML) macros to aid in transferring geographic data between different computer types (e.g., VAX and PRIME) via tape. The group is also developing procedures to transfer these data over the network.
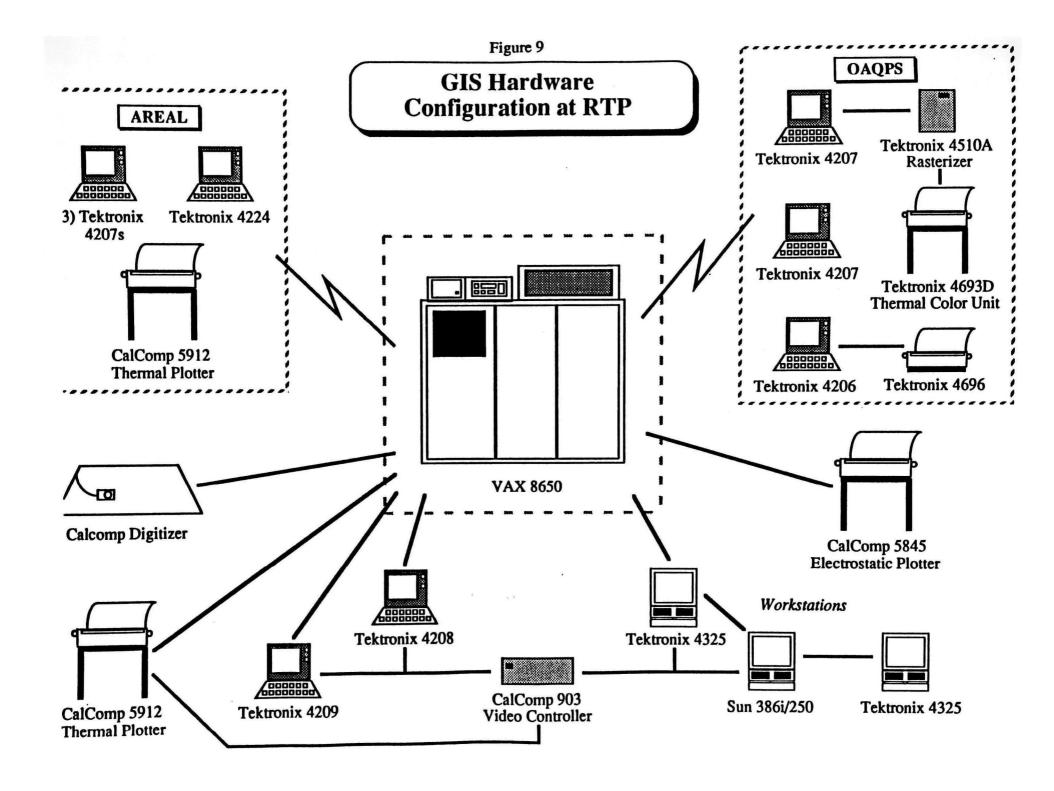
The NCC is in the process of installing a single seat (user) version of Dynamic Graphics Interactive Surface Modeling Software and associated software libraries on the VAX cluster. AREAL will be evaluating this software's surface modeling capabilities with regard to meteorological data.

Hardware

Hardware used at RTP includes the VAX 8650 (VAXB) of the NCC VAX cluster. A CalComp 5845 electrostatic plotter provides hard copy output. Figure 9 shows the hardware configuration for GIS at RTP.

A GIS training and support area is being set up adjacent to the NCC Training Center. This area will contain graphics terminals, workstations, thermal transfer plotter with video controller (RGB frame grabber), and a digitizing table. Other peripherals which can be used for GIS are located in AREAL, which has several graphics terminals and a thermal plotter, and in OAQPS, which has several graphics terminals and both ink jet and thermal printer/plotters.

Figure 9

GIS Hardware Configuration at RTP

AREAL

3) Tektronix 4207s

Tektronix 4224

CalComp 5912 Thermal Plotter

OAQPS

Tektronix 4207

Tektronix 4510A Rasterizer

Tektronix 4207

Tektronix 4693D Thermal Color Unit

Tektronix 4206

Tektronix 4696

VAX 8650

Calcomp Digitizer

CalComp 5845 Electrostatic Plotter

Workstations

CalComp 5912 Thermal Plotter

Tektronix 4209

Tektronix 4208

CalComp 903 Video Controller

Tektronix 4325

Sun 386i/250

Tektronix 4325

Constraints

Several requirements have been identified that will affect the integration of GIS processing into the offices and laboratories at RTP. For GIS to be incorporated as a useful tool into the daily work of RTP offices, these requirements must be met successfully. The requirements include:

(1) **Developing effective mechanisms to synthesize, reformat for use with GIS, and manage extremely large data bases used in monitoring and modeling atmospheric data.**

(2) **Educating EPA scientists and managers about the capabilities, limitations, and costs of GIS technology.** This includes understanding the benefit of GIS planning and implementation strategies. Initial steps towards meeting this requirement have been taken through the Agency's recent evaluation of GIS training needs. The need for instruction in both basic GIS concepts and planning for GIS projects has been identified. An Agency GIS training program that includes instruction in these areas should be implemented as soon as possible.

(3) **Successfully completing the RTP GIS pilot project.** Future applications of GIS technology in RTP will require management support and enthusiasm that will be generated by a successful pilot project.

Conclusion

The expertise and support provided by the GIS Technical Support Group at RTP has been a major factor in the successful implementation of GIS to date at RTP. RTP's GIS pilot project has been designed to produce an application that will assist air pollution researchers in their ongoing work beyond the life of the pilot project. The successful completion of the GIS pilot is key to gaining additional management support for the use of GIS at RTP and for incorporating GIS as a useful tool in RTP's offices and laboratories.

❏

Oregon Clean Water Strategy

Supporting the

Oregon Clean Water Strategy

Targeting with a
Geographic Information System

EXECUTIVE SUMMARY

The Oregon Clean Water Strategy project is a cooperative effort between EPA and the Water Quality Division of the Oregon Department of Environmental Quality (DEQ). The project involves the coordination and the collection of relevant information to support the Clean Water Strategy and the development of a methodology to prioritize water bodies. Data acquisition and creation of the GIS data base is on the EPA Headquarters PRIME computer using the ARC/INFO GIS software package. A user-friendly, menu-driven, "Decision Support Tool" was prototyped to assist managers and water quality analysts to display, query, and analyze the data base. This GIS application, along with map products and special reports, is being evaluated at DEQ and Region X with the intent of supporting water program prioritization and establishing memoranda of understanding with responsible land management agencies. Issues of data support and data quality also will continue to be evaluated. The system will be transferred to the Region X office for review by both DEQ and EPA staff.

Key factors in the development of the Oregon Clean Water Strategy project have included the following points:

REGULAR AND CONSISTENT COMMUNICATIONS AMONG ALL PROJECT PARTICIPANTS -- The project has depended on the cooperative efforts of the Oregon DEQ, the Environmental Results Branch of EPA's Office of Policy, Planning and Evaluation, the Office of Information Resources Management, the Office of Water, EPA's Region X Office, EPA's Environmental Research Laboratory at Corvallis, American Management Systems, and the Oregon Department of Energy. With this many participants, face-to-face meetings and other regular communications have been essential to forming a project consensus and to achieving the common goals of the project.

USE OF AVAILABLE STATE AND FEDERAL DATA RESOURCES -- Enhanced productivity has been achieved by using available digital data whenever possible.

GIS and the Oregon Clean Water Strategy

The Water Quality Act of 1987 amends the Clean Water Act and requires EPA and the states to carry out a number of new initiatives in conjunction with ongoing Clean Water Act programs. EPA's Office of Water has developed and released a number of guidance documents for implementing the new act. One of these guidance documents describes an optional process for states to develop Clean Water Strategies.

Development of a state's Clean Water Strategy is a three-step process composed of:

- waterbody/resource assessment,
- water resource targeting, and
- strategic management planning.

The goal of a State Clean Water Strategy is to integrate information across multiple water programs to effectively prioritize management activities. Development of a strategy is inherently a cross-programmatic, consultative process. Geographical information systems are a technology ideally suited to these tasks. For developing a Clean Water Strategy, the GIS facilitates integration of spatial and tabular data from various water quality programs, performs priority ranking analysis, and provides management level decision support.

The Oregon Clean Water Strategy project is a cooperative effort between EPA and the Water Quality Division of the Oregon Department of Environmental Quality (DEQ) to co-develop a methodology to implement a State Clean Water Strategy. The Environmental Results Branch of the Office of Policy, Planning and Evaluation (OPPE/ERB) is providing overall project guidance, coordination with senior staff at Oregon DEQ, and a role in the development of a prioritization methodology. The Program Systems Division of the Office of Information Resources Management (OIRM/PSD) is providing technical assistance by making the HQ GIS computer available for the project, lending staff support for GIS analysis and system management, and coordinating additional staff support in the Office of Water. American Management Systems (AMS) is providing project management, coordination among key participants in the project, and technical support relating to information management technologies and Geographic Information Systems. The participating agencies also include the EPA Region X Office, EPA's Environmental Research Laboratory at Corvallis, and the Oregon Department of Energy (ODOE).

Specifically, the project involves the coordination and the collection of relevant information to support the Clean Water Strategy (CWS) and the development of a methodology to prioritize water bodies. The project is drawing upon available information from several state agency programs, EPA national data systems, and the USGS Water Resources Division. A prototype CWS Decision Support Tool is being developed that will allow managers to display the high priority rivers, lakes, and estuaries across the state, subset the data geographically, and run various priority scenarios by adjusting the weighting of ranking factors.

Data acquisition and GIS development are occurring on the Washington Information Center HQGIS PRIME minicomputer with ARC/INFO software. Data communications and transfer utilities allow for downloading EPA program information from the National Computer Center at Research Triangle Park, North Carolina.

The system will be transferred to the EPA Region X office, where Oregon DEQ will remotely access the system through a PC ARC/INFO workstation. Further development and documentation of the effort will support OIRM in EPA/State data management issues and in providing guidance for future efforts.
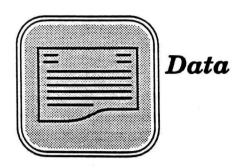
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Implementation Issues

Management/ Communications

Regular and consistent communications among the participants of the Oregon Clean Water Strategy project has been both challenging and crucial to the progress which has been attained at this juncture. Communication has been particularly challenging due to the number of project participants and the geographic distances from each other. Ironically, Oregon DEQ, the primary client for project is furthest from Washington, D.C., where much of the technical work is ongoing. Despite the distance, communication has been maintained and pursued with great vigor. Managers and staff from OIRM, OPPE, and American Management Systems gathered together with members of Oregon DEQ, Oregon DOE, and the ERL-Corvallis, in Portland to commence the project and develop a strategic plan. This initial face-to-face meeting was essential to forming a project consensus and "getting things off on the right foot". A subsequent trip to Oregon further clarified a number of technical issues and project objectives and greatly contributed to maintaining project momentum. This experience has certainly reinforced the need for direct communication and to the extent feasible, joint meetings. Telephone calls, conference calls, express mail, and electronic mail have also been used extensively to maintain good communications.

Another important aspect of communication has been the challenge to establishing realistic technical expectations where knowledge of GIS technology is initially quite limited. Educating the client or end-user about the power and complexity of GIS is essential to developing realistic project goals and objectives. Furthermore, the more the client understands the process of implementing a GIS, they are better able to anticipate needs or mold their expectations accordingly. For the Oregon Clean Water Project, two examples of the need for client understanding of GIS technology and applications development are worth noting. First, for reasons mostly beyond Oregon DEQ's direct control, the formulation of a ranking criteria for Oregon's water resources was considerably delayed from original projections. As a result, final GIS data base design and development was slowed. Part of the problem was attributable to Oregon DEQ's lack of knowledge about the data bases which were available to be incorporated in the Clean Water Strategy, partially a communications lapse on "Washington's" part. Secondly, Oregon had expectations to get a full "turn-key" Clean Water Strategy System which could run on its IBM PC ARC/INFO system. Although conceptually feasible, ultimately the size of the statewide data base and the complexity of the system's functional requirements have resulted in a decision to run the system in a PRIME minicomputer environment, permitting access by PC with an appropriate graphics emulator. Here again, better education of the client as to what is technically feasible, combined

with an earlier, more realistic assessment, by the project technical staff, of the technical feasibilities for system implementation, would have minimized some of the confusion and resulting frustrations which have occurred. However, with persistence and continued efforts at direct communication, reasonable solutions to these difficulties have been achieved.

In the final analysis, the real "story" to come out of the Oregon Clean Water project is the degree to which so many different organizations have been able to communicate and work together towards a common goal. Oregon DEQ has effectively communicated the values and priorities of Oregon's citizens pertaining to the State's water resources. These values and priorities are being implemented in a prototype GIS priority ranking and decision support tool. ERL-Corvallis has effectively made the case for using Ecoregions as a differentiating factor in assessment of water resource priorities based on the concept of attainable water quality. Subecoregions, compiled and digitized by ERL-Corvallis, are being incorporated into the Clean Water Strategy Decision Support System Prototype. OPPE's expertise and experience with priority ranking methods, based on a geographic approach, have been used extensively in the formulation of the Oregon Clean Water Strategy ranking scheme. OIRM's concerns about good data quality and the effective use of available State and Federal data resources have been heeded and resulted in enhanced productivity (e.g., no manual digitizing) and better quality data bases. None of these benefits would have accrued to this project without effective communication, and the willingness of all parties to contribute their ideas, knowledge, and expertise in a spirit of compromise.

Data

A major data objective of the Oregon Clean Water Strategy project has been to use available digital data, rather than to digitize new data from maps. In trying to meet this objective, the project has identified potential data from numerous sources, including those listed below. For each type of data, the data's owner and source format are also given. Not all of the sources have been incorporated into the current prototype CWS data base.

Data Base	Owner	Source Format
State Non-point Source Assessment for Surface and Groundwater	Oregon DEQ	GIS
Pacific NW Rivers Study (1:250,000)	Bonneville Power	GIS
Pacific NW Rivers Study (approx. 1:24,000)	Bonneville Power Oregon DOE	DBASE
Oregon Ecoregions	ERL-Corvallis	GIS
Oregon 305(b) Report	Oregon DEQ	paper
Oregon 304(l) List	Oregon DEQ	LOTUS
USGS Shallow Aquifers	USGS WRD	GIS
USGS aquifer withdrawal summary statistics	USGS WRD	paper
Listing of facilities and areas of concern to ground water problems	Oregon DEQ	LOTUS
USGS Geographic Names Information System	USGS WRD	GIS
NPDES Permit Violations Quarterly Reports, 1985-87	Oregon DEQ	paper
Oregon Estuary Management Plan	Oregon Dept. of Land Conservation and Development	GIS
Maps of estuaries showing areas closed to shellfishing	Oregon DEQ	paper

Data Base	Owner	Source Format
Drinking Water Facilities with Surface Water Intakes; EPA Water Supply Data Base;	EPA STORET	NCC data file
1982 River Reach Data Base Names File	EPA STORET	NCC data file
Oregon counties	USGS WRD	GIS
Oregon river basins	USGS WRD	GIS
Oregon Hydrologic Catalog Units	EPA STORET	NCC data file
Facility Index Systems (FINDS)	EPA	NCC data file

The data acquisition stage of the project took much longer than anticipated for several reasons:

- Locating and sending data from such a large number of digitial sources was a lengthy process. System problems at the Oregon DOE, specifically system loads, restrictions in access to tape drives, and a disk head crash, increased the time for acquiring data from that source.

- Some data to be used in the project were still being developed during the course of the project. Revisions to these data delayed the development of the data base for the Clean Water Strategy.

- Defining the criteria to be used for the Clean Water Strategy was a lengthy process that included numerous revisions to the criteria. As the criteria were modified, the data requirements for those criteria also had to be changed.

- Inadequate documentation was provided with some of the data. This resulted in numerous telephone calls to clarify aspects of the data.

- Because data from so many sources were needed for the project, extensive efforts were required for integrating data and verifying data quality. Some data files were at different scales and had different accuracies. During these data integration efforts, decisions had to be made regarding which data were appropriate for use in this application.

Staffing

With the number of different organizations involved in the Oregon CWS, several individuals have provided technical expertise, coordination support, or help with data acquisition or criteria development. The staffing consisted of an oversight/management group and a technical implementation group.
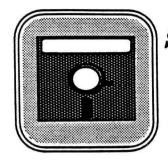
A technical team was assembled to work at EPA on the HQGIS PRIME. The team consisted of 2-3 AMS contractors and 2-3 EPA staff. Expertise within the group included the following:

- GIS analysts with expertise in ARC/INFO and knowledge of EPA and State data bases;
- Data systems analysts with expertise in EPA data sources;
- Environmental analysts with knowledge of the application area of priority ranking methodologies; and
- An EPA computer system manager with knowledge of the ARC/INFO PRIME installation and the Calcomp plotting environment.

An oversight/management group met regularly at EPA. This group included mid- and senior-level staff from OPPE and OIRM which regularly held status meetings along with members of the technical team.

Designated water quality specialists and management staff at DEQ maintained telephone contact with key points of contact at EPA. A lead GIS analyst with the EPA team acted as technical coordinator helping to balance user expectations and changing priorities with the technical implementation of the project.

The team worked well in identifying EPA national data bases, transferring the data to the GIS, and designing software modules for the menu-driven GIS application. However, the GIS team was hampered early in the project by the lack of a firm requirements definition by Oregon DEQ for the CWS data base. Oregon DEQ was involved with revisions of their water quality data which were to be part of the Clean Water Strategy. Because of the constant revisions and re-thinking of the requirements, it was very difficult for the GIS team to move forward on the GIS application. Once there was a firm commitment by the end users (DEQ) to a set of data requirements for support of the CWS, the team was able to quickly assemble the data base and design a prototype GIS application tool.

Software

Several packages have been used in conjunction with the Oregon Clean Water Strategy project. Both ARC/INFO on the Washington Information Center's (WIC) PRIME and PC ARC/INFO on a Compaq 386 have been utilized in the project. Typically, data obtained from EPA's National Computer Center at Research Triangle Center was formated into ARC/INFO coverages using PC ARC/INFO on the Compaq. These coverages were subsequently uploaded to the WIC's PRIME where they were further processed with the PRIME's ARC/INFO.

Other supporting software used for the project include the following:

- PC INFO
- DBASE (on the PC)
- LOTUS (on the PC)
- TGRAF terminal emulation software on a Compaq 386 and Macintosh II, which allowed both machines to emulate a Tektronix 4107 graphics terminal when logged onto the WIC PRIME; This permitted both machines to use ARC/INFO on the PRIME.
- STORET applications on the NCC IBM
- FINDS applications on the NCC IBM
- GATEWAY applications on the NCC IBM

Hardware

Figure 10 depicts the hardware used for the Oregon Clean Water Strategy project. Through dial-up capabilities, both the Compaq 386 and the Macintosh II located at AMS in Arlington, Virginia, accessed the WIC's PRIME 2750 and NCC's IBM 3090 mainframe.

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Figure 10

Oregon Clean Water Strategy GIS Hardware

National Computing Center

IBM 3090

EPA's Washington Information Center

PRIME 2750 (HQ-GIS)

Calcomp Electrostatic Plotter

Tektronix 4105

Tektronix 4207

AMS

Compaq 386/20

Macintosh II

Constraints

AMS has identified several constraints that have impacted the implementation of the Oregon Clean Water Strategy GIS Project. These constraints are described below.

(1) **Lack of sufficient lead time for Oregon to develop Clean Water Strategy criteria:** The time frame for completing the Clean Water Strategy was initially from June to September. However, at the initiation of the project, Oregon DEQ was committing much of its technical staff to finalizing a Non-point Source Assessment for public review. Consequently, DEQ did not have the resources in the early stages of the project to develop workable criteria, help direct the data acquisition, and answer questions concerning data needs. The modifications to the criteria by both DEQ and EPA staff meant that the GIS technical team spent much of the early stages of the project responding to shifting data requirements. The situation was improved by extending the time period to develop workable criteria and to allow DEQ time to focus on the problem.

(2) **The decision to begin the system development on the WIC PRIME precluded development of a PC-based support tool.** One of the early proposals for the Clean Water Strategy support tool was to have capabilities resident on PC ARC/INFO. However, the support and cooperation of the EPA Office of Information Resources Management directed the development of the GIS to the PRIME minicomputer at the Washington Information Center. Development of the GIS on the PRIME was advantageous and necessary because of increased storage capacity, additional software capabilities, multiuser capacity, and infrastructure and technical assistance. The PC workstation is being used as a terminal to the PRIME. Development of additional capabilities for the Clean Water Strategy that are resident on the PC will be deferred to a later date.

(3) **Poor locational data in EPA data bases:** Some of the EPA data bases proposed for use in the Clean Water Strategy have incomplete or inaccurate latitude/longitude data for facility locations. This was found to be the case for drinking water facilities in the Water Supply Data Base, STORET water quality monitoring stations, and permitted facilities in the FINDS data base. The locational information was not critical for implementation of the prototype Clean Water Strategy GIS; however, it may be a constraint for further refinements of the GIS.

(4) **Lack of standardization by the State Agency on the EPA Reach Data:** In implementing the Clean Water Strategy GIS, an Oregon DEQ version of the EPA River Reach Trace Files (graphical representation of surface waterbodies with unique EPA identification numbers) was used as a base map to represent surface waterbodies. EPA has standardized on the Reach data so that information in various EPA data bases can be cross-referenced on the EPA Reach number. Oregon DEQ, however, has not standardized on the EPA Reach data. Much of the programmatic data received from DEQ had to be manually re-interpreted in order to link this information to the EPA Reach data. DEQ was not concerned about maintaining an EPA standard data base when using the Reach data for their Non-point Source Assessment. Some of the reaches had been locally redigitized, and the EPA Reach identification number had been lost. This caused much concern at OIRM, which is responsible for guidance on data standards for GIS projects. The GIS team consequently had to evaluate carefully all efforts at integrating information based on the EPA Reach numbers (e.g., Drinking Water Utilities), because some information would be lost due to using non-standard Reach data. From the State's point of view,

the EPA Reach data (at 1:250,000 scale) does not contain all the waterbodies they would like to see. EPA currently has a cooperative program with USGS and Bonneville Power Authority to increase the resolution of the Reach data to 1:100,000 making the data more usable for state applications.

(5) **Lack of electronic communications:** E-mail was not available to the DEQ state office. E-mail works well because it is often easier to pass information over the network on a regular basis than to establish consistent telephone conversations.

(6) **Technology transfer from other EPA GIS installations could be improved.** Utilization of the Calcomp electrostatic plotter at the WIC had some early setbacks in the project. Some delays were unavoidable because the Calcomp had been recently purchased and was still in a testing phase. A few of the difficulties had to do with the interaction of the ARC/INFO software with the Calcomp plotter. Communication and assistance from other EPA GIS installations helped to clarify some of these difficulties.

(7) **Incomplete data documentation:** Numerous telephone calls were necessary to clarify aspects of the data. Documentation should include a complete data dictionary, map projection and units, source of the data, who compiled the data and when the compilation was done, how the data were created, and if the GIS data file is a secondary source. (E.g., the Reach files are a primary source of data. Some of the GIS coverages were derived from the EPA Reach files.)

Conclusion

The Oregon Clean Water Strategy Project is a prime example of a GIS that integrates information across multiple agencies and programs. The project has used available data from both Federal and State agencies, a factor which has resulted in enhanced productivity. The successes of the project have depended upon consistent communications among the many participants in the project and upon their willingness to work together effectively. This effort can serve as a good model for the development of Clean Water Strategies in other states.

❑

Appendix A

A. LIST OF INTERVIEWEES

REGION I

Information Management Branch

Michael MacDougall	Chief
Greg Charest	GIS Applications Manager

Waste Management Division, Water Supply Branch

David Delaney	Hydrologist
Stan Rydell	Hydrogeologist

REGION III

Information Resources Management Branch

Robert Braster	Chief, Information Management Support Section

Computer Sciences Corporation -- Contract Support

Douglas Freehafer	Programmer/analyst
Renee Gelblat	Programmer/analyst
David West	Programmer/analyst

Air Management Division, Air Programs Branch

Lewis Felleisen	Chief, Special Programs Section
Patricia Flores	Special Programs Section

Environmental Services Division, Environmental Assessment Branch

Diane Esher	Chief, Environmental Planning Section
Peter Stokely	Environmental Scientist, Wetlands and Marine Policy Section

Water Management Division, Drinking Water/Ground Water Protection Branch

Stuart Kerzner	Chief, Ground Water Protection Section
Ava Zandi	Ground Water Protection Section

CHESAPEAKE BAY PROGRAM

Lowell Bahner   Computer Sciences Corporation -- Contract Support

REGION IV

Joseph Franzmathes   Assistant Regional Administrator for Policy and
                                 Management

Office of Integrated Environmental Analysis

George Collins   Chief
Henry Strickland   GIS Coordinator
Jim Bricker   Engineer
Phyllis Mann   Environmental Scientist
Jerry Sorenson   Environmental Scientist

REGION VII

Office of Policy and Management, Environmental Review Branch

B. Katherine Biggs   Chief
Walt Foster   Biologist, Office of Integrated Environmental Analysis
Vickie Hale   Computer Sciences Corporation -- Contract Support
Bob Barber   Biologist, Wetland Protection Section

REGION VIII

Environmental Surveillance Branch, Environmental Monitoring and Assessment Section

Larry Svoboda   GIS Manager
Bill Monson   Statistician
Dick Sotiros   Engineer

Water Management Division, State Program Management Branch

Dale Vodehnal   Chief

Office of Policy and Management, Planning and Financial Control Branch

Doug Johnson   Management Analyst

ENVIRONMENTAL MONITORING SYSTEMS LABORATORY – LAS VEGAS

Advanced Monitoring Systems Division, Remote and Air Monitoring Branch

Mason Hewitt	Manager, Spatial Analysis Laboratory
Ross Lunetta	Remote Sensing Manager

Lockheed Engineering and Sciences Corporation – Contract Support

Jerry Carter	Scientist/Geologist
Dick Dulaney	Scientist/Geographer
Lawrence Fisher	Staff Engineer
David James	Senior Scientist
Frank Mynar	GIS Analyst
Mark Olsen	Supervisor
Jonathan Pickus	Senior Scientist

ENVIRONMENTAL RESEARCH LABORATORY – CORVALLIS

James Omernik	Research Geographer
Bill Tiffany	ADP Coordinator

NSI Technology Services Corporation – Contract Support

Denis White	Geographer
Andrew Herstrom	Geographer
Andrew Kinney	Contract Management
Gary Bishop	Geographer/GIS Specialist
Colleen Johnson	Scientist
Dorothy Mortenson	Geographer
Suzanne Pierson	Geographer
Barbara Rosenbaum	Geographer
Tony Selle	Geographer/GIS Specialist

RESEARCH TRIANGLE PARK

National Data Processing Division, National Computer Center
Unisys Corporation – Contract Support

Tom Scheitlin	GIS Technical Support
Gene Costello	GIS Technical Support

Atmospheric Sciences Research Laboratory

Cdr. James Reagan	Environmental Statistician