United States
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Administration and
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EPA

Geographic Information Systems

Training Recommendations

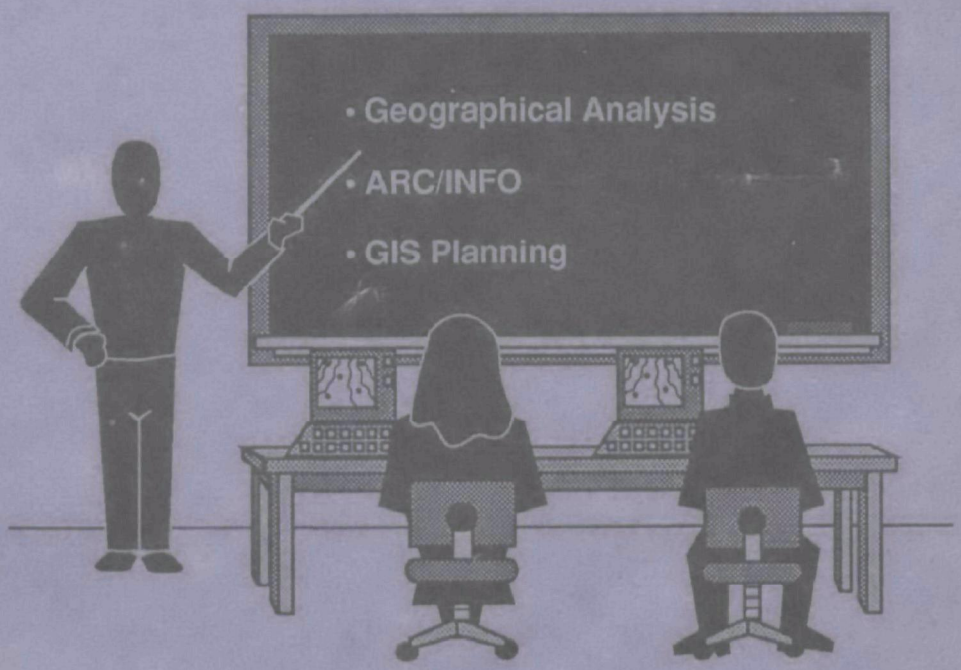

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TABLE OF CONTENTS

I. INTRODUCTION

This report on EPA Training Recommendations for 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 1 under Task Order Number N4B688015 of GSA Contract Number GS-00K-85AF-D2777. The objectives of this report are to identify EPA's GIS training requirements for managers, technical staff, and end-users and to make recommendations for satisfying those requirements.

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 training, 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
- Evaluation of existing EPA GIS programs to develop a case-study document outlining management, technical, staffing, and other issues pertinent to implementing GIS programs within EPA
- Development and implementation of a pilot GIS application using ARC/INFO software currently installed by EPA on the Washington Information Center (WIC) PRIME computer

Because EPA has selected the package ARC/INFO, a product of Environmental Systems Research Institute (ESRI) of Redlands, California, as its GIS software of choice, the training recommendations of this report have been made in light of EPA's current GIS training provided by ESRI. To date, EPA has not had the personnel or funding committed to developing and teaching its own GIS courses. Effective GIS instruction requires much more than a series of lectures and must be supported by detailed training materials, classroom data bases, and on-line, hands-on instruction and examples. Since the level of resources needed for development of that type of course has not been available, EPA has had to rely on ESRI's training.

In addition to considering current ESRI course offerings, this report has taken a much broader and longer-term perspective by addressing EPA's GIS and ARC/INFO training needs for the next several years. Consequently, recommendations are made that include training requirements that will evolve as the use of GIS spreads and matures within the Agency. Courses for which EPA may wish to assume instructional responsibility in the future are part of these long-term recommendations. Finally, since

this document considers both current and long-term GIS training in EPA, it serves as a statement of EPA's present and future GIS training needs both internally as well as externally to organizations such as ESRI.

This document is organized into the following major parts:

(1) **Section I: Introduction**
(2) **Section II: Executive Summary**
(3) **Section III: Current GIS Training at EPA;** This summary is provided as background material for the training recommendations presented in later sections.
(4) **Section IV: Recommended Strategy for GIS Training;** This section presents a recommended GIS curriculum by type of audience and identifies a sequence in which the curriculum should be implemented.
(5) **Section V: List of Core Courses;** A brief summary is given describing the core courses in the recommended GIS curriculum.
(6) **Section VI: List of Specialized Courses;** The specialized courses in the curriculum are summarized.
(7) **Section VII: Course Delivery Recommendations;** Fundamental principles for presenting GIS courses within EPA, criteria for selecting a good instructor, facilities needed for effective training, and use of alternative training media are discussed.
(8) **Section VIII: Training Support within EPA;** Support for GIS training that can be provided by several EPA offices is described.
(9) **Appendix A: Outline for a Course in Geographical Analysis and Fundamental GIS Concepts;** An annotated outline of contents for this course, which is part of the recommended curriculum, is presented.
(10) **Appendix B: Outline for a Course in GIS Planning;** This course is also part of the recommended curriculum, and an outline of its contents is presented.
(11) **Appendix C: List of Interviewees**

Acknowledgement is given to the following key contributors to this report:

- Mason Hewitt, EPA, Environmental Monitoring Systems Laboratory -- Las Vegas
- Tom Scheitlin, Unisys, GIS Technical Support at EPA's National Data Processing Division
- Jay Donnelly, U.S. Geological Survey, ARC/INFO training
- James Henderson, ESRI, Director of Customer Support and Training

II. EXECUTIVE SUMMARY

A comprehensive GIS training program is an important component of EPA's implementation of Geographic Information Systems (GIS). A training program is necessary to ensure that Agency personnel have the skills and expertise to take full advantage of this new technology. This section summarizes EPA's training needs and specific recommendations for a training program.

A. Current Training

EPA's current GIS training is provided by the Environmental Systems Research Institute (ESRI), who is the vendor for ARC/INFO, EPA's GIS software of choice. ESRI has extensive experience in providing ARC/INFO training to its hundreds of customers and currently has eleven courses listed in its training announcement. Continued reliance on ESRI for training has been necessitated by the lack of Agency personnel and funding committed to the development and teaching of its own GIS courses. EPA's current GIS training has consisted of the following courses:

- ESRI's basic two-week ARC/INFO course
- Selected ESRI advances courses, specifically:
  - Applications Programming (AML)
  - Introduction to the Triangulated Irregular Network (TIN) System
  - Introduction to the Coordinate Geometry (COGO) System
- ESRI's Introduction to GIS
- Several courses on the INFO data base and the PRIME and VAX operating systems, which serve as ARC/INFO prerequisites; These courses have been offered through EPA's National Data Processing Division (NDPD), not as part of a specific GIS training program, but as either regularly-scheduled classes or as courses offered on an as-needed basis.

This current array of courses does not meet all of EPA's present and future GIS training needs. Also, ESRI's basic ARC/INFO course has been criticized as being too complicated, poorly structured, and not focused sufficiently on EPA's specific requirements.

B. EPA's Training Groups

Three broad groups within EPA require different types of GIS training. These groups and their specific training needs are as follows:

1. Senior managers -- Assistant Administrators, Office Directors, Regional Administrators, Deputy Regional Administrators, Division Chiefs, and their Deputies

Senior managers do not need to know the technical details of GIS but must understand why GIS should be used, how GIS can help them to accomplish the goals of their programs, the resources required for GIS, and the extent to which resources must be committed to GIS before beneficial program results are seen.

2. Technical implementators -- GIS teams and their project/program managers that implement GIS technology and build GIS applications for end-users

   Technical implementators are analysts who need the following skills and knowledge:

   - Understanding and expertise in the concepts and methods of geographical analysis
   - Skills in life-cycle planning and implementation of a GIS project
   - Skills in requirements analysis and system design for GIS applications
   - ARC/INFO expertise
   - Knowledge of EPA programs which their GIS projects are supporting

3. End-users -- Environmental scientists, analysts, and other EPA personnel and their project/program managers who are applying GIS as part of their programmatic work for environmental research, analysis, prioritization, and decision-making

   End-users do not require detailed technical knowledge of ARC/INFO, but they must understand the concepts and methods of geographical analysis and GIS. They need to know how GIS can be applied to their specific programmatic work and understand the planning and implementation process for a GIS project.

C. GIS Training Recommendations

A GIS curriculum based on the training needs of the three groups defined above is recommended for EPA. Key recommendations that summarize major points of this curriculum, its development, and its limitations are as follows:

- For the present, **ESRI should be retained for teaching the basic ARC/INFO course as well as the advanced GIS courses** that the firm presently teaches. As described below, EPA has other more pressing needs for training courses that are not currently being met to which it should direct its limited training resources.

- **EPA should continue to work with ESRI to develop an ARC/INFO course tailored to EPA's requirements. The Agency should reevaluate periodically the need for its own ARC/INFO course** by looking at the demand for basic ARC/INFO training,

the extent to which ESRI's course meets EPA's needs, and the cost-effectiveness of developing an internal course.

- **EPA should develop and give courses that either (1) are directed at senior management and end-users, (2) focus on geographical concepts and methods, or (3) emphasize Agency-specific information.** The specific courses in the curriculum that EPA should develop and teach and approximate time frames for course development are as follows:

  Executive Briefing: Implemented in FY 89

  Geographical Analysis and Fundamental GIS Concepts
  GIS Planning: Prototypes for these two courses should be developed by the end of FY 89 and tested in FY 90. Final courses should be implemented by the end of FY 90.

  End-user ARC/INFO: A prototype could be developed by the end of FY 91 if there is sufficient demand for the course, which should be reassessed as GIS is more fully implemented throughout EPA. Implementation of the final course could occur in FY 92.

- Senior managers have GIS training needs that differ so much from the requirements of the other groups that a separate **executive briefing for senior managers** only is recommended.

- Instruction in geographical concepts and methods is distinct and different from the need for GIS technical training. Knowing how to execute ARC/INFO commands is not the same as understanding how to conduct sound geographical analyses. **It is absolutely essential that both technical implementors and GIS end-users be educated in geographical concepts and methods.** Towards this end, the course in Geographical Analysis and Fundamental GIS Concepts is recommended for both technical implementors and end-users.

- The GIS knowledge base acquired by some EPA units as they apply GIS to specific program areas needs to be transferred to the Regions so that they might take advantage of work that has already been done. **Under the umbrella of a GIS training program, development of a mechanism for accomplishing GIS technology transfer should begin as soon as possible.** The Office of Information Resources Management (OIRM) should facilitate the start of this effort, while the Environmental Monitoring Systems Laboratory at Las Vegas (EMSL-LV) should be the technical lead, consistent with its mission related to GIS technology transfer. The Office of Technology Transfer should also be involved with this effort.

- All EPA courses should incorporate applicable knowledge and experiences gained by EMSL-LV, the Environmental Research Laboratory at Corvallis, Region IV,

and NDPD's GIS Support Group at Research Triangle Park. This should not, however, be considered as a substitute for developing and implementing a mechanism for technology transfer focused on applications.

- Development of the EPA GIS curriculum should be a joint venture between OIRM, NDPD, and the GIS Centers of Excellence, with OIRM as the lead. **OIRM should take the lead in reviewing and resolving questions of specific responsibilities for development and delivery of the EPA courses.**

- Consideration should be given to a **partnership between EPA and academia** for development of EPA's GIS courses.

- **Adoption of a GIS training curriculum and resolution of who should develop and deliver each course should be done quickly.** Integration of GIS into Agency programs cannot be done without a training program that goes beyond the two-week ARC/INFO course. Sufficient lead time is needed for course development and for recruitment of skilled GIS trainers.

- Establishment of an **EPA educational review board** should be considered as a forum for reviewing GIS courses for content and relevancy.

- EPA should **enforce required prerequisites** and **implement a screening process** for students taking the basic ARC/INFO course.

- **EPA should not assume that the recommended curriculum satisfies all the educational needs associated with the integration of GIS into Agency programs.** For adequate training in geographical concepts and analysis and in the application of GIS to environmental problems, EPA should look to universities for educational support through degree programs. EMSL-LV's efforts to play a role in the development of university GIS curricula through its cooperative agreements with UC-Santa Barbara and North Texas University should be continued.

- EPA should emphasize **hiring people who have academic training in geographical concepts and methods** as GIS analysts.

- **It should *not* be assumed that instructors for EPA's data processing courses can automatically assume responsibility for GIS training.** GIS instructors must understand geographical concepts and methods and how GIS can be applied to environmental problems. Sufficient lead time may be required for recruiting qualified GIS instructors.

- NDPD has procured all equipment needed for a GIS training facility at Research Triangle Park. It is recommended that **EPA use the NDPD facility as a training site for those in EPA that do not receive on-site training.**

III. CURRENT GIS TRAINING AT EPA

A. Current Course Offerings

Table III-1 lists GIS-related courses that have been offered at EPA. EPA's current GIS training has consisted of the following three types of courses, all of which have been developed and taught by ESRI:

(1) ARC/INFO Training Course: This two-week basic ARC/INFO training course has provided the bulk of EPA's GIS training. The course covers the basics of GIS data base design, digitizing, creation of ARC/INFO coverages, data manipulation and analysis, and production of output maps and reports. Other capabilities of ARC/INFO and associated modules are mentioned briefly in the course. The intent of the course is to provide students with enough information so that they may use ARC/INFO on their own after completion of the course.

The two-week basic course has been taken by technical managers and staff who are implementing ARC/INFO as well as by persons who may be considered potential GIS end-users. Although some of these end-users are environmental scientists who have begun to utilize ARC/INFO in support of their work, others who have taken the course have not used the software to date.

(2) Selected advanced courses: Three of ESRI's advanced courses have been offered at EPA to date. These three courses are:

- Applications Programming (AML) -- A two-day course on designing, building, and maintaining application macros in the ARC Macro Language (AML)
- Introduction to the Triangulated Irregular Network (TIN) System -- A two-day course on the analysis and display of surface data
- Introduction to the Coordinate Geometry (COGO) System -- A one-day course on inputing and managing coordinate data obtained from typical survey measurements and descriptions

All three of these courses are intended for experienced ARC/INFO users. Other ESRI advanced courses that have not been taught at EPA are:

- Introduction to Database Design -- 3 days
- Cartographic Production -- 2 days
- Geographic Analysis -- 2 days
- ARC/INFO System Programming -- 4 days
- Systems Administration for ARC/INFO -- 2 days
- ARC/INFO Processing Techniques -- 2 days

TABLE III-1
CURRENT GIS-RELATED COURSES AT EPA

EPA Courses

- VAX Course 1
- VAX Course 2
- PRIME Orientation*
- Introduction to INFO**
- Advanced INFO**
- One-day course on INFO and VAX*

ESRI Courses

- ARC/INFO
- Applications Programming (AML)
- Introduction to the TIN System
- Introduction to the COGO System
- Introduction to GIS

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* Taught on an as-needed basis

** Future courses will probably be contracted to Henco and will be taught on an as-needed basis.

(3) Introduction to GIS: This course was developed by ESRI in June, 1988, in response to a request by EPA Region I for a class that provided an introduction to GIS for those who do not need to take the two-week ARC/INFO course. The intent of this two-day course is to provide managers and end-users with an overview of GIS with a minimum amount of detailed technical material. The course content includes the benefits of a GIS, a simplified description of how a GIS works, the major components of a GIS, and GIS functions. This course has been added to the latest ESRI catalog (dated September, 1988).

In addition to these three types of courses, several classes that have been offered through EPA's National Data Processing Division (NDPD) provide instruction on INFO, the relational data base management system used by ARC/INFO, and on the basics of the PRIME and VAX operating systems, under which ARC/INFO is running at EPA. These courses include:

- Introduction to INFO -- 2 days
- Advanced INFO -- 3 days
- PRIME Orientation -- 1 day
- VAX Course 1 -- 2 days
- VAX Course 2 -- 2 days

Future NDPD-sponsored courses on INFO will probably be taught by Henco, the vendor for INFO, and will be offered based on interest. The VAX courses are taught as regularly-scheduled classes, whereas the PRIME Orientation course is offered on an as-needed basis.

NDPD also has developed a one-day course that covers the basics of INFO and the VAX operating system and text editor. This scaled-down version of the "Introduction to INFO" course and "VAX Course 1" was taught in July, 1988, prior to a two-week ARC/INFO course.

B. Limitations of Current Training

The success of ESRI's two-week basic ARC/INFO course has been very mixed. The following criticisms have been directed towards the two-week course:

- The course is too long and tries to cover too much material.
- The course assumes that students have a greater knowledge of data base management and cartography than is often the case.
- The course spends too much time on digitizing and editing data.
- Some parts of the course teach commands in alphabetical order, rather than grouping commands in a logical sequence.
- Course materials are crude and out-of-date.
- Examples and exercises are not always relevant to EPA.

- Some of the ESRI instructors have not been good teachers or have not been very knowledgeable about the hardware on which the course has been taught.

ESRI has begun to address these criticisms in several ways. The Environmental Monitoring Systems Laboratory in Las Vegas (EMSL-LV) has provided to ESRI a training data base and training exercises that are relevant to EPA work.* Both the data base and exercises were been designed as "stop-gap" measures until ESRI provides a more tailored training course to address EPA's specific needs. ESRI is also restructuring the two-week course into two one-week segments that may be taken several weeks apart. The sequence of the course material is being modified so that the first week of the revised course will use an existing data base to give a thorough overview of ARC/INFO. The second week of the course will cover data base construction, analysis, and data management in more detail. This course revision is currently in the planning stage. Although no formal date for offering the revised course has been published, ESRI hopes to give the first presentation of the modified course in May, 1989.

Besides inadequacies in the course itself, a second major reason for the mixed success of the two-week ARC/INFO class has been the lack of screening students for the course. The class has been taken by those with an interest in GIS but with no plans of using the technology in the near future, as well as by a few who have no intention of ever using GIS. Such casual students displace those who should be included in the course or increase the class size to unmanageable levels.** Those who cannot use ARC/INFO almost immediately after completion of the course soon forget much of the detailed technical material that they have learned. Some of the ARC/INFO students have lacked prerequisite knowledge needed to benefit fully from the course, including knowledge of basic mapping concepts, geographical analysis, operating system commands, the system's text editor, and relational data base management systems. Without this prerequisite information, it has been impossible for some students to keep up in the course as it is being taught.

Few criticisms have been directed at the advanced courses taught by ESRI or at the "Introduction to GIS" course. To date, the latter class has been taught only in Region I, where it was very well received. Several sessions of the advanced courses have been taught only recently.

Beyond the limitations of the courses that are offered, all GIS training needs in EPA for both the present and the future are not met by the current array of courses. The specific training needs for different groups of people are described in the next section as part of the recommended strategy for GIS training.

* An extract data base from the Environmental Methods Testing Site (EMTS) project, which contains data for the Chattanooga Standard Metropolitan Statistical Area, has been provided by EMSL-LV for EPA's ARC/INFO courses.

** Eight students have been recommended by EMSL-LV as the maximum size of an ARC/INFO class.

IV. RECOMMENDED STRATEGY FOR GIS TRAINING

This section describes the recommended strategy for GIS training for EPA. Several groups of staff within EPA have different training needs, and their needs for training are described first. The recommended curriculum is then presented for each of the groups, followed by a discussion of a phased implementation plan for this curriculum.

A. GIS Training Groups within EPA

Three broad groups within EPA, two of which have been subdivided, require different types of GIS training. These groups are:

(1) Senior managers
(2) Technical implementors
    (a) Project/program managers of GIS teams
    (b) GIS teams
(3) End-users
    (a) Project/program managers of GIS end-users
    (b) Environmental scientists, analysts, and other EPA personnel utilizing GIS in support of their programmatic work

Each of these groups and their GIS training requirements are described below.

1. Senior Managers

This training group includes upper-level managers (i.e., Assistant Administrators, Office Directors, Regional Administrators, Deputy Regional Administrators, Division Chiefs, and their deputies) and mid-level managers. Typically, these managers do not need to know the technical details of GIS but must know how GIS will impact their programs. The questions that must be answered for senior managers include:

- What is GIS used for?
- How is GIS being used in other units within EPA with similar missions?
- How can GIS help to accomplish the goals of the manager's program?
- How may GIS affect the success or failure of a program?
- What resources are required for GIS in terms of both time, staff, and overall financial resources?
- How long is the implementation phase of GIS and what amount of resources must be committed before GIS will have a beneficial impact on the goals of the manager's program?

Senior managers also have little time to spend in training. Consequently, a GIS training session for senior managers must be limited to not more than two hours and

must focus directly on the specific information needed by management with little ancillary, but not necessary, information presented.

2. Technical Implementors

Technical implementors are the GIS teams that actually implement GIS technology and their project/program managers. GIS teams are comprised of analysts who interact with end-users to analyze the requirements of GIS applications, design and build data bases, program in ARC/INFO, produce output maps and reports, and design and program user-friendly sets of ARC/INFO commands (macros) that can be run easily by end-users. These GIS teams obviously need to be experts in ARC/INFO, data base design, and the life-cycle implementation of a GIS project. They must be able to locate possible sources of data and must know concepts, issues, and practices related to data standards and data quality. The GIS teams also must understand thoroughly the principles of geographical analysis and mapping, since much of the data with which they are working is geographical in nature. Finally, those working on a GIS team should have sufficient knowledge about the EPA programs that their GIS projects are supporting. The best GIS teams are those with a multi-disciplinary staff and expertise in EPA programs. Although this type knowledge is important for successful GIS applications, this report focuses only on information directly tied to GIS, not on the vast array of supporting environmental information that may be required for specific applications.

The training needs of the project/program managers of GIS teams are not as technically detailed as those of their analysts. Although these managers do not need to know ARC/INFO as thoroughly as their analysts do, they nevertheless should have a firm understanding of all technical issues related to life-cycle implementation and the use of GIS hardware, software, and applications. The training requirements for future division-level GIS program managers will center on their ability and understanding of planning GIS projects and the life-cycle implementation of GIS applications. Their training needs are similar to those of "end-user" managers, which are described below.

3. End-users

End-users are environmental scientists, analysts, and other EPA personnel and their project/program managers who are applying GIS as part of their programmatic work for environmental research, analysis, prioritization, decision-making, and the like. Because these individuals will be working with the technical implementors in applying GIS to the end-users' programs, end-users do not require detailed technical knowledge of ARC/INFO. However, to effectively use GIS in support of their programs, end-users need to understand basic concepts of geographical analysis, mapping, and GIS. They need to know how GIS can be applied to their specific programmatic work and must also have a firm understanding of planning GIS projects and life-cycle implementation issues. They must be knowledgeable about issues related to data quality and the potential impacts of data quality on project results and costs.

As use of GIS increases in EPA, some end-users may want to acquire sufficient knowledge about ARC/INFO to perform some basic operations on their own without needing to rely on the GIS teams for all support. At the simplest level, this would involve running macros created by a GIS team. Other individuals may wish to become proficient in a few basic ARC/INFO operations, such as overlaying different coverages of data, producing simple maps of those overlays, and performing ad hoc INFO queries against the data base.

B. Recommended GIS Curriculum

The recommended GIS curriculum for EPA is summarized in the following pages and in Table IV-1. This curriculum is designed as a series of courses with a phased implementation plan to be completed by approximately fiscal year 1992. The following subsections present the rationale and structure of the curriculum and specific curriculum recommendations:

(1) Curriculum Rationale
(2) Roles and Responsibilities for Curriculum Development and Training
(3) GIS Education Recommendations beyond the Curriculum
(4) Relationships between Currently Offered ESRI Courses and Planned EPA Courses

Descriptions of the core courses and of the specialized advanced courses are given in Sections V and VI, respectively.

1. Curriculum Rationale

Several factors are fundamental to the rationale and design of this curriculum and have resulted in the specific training recommendations represented by the curriculum itself:

- Because different groups in EPA have different GIS training needs, as described above, a curriculum with **specific courses for each training group** has been defined. In some cases, a course may satisfy training needs of two groups.

- The courses have been divided into **Core Courses** and **Specialized Advanced Courses**. The core courses represent the fundamental information needed for use of GIS. Because the teams of GIS technical implementors also require extensive technical knowledge about all aspects of GIS, other advanced courses will be needed by at least some members of a GIS team. It is not anticipated nor recommended that all team members take all of these advanced courses. Rather, these courses should be taken to reflect the specific responsibilities of individual team members. Those taking specialized courses would in turn be able to transfer information learned in the course to other team members on an as-needed basis.

TABLE IV-1
RECOMMENDED GIS CURRICULUM FOR EPA

	Senior Managers	Technical Implementors: Managers	Technical Implementors: GIS Teams	End-Users: Managers	End-Users: Staff
Core Courses					
EPA					
Executive Briefing	R				
Geographical Analysis and Fundamental GIS Concepts		R	R	R	R
GIS Planning		R	R	R	R
ARC/INFO System Prerequisites Introduction to INFO Operating system basics Text editor			R		O
End-user ARC/INFO					O
ESRI					
ARC/INFO			R		
Specialized Advanced Courses					
EPA					
Advanced INFO			O		
Specialized Applications Courses			O		O
ESRI					
Applications Programming (AML)			R		
Introduction to Database Design			S		
Systems Administration for ARC/INFO			S		
ARC/INFO Processing Techniques			O		
ARC/INFO Systems Programming			O		
Cartographic Production			O		
Geographic Analysis			O		
Introduction to the TIN System			O		
Introduction to the COGO System			O		

R: Recommended for all persons in a category
O: Optional, based on specialized needs
S: Site; At least one person from each ARC/INFO site should take this course.

New EPA courses and current ESRI courses that have not been offered at EPA are in ***bold, italicized type.***

- The knowledge learned through some of the specialized advanced courses may be gained through other ways. For example, someone who has worked extensively with relational data base management systems and has done requirements analyses and data base design work does not need to take the "Introduction to Database Design" course.

- Senior managers have GIS training needs that differ so much from the requirements of the other groups that a separate **executive briefing for senior managers only** is recommended.

- The need for **instruction in geographical concepts and methods is distinct and different from the need for GIS technical training.** Technical implementors must be trained in the operation of GIS software, building GIS data bases, writing user-friendly macros that can be run by end-users, and similar computer-oriented topics. The basic two-week ARC/INFO course and most of the advanced courses listed in Table IV-I are intended to satisfy this training need. Beyond this technical training requirement, however, is the **absolute necessity of educating both technical implementors and GIS end-users in geographical concepts and methods.** By its very nature, GIS is a tool that operates upon geographical data. For GIS to be used as an effective tool in supporting management decisions and in environmental analyses, its users must understand the principles and methods for the collection, analysis, and mapping of geographical data. Knowing how to execute ARC/INFO commands is not the same as understanding how to conduct sound geographical analyses. Towards this end, a course in Geographical Analysis and Fundamental GIS Concepts is recommended for both technical implementors and end-users. Appendix A presents an outline for this course. (It should be mentioned here that one short course is not sufficient to satisfy all EPA's training needs related to geographical concepts and methods. This point is discussed further in Section IV.B.3, "GIS Education Recommendations beyond the Curriculum.")

- In looking at sources of GIS training, **ESRI is currently the major supplier of training.** Although other agencies within the federal government were investigated as possible sources of training, none were found that are feasible at the present time. The U.S. Geological Survey (USGS) is teaching its own ARC/INFO training course and has considered developing classes for advanced ARC/INFO, ARC/INFO programming, and GIS for end-users. However, the USGS ARC/INFO class has a waiting list of students and could not accommodate EPA's needs. Furthermore, USGS does not offer agency-wide classes on basic mapping concepts or geographical analysis, since USGS employees generally have such knowledge when they are hired. The Defense Mapping School located at Fort Belvoir has not yet implemented a GIS training program.

- There is a fundamental requirement to teach the core courses from a problem-solving perspective oriented towards EPA's applications for GIS. Also, it is anticipated that the use of GIS will increase substantially throughout EPA, both at headquarters, the

Regions, and the Labs. This increasing demand for training, as well as the critical need to orient training towards EPA's needs and programs, has led to the recommendation that **EPA assume responsibility for developing and giving some training courses over the next four years.** EPA would develop and teach most of the core courses, while ESRI would be retained for the foreseeable future for both the basic ARC/INFO course and all the specialized advanced courses that the firm presently teaches. If other vendors or organizations develop extensive advanced ARC/INFO courses in the coming years, such alternative sources should be investigated. Until EPA's courses are available, ESRI courses will be used as substitutes.

- Some in EPA have suggested that the Agency move towards developing its own basic ARC/INFO course to replace the ESRI course. At the present time, it is felt that the more pressing need is to devote limited EPA resources to develop the Executive Briefing, the Geographical Analysis and Fundamental GIS Concepts course, and the GIS Planning course. ESRI's current course offerings do not meet all of the specific Agency needs that these internal courses will satisfy. On the other hand, ESRI is in the process of revising its ARC/INFO course and is incorporating many of EPA's suggestions for improvements. The sequence of material presented in the course is being modified, and the course will be structured into two one-week segments that can be taken several weeks apart. Until other Agency GIS training needs are met, the more cost-effective approach is for **EPA to continue to work with ESRI to develop an ARC/INFO course tailored to EPA's requirements.** The Agency should reevaluate periodically the need for its own ARC/INFO course by looking at the demand for basic ARC/INFO training, the success of the revised ESRI course, the extent to which ESRI responds to EPA's requests for a course tailored to the Agency, and the cost-effectiveness of developing an internal course.

- "Specialized Applications Courses" in the curriculum refer to the knowledge and experience that is being acquired by some EPA units (e.g., EMSL-LV, ERL-Corvallis) as they apply GIS to specific program areas (e.g., CERCLA, RCRA, water, acidic deposition). As Regions move from the pilot project phase towards developing applications focused on specific programs, **the GIS knowledge base acquired by other EPA units needs to be transferred to the Regions so that they might take advantage of work that has already been done.** This requirement for technology transfer of GIS knowledge and experience assumes that GIS applications will be developed in the Regions. Rather than define specific courses at this time under the title "Specialized Applications Courses," it is recommended that an effort should begin to define the mechanism by which this technology transfer should occur. Questions that need to be resolved include the following:

  - What is the preferred mechanism(s) of transferring GIS knowledge and experience that have been accumulated by a specific EPA unit to others, especially to the Regional GIS teams? (e.g., formal course or seminar, on-site assistance, transfer of application macros, etc.)
  - What are the appropriate steps for accomplishing this technology transfer?

- How will needs for technology transfer of GIS applications be identified?
- Who has what responsibilities for implementing the various steps that are identified to transfer GIS applications and knowledge specific to a program area?

Under the umbrella of a GIS training program, development of a mechanism for accomplishing GIS technology transfer should begin as soon as possible. OIRM should facilitate the start of this effort, while EMSL-LV should be the technical lead, consistent with its mission related to GIS technology transfer. The newly-formed Office of Technology Transfer should also be involved with this effort.

- As another way to transmit Agency GIS knowledge, **all EPA courses should incorporate applicable knowledge and experiences gained by EMSL-LV, the Environmental Research Laboratory at Corvallis, Region IV, and the GIS Support Group at NDPD.** This incorporation of Agency experiences into the other courses of the GIS curriculum should not be considered as a substitute for developing and implementing a mechanism for technology transfer which is focused on applications.

- The curriculum has been designed with a **long-term perspective.** All EPA courses in the curriculum will probably not be available or in demand until approximately fiscal year 1992. Section IV.C discusses a phased implementation plan for the curriculum in which targets for specific fiscal years are described.

- **Understanding certain prerequisite information before taking the basic ARC/INFO course is essential.** Without basic knowledge of INFO, which is the data base management system used by ARC/INFO, and of the operating system and text editor used on the student's computer, a student in the ARC/INFO course will lack the fundamentals needed to get the most benefit from the course and may quickly fall behind in the course. EPA already has several classes offered through the National Computer Center Training Office that can satisfy these prerequisites. Everyone who takes either the basic ARC/INFO course or the planned end-user ARC/INFO course must know this prerequisite information.

- **EPA should implement a screening process for students taking the basic ARC/INFO course.** The screening process would limit the course to those students that really need the course and will be using ARC/INFO in the near future. Persons that only have an interest in GIS and do not plan on using ARC/INFO in the next month or two should not be permitted to take the course, since such students displace those who need the course or increase the class size to unmanageable levels. The screening process could also ensure that ARC/INFO prerequisites have been satisfied by prospective students.

2. Roles and Responsibilities for Curriculum Development and Training

The following recommendations concern the roles and responsibilities for GIS curriculum development and training:

- Development of the EPA GIS curriculum should be a joint venture between OIRM, NDPD, and the GIS Centers of Excellence, with OIRM as the lead. With its training office, facilities, and equipment, NDPD should have a major role in GIS training efforts.* EMSL-LV should be a key contributor to curriculum development through its extensive experience as a center for GIS research and development. **OIRM should take the lead in reviewing and resolving questions of specific responsibilities for curriculum development and delivery.** Questions that must be addressed include the following:

  - Who will develop each course?
  - Who will fund course development?
  - Under which program will training be offered, and who will have responsibility for course delivery?
  - Should advanced training be centralized at one facility?
  - Who will fund specific offerings of courses, or will courses be offered on a cost recovery basis?
  - How do the decisions on responsibility for course delivery and funding impact implementing a screening process for students wanting to take the basic ARC/INFO course?

Determination of who is responsible for delivery of a specific course will depend in part on for whom the course is designed (e.g., senior EPA managers, new GIS analysts, end-users, etc.) as well as on which program is offering the course.

- Some in the Agency have recommended that a **partnership between EPA and academia** be used to develop the GIS courses. This recommendation should be given careful attention as the questions of specific responsibility for course development are resolved. Participation by academia in meeting EPA's overall GIS educational needs through degree programs is addressed below under "GIS Education Recommendations beyond the Curriculum."

- **Resolving the questions of specific responsibilities for course development and delivery should be done quickly,** so that implementation of EPA's GIS courses can proceed. Integration of GIS into Agency programs cannot be done without a training program that goes beyond the two-week ARC/INFO course. Sufficient lead time will be required for course development and recruiting skilled GIS trainers, and these tasks cannot begin until GIS training roles in EPA have been resolved.

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* Facilities needed for effective training and those available at NDPD at Research Triangle Park are described in Sections VII.C and VIII.B, respectively.

- **Consideration should be given to forming an EPA educational review board to review GIS courses for content and relevancy.** As the use of GIS expands in the Agency, the board would ensure that the courses continue to be relevant towards EPA's training needs. The board should be comprised of representatives from EPA's lead GIS offices as well as representatives from a Regional GIS team(s).

3. GIS Education Recommendations beyond the Curriculum

GIS education recommendations that go beyond the curriculum presented in Table IV-I are given below.

- **EPA should not assume that the recommended curriculum presented above satisfies all the educational needs associated with the integration of GIS into Agency programs.** Especially in the area of geographical concepts and methods, a one day course in "Geographical Analysis and Fundamental GIS Concepts" can only introduce end-users and others to basic concepts and methods. More thorough training is needed for someone to effectively apply those concepts and methods to environmental problems by using a GIS.

- For adequate training in geographical concepts and analysis and in the application of GIS to environmental problems, **EPA should look to universities for educational support through degree programs.** The efforts of EMSL-LV to play a role in the development of university GIS curricula through its cooperative agreements with UC-Santa Barbara and North Texas University should be continued.

- **EPA should emphasize hiring people who have academic training in geographical concepts and methods as GIS analysts.** The conceptual and analytical understanding gained through a university degree program cannot be matched by a series of short courses developed by EPA.

- As the use of ARC/INFO spreads throughout EPA, the Agency will gain in advanced knowledge of the use of ARC/INFO as applied to environmental problems that needs to be shared throughout the Agency. Such knowledge will consist of techniques and tips on the most efficient use of ARC/INFO, macros that may be shared, and other strategies for effectively using environmental data. Because this type of knowledge will be continually growing, it is recommended that **an Agency-wide GIS user group be established** to transfer such information. The group should be able to communicate and send macros and other material over electronic mail. At periodic regional or national meetings, such as the annual ARC/INFO conference hosted by ESRI, the EPA user group could meet to share new techniques. Technical memoranda, such as the series instituted by the Spatial Analysis Laboratory at EMSL-LV, may also be used to transmit various techniques and methodologies. It is felt that such methods provide a better mechanism for sharing a growing base of advanced knowledge than a formal course, which most individuals would attend only once.

4. Relationships between Currently Offered ESRI Courses and Planned EPA Courses

Table IV-2 lists new EPA courses that are part of the recommended GIS curriculum and current ESRI courses that may be considered precursors to the planned EPA courses. The following paragraphs contrast the EPA courses with the ESRI courses and explain the reasons for developing new EPA courses.

It first should be pointed out that the ESRI courses fill a pressing need for GIS and ARC/INFO training within EPA and should continue to be taught until the replacement EPA courses are available. In fact, the ESRI courses will serve as the basis for developing the EPA courses, and the need for advanced GIS training will continue to be met by ESRI courses. However, as discussed above, the need to teach GIS from a problem-solving perspective focused on **EPA applications and the growing demand for GIS training dictate that EPA develop its own core courses.**

Executive Briefing: As described above, senior managers require a briefing on GIS that focuses directly on the benefits of GIS to EPA programs and the resources required for GIS. Such a briefing is best developed and taught by someone internal to EPA that directly knows the Agency's programs and perspective. Although some material in ESRI's two-hour introduction to the two-week ARC/INFO course and in the two-day "Introduction to GIS" course may relate to the executive briefing, neither of these two formats focuses on EPA applications or on Agency resources supporting GIS. In addition, the two-day "Introduction to GIS" course is far too long to accommodate the schedules of senior managers, who have limited time to spend in training. Both of these ESRI courses are also attended by those not in management positions. Addressing the information requirements of senior managers can best be done in a setting where questions and discussion can focus directly on management issues without being sidetracked by questions that are not of immediate concern to management.

Geographical Analysis and Fundamental GIS Concepts: ESRI's "Introduction to GIS" serves as a sound base and prototype for developing an EPA course on "Geographical Analysis and Fundamental GIS Concepts." Like the ESRI course, the EPA course is intended to cover GIS concepts so that an end-user or a technical implementor new to GIS can obtain a good understanding of GIS basics. However, the EPA course is intended to go beyond the ESRI course in two ways. First, the ESRI course takes a technology-based approach in its description of GIS concepts. The EPA course will be designed to present GIS concepts from a problem-solving perspective that focuses on the application of the technology to EPA programs. Second, the EPA course will also stress basic concepts of mapping and geographical analysis much more than the ESRI course. Use of GIS depends on a fundamental understanding of mapping concepts and principles of geographical analysis. It cannot be assumed that all end-users or technical implementors will have this understanding. Appendix A describes in further detail the contents of the new EPA course.

TABLE IV-2
PRECURSORS TO NEW EPA COURSES

Current ESRI Course	New EPA Course
Two-hour introduction to ARC/INFO* Introduction to GIS	Executive Briefing
Introduction to GIS	Geographical Analysis and Fundamental GIS Concepts
Introduction to Database Design	GIS Planning
ARC/INFO*	End-user ARC/INFO

* "ARC/INFO" refers to the two-week basic ARC/INFO training course.

It should be emphasized that ESRI's "Introduction to GIS" fills a definite void and should continue to be taught in its present form until the EPA course is developed. As with the other courses to be developed, the EPA perspective on GIS applications within the Agency which will be incorporated into the new course will make the course of unique value to EPA staff.

GIS Planning: The "GIS Planning" course is intended to be a half-day or one-day course that will cover life-cycle planning of a GIS project. The course will also incorporate standard EPA life-cycle guidance for automation projects. Although the course will be oriented towards end-users, technical implementors also need to understand the course's material.

Although ESRI's "Introduction to Database Design" covers much of the material anticipated for inclusion in an EPA course on GIS planning, the ESRI course is more appropriate for technical implementors. The ESRI class, which to date has not been taught at EPA, is a three-day course that also covers conceptual and physical data base design, subjects which are of the utmost importance to technical implementors but not to end-users. Data base design is a specialized job that requires the expertise of GIS teams trained in that subject. ESRI's "Introduction to Database Design" should be taught to GIS teams to provide that type of specialized knowledge. However, a shorter and less technical class is needed for the numerous end-users who require an understanding of issues involved in the life-cycle of a GIS project. It is recommended that technical implementors also attend the "GIS Planning" course to receive EPA-specific life-cycle guidance and information. Appendix B describes the contents of the EPA "GIS Planning" course.

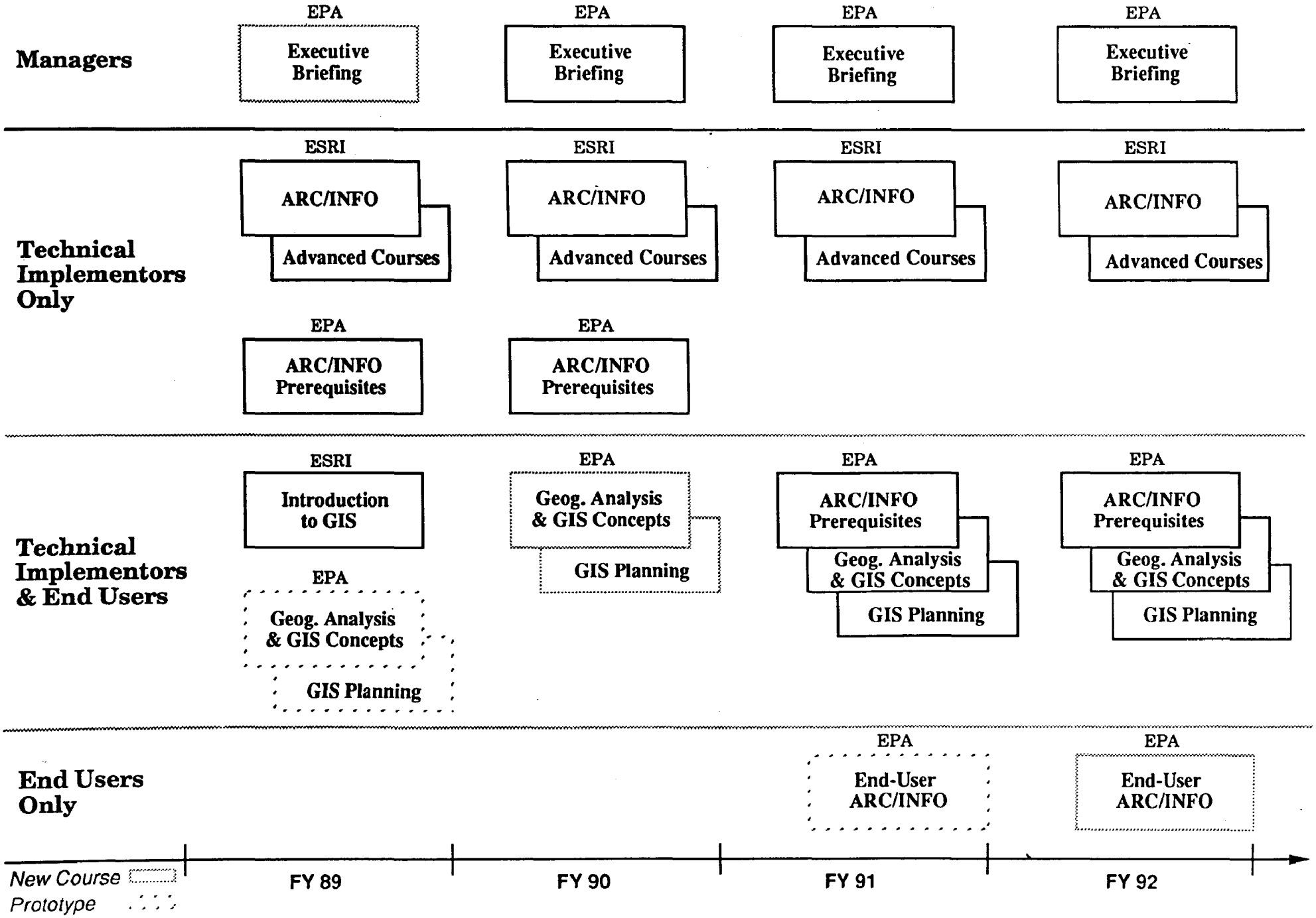
End-user ARC/INFO: As use of ARC/INFO increases in EPA, some end-users may want to acquire sufficient knowledge about ARC/INFO to perform some basic operations on their own without needing to rely on the GIS teams for all support. The "End-user ARC/INFO" course is designed to fill that training need. The course would cover the use of macros developed by GIS teams as well as some analytical ARC/INFO operations, such as overlaying data coverages, producing simple maps of those overlays, and performing ad hoc queries against the data base. ESRI's two-week ARC/INFO course is too long and detailed to meet these end-user training needs, as well as too expensive for a much more limited set of training requirements. It is anticipated that the demand for the "End-user ARC/INFO" course will not develop for a year or two until ARC/INFO is utilized more throughout EPA.

C. Phased Implementation Plan for GIS Curriculum

The future GIS curriculum that has been described cannot be implemented immediately, since time is needed to develop quality courses. Figure IV-1 depicts a phased implementation plan for the curriculum.

Figure IV - 1

Phased Implementation Plan for GIS Curriculum



Of the five EPA courses to be developed, the "Executive Briefing" should be developed first. The briefing should be prepared, tested, and implemented by the end of FY 89. Because there currently is no ESRI course that adequately substitutes for this briefing, it is imperative that the briefing be developed as soon as possible. Full-scale implementation of GIS throughout EPA requires the support of management, and an executive briefing on GIS is needed to garner that support.

The next courses to be addressed are the "Geographical Analysis and Fundamental GIS Concepts" and "GIS Planning" courses. EMSL-LV plans to teach a prototype of the "GIS Planning" course in March, 1989. A prototype for "Geographical Analysis and Fundamental GIS Concepts" should also be developed by the end of FY 89. The materials provided in Appendices A and B of this report provide starting points for those prototypes. During FY 90, the two prototype courses should be tested and refined. The final courses should be implemented by the end of FY 90.

After the "Geographical Analysis and Fundamental GIS Concepts" course is implemented, ESRI's "Introduction to GIS" course is to be removed from the EPA curriculum. Until the EPA course is available, however, the ESRI course is to be taught to satisfy EPA's training requirements in this area.

It is anticipated that the development of a prototype for EPA's "End-user ARC/INFO" course could begin in FY 91 and be completed by the end of that fiscal year. The demand within EPA and the extent to which ARC/INFO is used throughout the Agency need to be considered in planning the actual timing of the development of this course. Assuming that the anticipated need for the "End-user ARC/INFO" course occurs, implementation of the final course could occur in FY 92.

In Figure IV-1, it should be noted that as the "End-user ARC/INFO" course is developed, the ARC/INFO prerequisites move from being applicable for technical implementors only to courses for both technical implementors and end-users. This occurs because the prerequisites, which are currently available from several EPA NDPD courses, are needed by end-users doing simple work in ARC/INFO, as well as by technical implementors.

V. LIST OF CORE COURSES

This section presents a summary of each core course in the recommended GIS curriculum for EPA. These courses are:

- ARC/INFO
- ARC/INFO System Prerequisities
- Introduction to INFO
- PRIME Orientation
- VAX Course 1
- VAX Course 2
- End-user ARC/INFO
- Executive Briefing
- Geographical Analysis and Fundamental GIS Concepts
- GIS Planning
- Introduction to GIS

For each course the following information is given when appropriate:

- Description
- Status (new course to be developed, course currently taught by whom)
- Audience
- Prerequisites
- Format of the course
- Length
- List of topics to be covered in the course

ARC/INFO

Description: This course is the basic training course for ARC/INFO. After completion of this course, students should be able to use ARC/INFO with their own projects. Because the package contains over four hundred commands, a person completing the course will be a novice ARC/INFO user. Expertise in the package comes only after about one year's use of the software.

Status: This course is currently taught by ESRI. As discussed in Section IV of this report, it is recommended that EPA reevaluate periodically whether there is the demand for an EPA-developed and taught ARC/INFO course and whether such a course would be cost-effective.

Audience: This course is designed for technical implementors who will be using ARC/INFO on a daily basis. Only those who currently have ARC/INFO installed or who have installations planned for less than one month after completion of the course should enroll. Those with a casual interest in GIS or ARC/INFO should not take this course.

Prerequisites: A student should understand the material covered in the "Geographical Analysis and Fundamental GIS Concepts" course as well as have a basic understanding of INFO, the system's operating system, and its text editor. For more information on these prerequisites, reference the entries in this section for "Geographical Analysis and Fundamental GIS Concepts" and for "ARC/INFO System Prerequisites". Students should not be allowed to take the ARC/INFO course without these prerequisites, because keeping up in the course without understanding these basics is most difficult. EPA should implement a screening process for students wanting to take the ARC/INFO course to ensure that they satisfy the prerequisites and therefore will get full value from the course.

ESRI is in the process of adopting a review process whereby the extent to which students meet these prerequisites is evaluated before the ARC/INFO course begins. Those students who are lacking in this basic knowledge will be told that they must spend extra time outside of class in the first day or two learning the prerequisite information. Otherwise, withdrawal from the class is recommended. For assistance in meeting the prerequisites, ESRI sends written pre-training material to students two weeks before the start of the course.

Format: The format of the ESRI course consists of lectures supplemented with a videotape, slides, overhead transparencies, and hands-on exercises.

On-line demonstrations and exercises consume approximately half of the course time.

EPA has been providing input to ESRI for development of a version of the ARC/INFO course tailored to meet EPA's specific needs. Key requirements for such a course are examples and exercises that are directly related to EPA programs and environmental problems. The data base used for the exercises should contain data elements that might commonly be included in an EPA GIS data base.

It is also important that the course be taught with the computer that students will be using following completion of the course. For example, if future applications will be developed in ARC/INFO on a PRIME, then the course should also use a PRIME computer.

Length:

The current ESRI ARC/INFO course is taught in ten days, which are scheduled as two consecutive weeks. ESRI is in the process of modifying this structure so that the course will be taught as two one-week segments that may be taken several weeks apart. ESRI hopes to have this restructured course available in May, 1989.

This restructuring of the ARC/INFO course into two one-week segments is strongly recommended. Typically, a two-week period is too long to be in training for both the amount of material communicated in the course as well as the time spent away from the office. The ARC/INFO course is a very intensive course that conveys a large amount of technical information in a short time. Students need to grasp the fundamentals during the first week and then reinforce those fundamentals through intensive practice between the two weeks of the course, rather than being overloaded with too much information. Although class exercises are designed to provide some practice, it is only after students have more hands-on experience with the software that they are able to proceed effectively in learning additional material. The break between weeks of the course also allows students time to relate the course material to future projects where they will be applying ARC/INFO and to formulate questions about their initial projects that can be addressed during the second week of the class.

Structuring the ARC/INFO course as two separate one-week segments also will ease the burden of being away from the office. Most students in the course have other responsibilities that must receive attention. Those who spend two weeks in a course often have too many other pressing matters which need attention after their return to the office that time cannot be spent immediately on using ARC/INFO. By

limiting each part of the course to one week, this situation should be eased somewhat, allowing students to use ARC/INFO sooner after their return from the course.

It is recommended that students take the two weeks of the revised ARC/INFO course approximately one month apart. In most cases, a one-month interval should allow enough time for students to review material from the first week and to practice using ARC/INFO commands before taking the second week of the course. Because students need the material from both weeks to effectively apply ARC/INFO, an interval between course weeks that is longer than one month would limit students in moving ahead with using ARC/INFO for their applications.

A set of exercises should be provided to students to work between the two class weeks. These exercises would reinforce the information and skills learned during the first week in preparation for the second week of the course.

Topics to Be Covered:

The ESRI catalog of courses dated September, 1988, lists the following topics as being covered in the two-week ARC/INFO course:

Introduction GIS
Overview of ARC/INFO
Data base design
Spatial data automation
Attribute data automation
Attribute data manipulation
Data base construction
Data base management
Spatial data manipulation
Data analysis
Data display (reports and graphics)
Network analysis
System interfaces
ARC Macro Language (AML): An overview
Batch processing

As part of the restructuring of the course from two weeks to two one-week segments, ESRI is also changing the sequence in which material in the course is presented. The first week of the current course steps through the process of building a GIS data base, including digitizing a map, creating topology, entering attribute data, and editing both spatial and attribute data. The first segment of the revised class would

use an existing data base to give a thorough overview of ARC/INFO. During the weeks between the two segments of the course, students would be able to practice simple analyses and output operations with ARC/INFO using a sample data base. When students return for the second class segment, they will have a firm understanding of how ARC/INFO may be applied. The second segment will then cover in more depth the process of building a data base, data analysis, and data management. It is felt that students will learn ARC/INFO better by getting a good overview first, rather than getting bogged down in details of data base construction during the first week.

The following guidelines can also be given for a revised ARC/INFO course, based on EPA's experience with the current course:

- The first week of the course should provide enough information so that students can be using ARC/INFO after the first week.

- The course should use a data base appropriate to EPA and environmental problems. Course examples and exercises should be relevant to EPA.

- The current ESRI course spends too much time on digitizing and editing coverage data. In many cases EPA applications will be starting with existing data bases that must be converted to ARC/INFO coverages, not with hard-copy maps that must be digitized. Consequently, the version of the revised course taught to EPA should step through an example of converting data from an existing EPA data base into ARC/INFO coverages. Conversions from other relational data base management systems to ARC/INFO coverages also should be addressed.

- The current ESRI course describes various commands in alphabetical order. The revised course should present ARC/INFO commands in a logical sequence that groups commands according to logical function. An alphabetical index of commands should be present to allow cross-referencing of various commands.

- The revised class should clearly describe the differences between the various overlay commands.

- The revised course should spend much more time than the current course on ARCPLOT for producing output maps.

- Finally, the revised course should take a project through the various stages of applying ARC/INFO to the project, from creating

coverages through producing end products of analyses and output maps. This sequence would best be done during the second week of the ARC/INFO course, after students have been given a good overview of the package.

ARC/INFO SYSTEM PREREQUISITES

Description: Four subjects are included under the heading "ARC/INFO System Prerequisites:"
(1) Introduction to INFO, the relational data base management system used by ARC/INFO
(2) Basics of the operating system under which ARC/INFO is running
(3) Basics of the system's text editor
(4) "Geographical Analysis and Fundamental GIS Concepts"

The course in "Geographical Analysis and Fundamental GIS Concepts" is described as a separate entry in Section V. The following paragraphs refer to the other three prerequisites listed above.

Status: Several courses that have been offered through EPA's National Data Processing Division (NDPD) can be used to meet these prerequisites. These courses are:

- Introduction to INFO
- PRIME Orientation
- VAX Course 1
- VAX Course 2

Descriptions of these courses are given on the following pages.

To use these courses to satisfy the prerequisites for ARC/INFO, both the "Introduction to INFO" and either "PRIME Orientation" or "VAX Course 1" must be taken. Because the "Introduction to INFO" is a two-day course and the PRIME and VAX courses are one day and two days in length, respectively, three or four days are required to obtain the prerequisite information from these classes.

To reduce the amount of training time required for prerequisite material, NDPD developed a one-day class that covered the basics of INFO and the VAX operating system and text editor. This scaled-down version of the two courses was offered in July, 1988, prior to a two-week ARC/INFO course.

Based on the demand for prerequisite training for ARC/INFO courses, EPA should consider offering the one-day course covering the basics of INFO, the VAX operating system, and the VAX text editor on a regular basis. A similar course on INFO and the PRIME operating system and editor also could be developed.

It should be emphasized that these one-day courses, which would devote half a day to INFO, do not allow a student to become fluent in INFO. The purpose of the one-day courses is to provide enough information on basic INFO concepts and the operating system to allow a student to take the ARC/INFO course. Anyone who will be doing extensive queries or programming in INFO should take at least the two-day "Introduction to INFO" course and probably the "Advanced INFO" course, which is described in Section V.

The remaining items in this entry refer to these one-day courses. The list of "topics to be covered" are those subjects that should be addressed in the courses.

Audience: The courses are intended for anyone who needs to acquire this information prior to taking "ARC/INFO" or "End-user ARC/INFO."

Prerequisites: None

Format: Lecture material in the courses should be supplemented by hands-on exercises.

Length: One day; This includes a half day on the operating system and text editor and a half day on INFO.

Topics to Be Covered:

Operating System Basics
Login and logoff the system
Create, copy, rename, and delete files
Understand the directory file structure

Text Editor
Create a file, enter information, edit information, save the file
Recall the file for additional editing
Search and replace operations, global replacements
Insert and delete lines in the file

INFO
Concepts of tables, keys, unique keys
Create and update tables and keys
Relate and join tables
Produced simple reports

INTRODUCTION TO INFO

Information for this class is taken from the "EPA/NCC Training Course Syllabus" dated Spring, 1988, and developed by NDPD's training office located at Research Triangle Park.

Description: The course will help new users become proficient in INFO. Basic features of INFO are explained, including data base creation, data retrieval, data management, report writing, and an introduction to programming.

Status: Henco, the vendor of INFO, will probably teach this course in the future under contract to NDPD. The course will be offered on an as-needed basis.

Audience: PRIME users who wish to learn about the functions and capabilities of INFO. (Users who need a good understanding of INFO prior to taking an ARC/INFO course.)

Prerequisites: PRIME Orientation

Length: Two days

Topics to Be Covered:

Introduction to INFO
Datafile management
Revising datafile characteristics
Data entry
Data retrieval
Query language
Data manipulation
Output form files
Relating datafiles
Programming
Advanced INFO topics

PRIME ORIENTATION

Information for this class is taken from the "EPA/NCC Training Course Syllabus" dated Spring, 1988, and developed by NDPD's training office located at Research Triangle Park.

Description: This course provides an introduction to the EPA PRIME computer system. Featured are the hardware, common software, menus, capabilities to communicate with other system, ELINK (a local electronic mail system that is similar to EMAIL), and additional menu options. Basics of the PRIMOS operating system, including file handling, the editor, and some PRIMOS commands, are covered.

Status: The course is taught by the NDPD training office staff on an as-needed basis.

Audience: Beginning users of the PRIME computer systems. (Users who need to understand the basics of the PRIMOS operating system prior to taking an ARC/INFO course.)

Prerequisites: None

Length: One day

Topics to Be Covered:

PRIME overview
Introduction to PRIME computers
Common software
Communication software
Additional PRIME functions

VAX COURSE 1

Information for this class is taken from the "EPA/NCC Training Course Syllabus" dated Spring, 1988, and developed by NDPD's training office located at Research Triangle Park.

Description: This course is designed to familiarize the end user with the basics for using the VAX/VMS computer. Operating system commands will be covered, as well as the essentials of constructing command procedures for repeated usage. The VAX batch environment, editing, and NCC communication basics are detailed as part of the ovarall presentation.

Status: The course is taught by the NDPD training office staff on a regularly-scheduled basis.

Audience: Users of the VAX/VMS computer who require a basic beginning level explanation of the system. (Users who need to understand the basics of the VAX/VMS operating system prior to taking an ARC/INFO course.)

Prerequisites: None

Length: Two days

Topics to Be Covered:

VAX/VMS overview
Basic system use
Simple commands
VAX files
DCL commands, logicals, symbols
Command procedures
Login.com - special command procedure
Batch processing
Editing
VAX clusters and networking

VAX COURSE 2

Information for this class is taken from the "EPA/NCC Training Course Syllabus" dated Spring, 1988, and developed by NDPD's training office located at Research Triangle Park.

Description: This course is designed to expand the knowledge of the VAX/VMS user. Concentration areas include additional information on system usage as indicated below by the topics to be covered.

Status: The course is taught by the NDPD training office staff on a regularly-scheduled basis.

Audience: The course is targeted towards users of the VAX/VMS computer system who require a more in-depth knowledge of system capabilities. The need for this level of understanding generally arises in the program development environment. Any intensive VAX user could benefit from the course material, even if FORTRAN is not the local language of choice for development. (This course is not needed as a prerequisite for an ARC/INFO course. However, those who may be doing intensive programming on the VAX in conjunction with their use of ARC/INFO may wish to take the course.)

Prerequisites: VAX Course 1

Length: Two days

Topics to Be Covered:

EVE - The Extensible VAX Editor
Advanced Command Procedures and Lexicals
VAX Librarian Utility
DCL commands for programming support
FORTRAN language features
FORTRAN compiler and VMS linker
VAX Run Time Library and FORTRAN
VAX file handling and FORTRAN
VAX Symbolic Debugger
VMS System Services

END-USER ARC/INFO

Description: This course is designed for those end-users who want to acquire sufficient knowledge about ARC/INFO to perform some basic operations on their own without needing to rely on a GIS team for all support. For such end-users, the two-week ARC/INFO course is too long and contains too much detailed information for their needs. The "End-user ARC/INFO" course will assume that end-users will be starting with existing ARC/INFO coverages. Thus, the course will contain no material on data base design, data automation, digitizing, ARCEDIT, or similar capabilities but will focus instead on data analysis and simple output operations.

Status: This course has not been developed yet but is part of the recommended GIS curriculum for EPA. It is anticipated that as use of ARC/INFO matures and spreads throughout EPA, the demand for this course will grow. Based on that demand, a prototype of this course should be available by the end of FY 91, with the final course ready by the end of FY 92.

Audience: The targeted audience for this course is EPA personnel who utilize ARC/INFO as a tool in support of their work. Those end-users who want to perform data analyses in ARC/INFO or ad hoc INFO queries on their own would benefit from the course.

Prerequisites: A student should have a basic understanding of the material covered in the "Geographical Analysis and Fundamental GIS Concepts" course as well as an understanding of INFO, the system's operating system, and its text editor. For more information, reference the former course entry in this section as well as the entry entitiled "ARC/INFO System Prerequisites."

Format: Course lectures should be structured around examples and hands-on exercises relevant to EPA programs and environmental problems. Course material that the students can take with them upon conclusion of the course should have additional examples that utilize ARC/INFO coverages extracted from common EPA data bases. Students can use these examples as models for their work.

Length: Three days

Topics to Be Covered:

Use of macros, especially macros already developed by EPA
INFO data base manipulation
Ad hoc INFO queries
Basic data analysis operations, such as overlays and buffer generation
Simple output operations for generating maps and reports (includes basic ARCPLOT commands)

EXECUTIVE BRIEFING

Description: The purpose of the Executive Briefing is to inform senior managers of the uses of GIS in EPA, the ways in which GIS may help managers to accomplish EPA program goals, and the resources required to support GIS. The briefing is a non-technical presentation directed towards the needs of managers and is not intended to be a "training session" on the use of GIS or ARC/INFO.

Status: At the present time this briefing has not been developed but is part of the recommended GIS curriculum for EPA. The Executive Briefing should be prepared and implemented by the end of FY 89.

Audience: The Executive Briefing is intended for senior managers (i.e., Assistant Administrators, Office Directors, Regional Administrators, Deputy Regional Administrators, Division Chiefs, and their deputies). Mid-level managers down to the level of branch chiefs may also wish to attend this briefing.

Prerequisites: None

Format: The Executive Briefing is not a formal training course like the other courses in the recommended curriculum. As its name suggests, the briefing must be designed to accommodate the needs and schedules of busy managers. The preferred format for the briefing is a very colorful, graphical, fast-moving 35mm slide show that may be supplemented by a graphical GIS presentation on a workstation projected onto a large screen. The briefing should be filled with EPA examples that include not only EPA programs that are applying GIS but also situations in which programs and projects could have been more successful if GIS had been used. All material in the briefing should be presented in non-technical language. There should be no hands-on work or problem-solving by the managers during the briefing.

The briefing should be supplemented by a colorful package that managers can take with them at the conclusion of the briefing. This package should contain copies of the slides shown during the presentation as well as additional graphical examples and maps of the use of GIS in EPA.

If possible, the briefing should be given by an EPA manager who is both well-versed in GIS and understands management's concerns about applying new technologies. A manager would be more likely to

have a better appreciation for the perspective of other managers than a GIS technical implementor would. If the instructor is not an EPA manager, then he/she should have had either coursework or experience is management and the application of new technologies.

Presentations of the briefing should be limited to six to eight managers at a time in a comfortable setting that allows them sufficient room to spread out. Individuals who are curious about GIS but who are not managers should not be allowed to attend the briefing. The course on "Geographical Analysis and Fundamental GIS Concepts" could be attended by non-managers to get an overview of GIS.

Length: The briefing should be limited to a maximum of two hours. A period of approximately twenty or thirty minutes should be built into the briefing for questions and discussion.

Topics to Be Covered: The briefing should be given from the perspective that GIS is a tool that management can use to make decisions related to EPA programs. GIS can be used to tie programs and their results to changes in environmental quality. Based on this perspective, the briefing should address the following questions:

What is GIS?
How is GIS being used in EPA, especially in other units that may have similar missions?
How can GIS help managers accomplish the goals of their programs?
How may GIS affect the success or failure of a program?
What resources (staff, time, hardware, software, overall financial commitment) are required to get started with GIS?
How long is the start-up period for GIS, and what resources must be committed before GIS will have a beneficial impact on program goals?
What resources (staff, time, ongoing financial resources) are required to support GIS on an ongoing basis?
What are the impacts of GIS on the current workplace? What will be the impacts on existing staff, hardware, and the way work is presently done?
What trade-offs may be necessary to balance concerns of accuracy and data quality with both the need to produce immediate results and funding limitations?

GEOGRAPHICAL ANALYSIS AND FUNDAMENTAL GIS CONCEPTS

Description: The purpose of this course is to instruct end-users and technical implementors in basic concepts of mapping, geographical analysis, and GIS. Since GIS is based on geographical data that are best displayed through maps, it is vital that all end-users and technical implementors understand fundamental principles of maps and geographical analysis. The course also serves as a good introduction to GIS for those with no prior exposure to the subject. Rather than taking a technology-based approach, the course is designed to be taught from a problem-solving perspective that focuses on application of GIS to EPA programs and environmental problems.

Status: This course is not available at the present time but is part of the recommended GIS curriculum for EPA. A prototype of the course should be developed by the end of FY 89. During FY 90, the course should be tested, and the completed version should be available by the end of FY 90. Until this course is available, ESRI's "Introduction to GIS" should be used as a substitute, as described in Section III.

Audience: The course is directed towards all end-users and technical implementors. Technical implementors who are currently using GIS and understand fundamental concepts of mapping and geographical analysis do not need to take the course. However, those who know ARC/INFO but have limited knowledge of mapping and geographical analysis would benefit by taking the course.

Prerequisites: None

Format: The course should be presented in a lecture format with the usual supporting slides and overhead transparencies and a limited number of hands-on exercises. All concepts should be illustrated by examples relevant to EPA. The materials used for these examples may include slides or overheads of actual maps as well as ARC/INFO demonstrations. Whenever possible, concepts should be demonstrated by using an on-line ARC/INFO application or maps produced by ARC/INFO. The course should be structured so that student participation in the hands-on exercises is optional.

Length: One day

Topics to Be Covered: Appendix A describes in detail the topics to be covered in the course.

GIS PLANNING

Description: This course provides instruction on life-cycle planning of a GIS project, including standard EPA life-cycle guidance for automation projects. The course is designed to give end-users and technical implementors an understanding of the various stages of a GIS project and the types of decisions that must be made at each stage. The implications of making (or not making) certain types of decisions at various stages in a project are discussed.

Status: EMSL-LV plans to teach a prototype of this course during March, 1989. Based on EMSL-LV's experiences in teaching the prototype, the course should be refined, and a final version should be available by the end of FY 90.

Audience: The course is recommended for both end-users and technical implementors. Although technical implementors who have taken ESRI's "Introduction to Database Design" will have covered some of the same topics in that course, they should take the "GIS Planning" course also for EPA-specific information and the Agency's perspective on GIS project planning.

Prerequisites: None

Format: A lecture-format with supporting slides and/or overhead transpancies will be used for the course. The GIS project planning process should be illustrated by using several actual projects of differing sizes and scopes. The critical importance of planning should be emphasized by examining both projects that succeeded because of good planning as well as projects where problems developed due to inadequate planning.

Length: Half a day or one day

Topics to Be Covered: Appendix B describes in detail the topics to be covered in the course. The course material is based on GIS Technical Memorandum 1-88, "GIS Project Planning and Data Set Selection", written by EPA's Environmental Monitoring Systems Laboratory staff at Las Vegas. Comments made by GIS Technical Support at the National Data Processing Division, Research Triangle Park, have also been incorporated into the recommended course topics.

INTRODUCTION TO GIS

Description: The course provides an overview of basic GIS concepts and applications with a minimum amount of detailed technical material. As discussed in Section III, this course is serving as a substitute for a future EPA course entitled "Geographical Analysis and Fundamental GIS Concepts" until the EPA course is available.

Status: The course was developed by ESRI in June, 1988, in response to a request by EPA Region I for a class that provided an introduction to GIS. ESRI has added the course to its catalog of course offerings dated September, 1988.

Audience: The course should be taken by all end-users and technical implementors new to GIS who need a good understanding of basic GIS concepts.

Prerequisites: None

Format: The course is taught through a combination of a video tape presentation, lectures with overhead transparencies, and a hands-on tutorial with supplemental exercises.

Length: Two days

Topics to Be Covered: ESRI's class materials list the following topics to be covered:

Introduction
- GIS applications (video tape)
- Benefits of GIS
- Importance of data base

How a GIS works
- Spatial data
- Topology
- Thematic data
- The layer concept

GIS components
- Hardware
- Data
- Software
- People
- Administrative procedures

Functions of a GIS
- Data input
- Updating functions
- Spatial manipulations
- Thematic manipulations
- Output
- Management functions
- Analysis functions
- Query

Data automation techniques
- Preparation
- Organization
- Digitizing alternatives

VI. LIST OF SPECIALIZED COURSES

This section presents a summary of the specialized advanced courses in the recommended GIS curriculum for EPA. As stated earlier, it is not recommended that all GIS team members at an ARC/INFO site take these courses. The extent to which these courses are offered for EPA staff should be based on specialized needs. Because advanced GIS training requirements will change as ARC/INFO use grows within EPA, a survey of the need for these courses should be conducted in one or two years.

The courses summarized in this section are:

EPA Course
- Advanced INFO

ESRI Courses
- Applications Programming (AML)
- ARC/INFO Processing Techniques
- ARC/INFO Systems Programming
- Cartographic Production
- Geographic Analysis
- Introduction to Database Design
- Introduction to the COGO System
- Introduction to the TIN System
- Systems Administration for ARC/INFO

For each course the following information is presented:

- Description
- Status
- Audience
- Prerequisites
- Length
- List of topics to be covered in the course

Information for EPA's "Advanced INFO" course is obtained from the "EPA/NCC Training Course Syllabus" dated Spring, 1988, and developed by the National Data Processing Division's training office. The information for the ESRI courses is taken from the firm's "Training Center Announcement and Course Description" dated September, 1988, and developed by ESRI's Education and Training Center.

ADVANCED INFO

Description: For those who will be programming in INFO, this course builds on the material presented in "Introduction to INFO." The emphasis is on sound programming concepts and commands. Some time will be spent reviewing INFO commands, introducing commands that provide more efficiency in INFO, and accessing existing files.

Status: Henco, the vendor of INFO, will probably teach this course in the future under contract to NDPD. The course will be offered on an as-needed basis.

Audience: Experienced INFO users who want to expand their application of the package.

Prerequisites: Introduction to INFO

Length: Three days

Topics to Be Covered:
System design
Programming in INFO
Input forms
External files
Design notes
Programming techniques
Multi-user systems

APPLICATIONS PROGRAMMING (AML)

Description: This course is designed to give guidance for designing, building, and maintaining application programs written in the ARC Macro Language (AML). The course begins with an introduction to AML coding and exercises using AML. AML Users Guides are used heavily in all exercises. An overview of the System Design and Implementation Process (SDIP) is presented next. A group exercise is used to design and produce an application using AML and SDIP.

Status: This ESRI course has been taught to EPA staff. The course is included in the recommended GIS curriculum for EPA.

Audience: This course should be taken by GIS teams that are supporting GIS applications throughout EPA.

Prerequisites: Students must have taken the ARC/INFO Training Course or have the equivalent experience. They must also have more than six months experience working with ARC/INFO on a daily basis. Exposure to the project design process and experience with a programming language is strongly recommended.

Length: Two days

Topics to Be Covered:

Coding introduction
First AML macros
AML interfaces
System design and implementation process
Determine functionality
System design
Program specification
Production

ARC/INFO PROCESSING TECHNIQUES
NAVIGATING INFO

Description: This course deals mainly with structuring an ARC/INFO data base to minimize resource (computer and people) utilization. Particular attention is paid to large data bases (25,000 plus features).

There are three major sections. The first is an in-depth review of all the different types of relationships (RELATES) that can be established in INFO and how these relationships can be used to optimize resource utilization and perform basic data checking functions. Included in this first section is a thorough discussion of Item types, Relates, Reselects, Key Index Files, Double and Phantom Arrays, Redefined Keys, and External data bases.

The second section, Basic Processing, examines INFO programs and macros to do basic error checking, data base restructuring, histograms, and conflation.

The third section, Advanced Processing, is devoted mainly to line and network coverages and includes Node valence tables, dangling and orphan arcs, node-arc lists, ALLOCATE operations, geocoding, and linked list data structures.

The major objective of this course is to utilize INFO efficiently and creatively. After completing this course, students will be able to cut resource utilization in ARC/INFO by more than half in many instances.

Status: To date, this ESRI course has not been taught to EPA staff.

Audience: Experienced ARC/INFO users who want to increase their productivity and efficiency in the advanced processing of ARC/INFO data.

Prerequisites: Students must have taken the basic ARC/INFO Training Course and should have a minimum of six to twelve months experience in processing ARC/INFO data. Some experience with INFO programming techniques and exposure to basic AML macro-building is highly recommended.

Length: Two days

Topics to Be Covered:

Item definitions
ORDER, LINK, APPEND, SUMMARY, FILL, TABLE relates
RESELECTs
Program sections ODD and EVEN
Key index files
Double and phantom relates
Arrays
Adjacent and non-adjacent redefined keys
Kicker files
Missing and unknown codes, code occurrence
File restructuring
Splitting and coding arcs
Node valence
Dangling and orphan arcs
Arcs surrounding a node
Travel time to a node
Linked list navigation

ARC/INFO SYSTEM PROGRAMMING

Description: This course will show students how ARC/INFO can be used to develop system application programs. The architecture of the ARC/INFO system will be presented with a detailed description of the ARC/INFO data model and the subroutine libraries. The course is organized as a series of morning lecture presentations followed by programming workshops each afternoon. At the end of the course, the students will understand the internal architecture of the ARC/INFO system and the programming tools provided with it.

Status: To date, this ESRI course has not been taught to EPA staff.

Audience: Experienced ARC/INFO users who have the ability and the need to develop FORTRAN programs with the ARC/INFO software libraries.

Prerequisites: ARC/INFO Training Course, very experienced in the use of ARC/INFO, extensive FORTRAN programming knowledge

Length: Four days

Topics to Be Covered:

Architecture of ARC/INFO
ARC/INFO programming conventions
Reading and writing coverage data
Reading and writing attribute data
Interfacing ARC/INFO with other GIS data
ARC/INFO support modules
The ARC/INFO workstation concept
Tools for the user interface
Tools for graphic input
Tools for graphic display
Putting it all together -- ARCPLOT
Putting it all together -- ARCEDIT

CARTOGRAPHIC PRODUCTION

Description: Students will be introduced to basic cartographic theory of graphic layout, symbology, etc., and will use ARC/INFO to produce high quality, computer generated maps. Techniques to be utilized include creating custom symbols lookup tables, ancillary text (including titles, legends, keys, etc.), and the creation and use of map annotation with ARCEDIT and ARCPLOT. Emphasis will also be placed on the use of macros for producing a series of standard map products.

Status: To date, this ESRI course has not been taught to EPA staff.

Audience: New or experienced ARC/INFO users interested in producing high quality maps for presentation and display.

Prerequisites: Students must have taken the ARC/INFO Training Course. It is highly recommended that students have three to six months experience using ARCPLOT and ARCEDIT.

Length: Two days

Topics to Be Covered:

Cartographic design
ARCPLOT cartographic capabilities
Effective use of symbology and annotation
Cartographic production methodology
Advanced techniques with ARCEDIT and ARCPLOT
Developing and using macros for cartographic production
Creating custom fonts and symbol sets
Using the "Map Composer"

GEOGRAPHIC ANALYSIS

Description: The course will discuss the basic elements and concepts of geographic analysis as they relate to the functions of ARC/INFO. The process of developing and implementing logical models will be described, as well as basic modeling techniques using both spatial and thematic data. Emphasis will be on the use of INFO programming, together with macros for implementing the models.

Status: To date, this ESRI course has not been taught to EPA staff.

Audience: Experienced ARC/INFO users who want to increase their proficiency in geographic analysis and the process of developing and implementing complex spatial analysis models.

Prerequisites: Students must have taken the ARC/INFO Training Course. Some INFO programming experience is highly recommended for persons interested in this course.

Length: Two days

Topics to Be Covered:

Principles and concepts of geographic analysis
The analysis process/types of models
Model design and verification
INFO programming techniques for spatial analysis
Spatial and thematic modeling techniques
Modeling applications
- Suitability/capability modeling
- Forecast modeling

INTRODUCTION TO DATABASE DESIGN

Description: The course will give students an introduction to data base design methodology, including the considerations of project scope, resource requirements, users' needs, data sources, data quality, and data base project management. Students will acquire a basic knowledge of the concepts and process of designing and building a large, integrated GIS data base.

The course will also introduce students to the methods of building and maintaining a well-structured GIS data base. Included is a discussion of geographic control and registration, map preparation, data automation processes, automated map libraries, data dictionary, and data transfer/archival.

Status: To date, this ESRI course has not been taught to EPA staff.

Audience: The course is recommended for EPA's GIS teams, especially those who are designing and building new GIS data bases. It is recommended that at least one member of each GIS team take this course. Those who have sound experience in requirements analysis and logical and physical data base design in a non-GIS environment probably do not need the course.

Prerequisites: Students must have taken the ARC/INFO Training Course. It is highly recommended that students have at least six months experience in GIS applications or in traditional DBMS applications using a Relational Data Model.

Length: Three days

Topics to Be Covered:

User needs assessment
Requirements analysis
Conceptual design
Physical/detailed data base design

INTRODUCTION TO THE COGO SYSTEM

Description: The course will include a review of surveying and mapping principles, introduction to Coordinate Geometry (COGO), an overview of land records, a description and capabilities of the ESRI COGO system, procedures for processing COGO data, display of COGO data, and conversion of COGO data to ARC/INFO coverages.

Status: This ESRI course has been taught to EPA staff.

Audience: Experienced ARC/INFO users who have a need to input and manage coordinate data obtained from typical survey measurements and descriptions.

Prerequisites: Students must have taken the ARC/INFO Training Course. Students should be familiar with fundamental surveying and mapping principles, as well as the basic techniques of measuring and recording locations with standard surveying instruments. Some knowledge of legal descriptions is desirable for the course.

Length: Two days; A one-day version of this course has been taught to EPA staff.

Topics to Be Covered:

Review of surveying and mapping principles
Introduction to the ESRI COGO System
COGO data files
Processing COGO data
Locating points
Creating and processing traverses
Coordinate manipulation (transformation)
COGO feature description
Display of COGO data
Converting COGO data files to ARC/INFO coverages
Data management issues with COGO data

INTRODUCTION TO THE TIN SYSTEM

Description: The course will give students an introduction to the nature and characteristics of surface data and the TIN system. It will include the description of surfaces, sampling surface data, converting surface data from one form to another, the concepts of the TIN system, and the structure of TIN data. The course will also cover capabilities for analysis and display of TIN data, conversion of TIN data to other forms of data in the ARC/INFO system, typical errors in processing TIN data, and techniques for handling surface data.

Status: This ESRI course has been taught to EPA staff.

Audience: Experienced ARC/INFO users who have a need to do analysis/display of surface data, such as topography.

Prerequisites: Students must have taken the ARC/INFO Training Course. It is highly recommended that students have some familiarity with the use of Digital Elevation Models (DEM) or Digital Terrain Models (DTM). Prior experience with "raster" data, such as GRID, will be very useful in the course.

Length: Two days

Topics to Be Covered:

Surface data and sampling in TIN
Display and analysis products
Data input to TIN
Processing data with TIN
Using VIEW
TIN applications

SYSTEMS ADMINISTRATION FOR ARC/INFO

Description: This course teaches the skills, techniques, and knowledge required to install and maintain ARC/INFO software, the installation of graphics devices, and interface requirements for unsupported graphics equipment.

Status: To date, this ESRI course has not been taught to EPA staff.

Audience: Computer systems administrators at sites who are acquiring or have recently acquired ESRI software.

Prerequisites: Systems administration training from a site's computer vendor

Length: One day

Topics to Be Covered:

Process of ARC/INFO software execution
Steps for software installation
Confidence tests for installations
Device installation and interfacing
File protection and access considerations
Data base maintenance considerations
Data base and system back-up considerations
Customizing your ARC/INFO installation

VII. COURSE DELIVERY RECOMMENDATIONS

The success of any course in transmitting knowledge to students depends in part on the manner in which the course material is delivered. This section presents recommendations on delivery of the courses that are part of the GIS curriculum for EPA. Fundamental principles of training that can make the difference between a successful course and an unsuccessful course are discussed first, followed by a review of criteria that an instructor must meet to be qualified to teach these courses. Finally, brief consideration is given to facilities needed for effective training and to alternative training media.

A. Fundamental Principles of Training

Several fundamental principles of training that should be applied to all courses in the GIS curriculum are described in the following paragraphs:

- **Training should be done from a problem-solving and decision-making perspective.** Although GIS may be a new and interesting technology, the application of that technology to environmental problems and to Agency decision-making is the factor that drives the use of GIS in EPA. Course material should demonstrate how GIS will help EPA staff in their jobs. This especially should be done for the management "Executive Briefing." If managers do not understand how GIS will assist them in accomplishing the goals of their programs, the use of GIS in EPA will lag. Consequently, it is important that specific instructional material, especially in the core courses, be related frequently to environmental problems and decision-making.

- **Train by EPA-related examples.** One of the best ways to relate course material to a problem-solving and decision-making perspective is to train by EPA-related examples. Using a data base that contains data familiar to EPA staff is one method to constantly reinforce the application of GIS to EPA's work. In addition to using an environmental data base, all methods of analysis should be illustrated by examples of situations in which those analytical methods have been (or could be) used in EPA. For instance, the concept of buffer generation could be demonstrated in ARC/INFO by creating areas around streams where landfills are prohibited. Actual EPA projects in which buffer generation has been used could also be cited.

Besides using examples to illustrate analytical methods, basic concepts presented in the courses should also be supported by examples. Although it might not be practical to provide an EPA example for every concept that is discussed, groups of concepts could be illustrated with an example that emphasizes the importance of understanding the basics. Providing negative examples of problems that could develop if fundamental concepts are ignored or not understood is also an effective way of reinforcing material whose importance may not be apparent. For example, the "Geographical Analysis and Fundamental GIS Concepts" course describes basic

mapping concepts (reference Appendix A). As a group, these concepts could be illustrated by citing a situation in which failure to understand the implications of different map scales or projections could result in erroneous conclusions about information displayed on such maps.

- **All courses involving software training should include hands-on exercises.** Hands-on exercises are vital in reinforcing concepts that have been introduced through lectures. It is only after a student has had actual experience with a software product that the student really understands how to use that product.

- **Relate technology and information back to the decision-making process.** This principle is tied to the principle of training from a problem-solving and decision-making perspective. In a GIS course, it is easy to become so involved in techniques or in colorful, graphical outputs and the supporting hardware that an overall perspective of applying technology to decision-making is lost. In all GIS courses the interrelationships between technology, information, and the decision-making process should be reinforced periodically. Students should be reminded that the purpose of GIS technology is to provide better ways for applying spatially-based information to the decision-making process. With this perspective, students will be more likely to structure data gathering, analysis, and output activities around an environmental problem or decision, rather than structuring a problem or decision around an exciting technology.

- **Remember who the audience is.** As described in Section III, different groups in EPA have different training needs. Instructors must always remember who the audience is for a specific course because different types of information are important to different groups. For example, all course material for senior managers eventually must be tied to the impacts of GIS on programs and to required resources. Although technical information may be interesting to an instructor, senior managers will quickly lose interest in a course that concentrates on technology as opposed to the impacts of applying that technology.

- **Students should be given handouts appropriate to the course.** At a minimum all courses should provide students with copies of the slides or overhead transparencies used in the course. If possible, these handouts should contain more details than could be included on the slides or transparencies. The handouts also must be available for the first day of class so notes can be taken on the handouts. For all courses with exercises, complete procedures for arriving at the answers to the exercises should be provided. Additional exercises and listings of sample data bases for the exercises are valuable material that will assist those students who want more practice in applying course concepts.

- **Students should be given time to review and practice with sample data after a course.** One of the most counterproductive occurrences that can affect the success of training is to have a long period after the completion of a course before

students can apply the course material. This is especially true for detailed technical material such as that in ARC/INFO courses. Although this is properly a management issue, it is important to emphasize the need for students to apply their new knowledge soon after completion of a course. For those students who take the two segments of the revised ARC/INFO course several weeks apart, the period between the two one-week segments must include review and practice time with a sample data base. Otherwise, the second week of the course will be less beneficial than it could be. Managers should provide for review and practice time in the work loads of students taking the two-week ARC/INFO course. As mentioned earlier in this report, students also should not take the two-week course unless their site has installed ARC/INFO or will be installing the package within one month.

B. Criteria for Qualified Instructors

Qualified instructors for EPA's GIS curriculum should meet several criteria in addition to having good teaching skills. One of the most important of these criteria is having a sound understanding of how GIS can be applied to environmental problems. As discussed above, GIS is important to EPA in terms of how it may assist the Agency in accomplishing programatic goals and in making decisions. If an instructor does not appreciate how GIS can assist in these ways, then the course will not be as successful as it could be.

Understanding the application of GIS to environmental problems is an important criterion for good ESRI instructors as well as for EPA instructors. EPA has requested that ESRI have a small set of instructors that teach all courses offered to EPA, so that these instructors will become familiar with Agency needs and applications. EPA should continue its efforts to ensure that ESRI provides qualified instructors that understand EPA's GIS applications.

For each course that is part of the recommended curriculum, the instructor obviously must possess expertise in the specific course material that will be taught. Knowledge about ARC/INFO does not by itself qualify an instructor to teach other courses. For example, an expert in basic ARC/INFO who has minimal experience in TIN should not be teaching a course in TIN. Likewise, instructors should have experience in the particular operating system on which a course will be taught. VAX experience is not sufficient to teach a course on a PRIME.

Because qualified instructors for EPA's GIS courses must understand GIS software and its application to environmental problems, it should not be assumed that instructors for EPA's data processing courses can also be effective GIS teachers. **Data processing training experience cannot substitute for GIS knowledge when GIS instructors are selected.** Since sufficient lead time may be required to recruit qualified GIS instructors, decisions on which office(s) will be responsible for developing and delivering each of EPA's GIS courses should be made as soon as possible.

C. Facilities Needed for Effective Training

The quality of training facilities impacts the overall success of a training course. Both the training facility itself, the availability of hardware and software needed for GIS training, and the support staff are important to the quality of a training center.

The room where training is conducted should be large enough so that there is enough space for students to spread out with their training materials and take notes. The room should have equipment for showing slides and overhead transparencies as well as a projection system or large monitor for the terminal used by the instructor. Since much of the training in ARC/INFO classes is through online demonstrations and examples, students must be able to see clearly the instructor's demonstrations, without having to crowd around one terminal. The room must also be arranged so that all students have unobstructed views of projected materials.

Special hardware and software needed for GIS courses include a digitizer, graphics terminals and terminal emulators, a plotter-screen dump facility, and a printer. If EPA moves to a workstation platform for GIS in the future, a workstation must also be available in the training facility. The importance of having all appropriate equipment for GIS training cannot be emphasized enough, because the courses are far less effective if various operations cannot be demonstrated. There should be enough graphics terminals so that one terminal is shared by no more than two students. There should also be sufficient desktop space around each terminal so that manuals and papers can be laid beside each terminal while students are conducting online exercises. At least one complete set of documentation appropriate to the class must be available for student use. This documentation would include manuals for ARC/INFO and its various modules, INFO, the system's text editor, operating system file management commands, and the terminals or terminal emulators in use. If terminal emulators are used, keyboard templates should be available for all of the training terminals.

The support staff for a training center is key to its smooth operation. If hardware, software, or other equipment malfunctions, quick resolution of the problem is often critical for students to get the full benefit from a training session. Qualified support staff should be readily available to provide such services when needed.

D. Alternative Training Media

At the present time training media that are alternatives to instructor-led courses are very limited for GIS. ESRI is completing PC training modules for PC ARC/INFO which will eventually serve as prototypes for self-training on other hardware platforms. The PC-based training will guide a user at a PC through a training session and will be supplemented with workbooks. ESRI also is in the process of developing videos for PC ARC/INFO modules, in addition to the video that has been available for some time on the PC ARC/INFO Starter Kit. Despite these efforts the most viable training vehicles

for the next year or two are the instructor-led courses that combine lectures with hands-on experience.

VIII. TRAINING SUPPORT WITHIN EPA

This section lists support to GIS training that can be provided by several offices within EPA, specifically by EMSL-LV, the National Data Processing Division, and the EPA Institute. Consideration is also given to the need for support of "continuing education" for GIS.

A. Support by EMSL-LV

In its role as a primary center for research and support of GIS within EPA, the Spatial Analysis Laboratory of the Environmental Monitoring Systems Laboratory in Las Vegas (EMSL-LV) has identified several ways in which the unit has or can support GIS training within the Agency. One way that EMSL-LV already has assisted Agency training efforts is by providing suggestions to ESRI for improvements in its two-week ARC/INFO training course. In February and May, 1988, EMSL-LV staff met with ESRI training personnel to recommend improvements in the course. During another meeting in September, 1988, ESRI indicated that the two-week course was being revised and that many of EMSL-LV's recommendations were being addressed by the revision. ESRI has recently invited the Manager of the Spatial Analysis Laboratory to sit on ESRI's Educational Review Board. Through this opportunity, EMSL-LV will have an ongoing forum through which to provide input to ESRI on all of the firm's training.

EMSL-LV has also supplied a training data base and training exercises to be used by ESRI in the two-week ARC/INFO courses taught to EPA. Both the data base and exercises were designed as "stop-gap" measures until ESRI provides a training course more tailored to EPA's needs. Use of a data base that is relevant to EPA's work has made ARC/INFO training more applicable to EPA staff.

A third way that EMSL-LV may support GIS training is by providing on-site assistance to a Region or office after the basic ARC/INFO training course has been taken. An important factor contributing to the success of initial GIS projects is to have on-site expertise immediately after the basic ARC/INFO training course. This on-site support will allow novice ARC/INFO users to receive immediate answers to their questions as they are implementing the software for the first time. If this support is given by EPA, rather than by ESRI, novice users will also benefit from accrued Agency expertise in applying GIS to EPA programs. EMSL-LV has provided on-site support to Regions I and VII and has indicated that it may be able to offer on-site support to supplement basic ARC/INFO training.

EMSL-LV's GIS technical memoranda are another direct support to GIS training. The first memorandum is entitled "GIS Project Planning and Data Set Selection" and gives valuable information on those two subjects. Other memoranda that are currently in the draft stage deal with Digital Line Graph processing and the one-to-many relation

in ARC/INFO. These memoranda are an important source of ongoing GIS training within EPA.

Finally, EMSL-LV recognizes the need for special management education for GIS. EMSL-LV has indicated its willingness to provide input to the development of management training.

B. Support by the National Data Processing Division

The National Data Processing Division's (NDPD) training office at Research Triangle Park (RTP), North Carolina, and its Washington Information Center (WIC) in Washington, D.C., provide data processing training to EPA. . Contract support managers at both centers have stated a desire to be involved with GIS training. That involvement could include support in the preparation of EPA's GIS courses as well as in teaching those courses, if it is cost-effective to do so and if the sites have appropriate facilities for GIS training. Both sites have a staff that is experienced in developing and giving data processing classes, although it should be noted that data processing training experience does not by itself qualify someone to develop and teach GIS courses (reference Section VII.B). Both sites also handle all administrative details of course registration, student notification, prerequisite checks, and course set-up for those courses that are offered through their offices. Their courses are publicized in a monthly schedule of classes. NDPD has a GIS Support Group at RTP which provides user support for GIS hardware and software on NDPD's VAX system and technical expertise for GIS applications.

NDPD's office at RTP has procured all equipment needed for a GIS training facility. This training facility includes the following equipment:

- Ten PCs with Tektronix emulation software that are connected to NDPD's VAX cluster; These PCs are all located in the GIS classroom.
- Instructor PC with Tektronix emulation software and a 25-inch monitor for demonstrations
- An adjacent workroom / GIS support area equipped with:
  - Sun and Tektronix graphic workstations
  - Printer
  - Digitizer
  - Plotter facility

With the establishment of a fully-equipped GIS training facility, it is recommended that EPA use the NDPD facility at RTP as a training site for those in EPA that do not receive on-site training. As a training program is planned, NDPD should be consulted in greater detail regarding the level of support that could be provided by it facilities at both RTP and the WIC.

C. Support by the EPA Institute

The EPA Institute provides in-house training to EPA employees in a variety of areas, including job skills, program-specific topics, and training on how to share one's expertise and knowledge with others. The EPA Institute has recently compiled a catalogue of courses offered throughout EPA. The catalogue includes courses taught not only by the EPA Institute but also by other offices, the Regions, and the Labs.

As a GIS training program is implemented in EPA, GIS courses could be listed in the EPA Institute's catalogue. This would increase the publicity for GIS courses within all parts of the Agency. EPA instructors for GIS courses may also wish to take the Institute's instructor training course, which covers effective presentation methods and training techniques.

D. Continuing Education for GIS

Even after individuals have taken several GIS training courses and are experienced ARC/INFO users, there remains the need to keep up with new developments in a rapidly changing technological environment. Some methods for meeting this need for continuing education are as follows:

- As discussed in Section IV, an Agency-wide GIS user group could be established to transfer techniques and tips on the use of ARC/INFO, macros, and other advanced knowledge related to the use of GIS.

- Technical memoranda like those produced by EMSL-LV are a good mechanism for communicating GIS expertise throughout the Agency.

- Workshops or seminars on specialized applications of GIS could be offered by those who have implemented such applications.

A. OUTLINE FOR A COURSE IN GEOGRAPHICAL ANALYSIS AND FUNDAMENTAL GIS CONCEPTS

This appendix presents an outline for a course in "Geographical Analysis and Fundamental GIS Concepts." The purpose of this course, which is part of the recommended GIS curriculum for EPA, is to instruct end-users and technical implementors in basic concepts of mapping, geographical analysis, and GIS. The course is designed to be a good introduction to GIS for those with no prior exposure to the subject. Technical implementors who have worked with GIS and have a good understanding of mapping concepts and geographical analysis do not need to take the course.

As discussed in Section IV, ESRI's "Introduction to GIS" is a sound base for developing the EPA course outlined in this appendix. The EPA course is intended to go beyond the ESRI course in two ways:

(1) ESRI's "Introduction to GIS" takes a technology-based approach in introducing basic GIS concepts. The EPA course outlined here takes a problem-solving approach in presenting GIS concepts and emphasizes the application of GIS to EPA programs.

(2) The EPA course stresses basic concepts of mapping and geographical analysis, which are only touched on lightly and indirectly in the ESRI course. Since the use of GIS depends on an understanding of fundamental mapping concepts and principles of geographical analysis, it is important that all end-users and technical implementors of GIS understand these concepts.

In the outline below, special mention is given to those sections that relate to these two differences.

To make this course particularly relevant to EPA, examples related to environmental problems should be used throughout the course to illustrate concepts. Section VII of this report describes the importance of training by example.

A Course in Geographical Analysis and Fundamental GIS Concepts

I. Introduction -- placement of GIS and its use in perspective

A. What is GIS?

GIS is a system to collect, store, retrieve, analyze, and display geographical data. GIS requires special hardware, software, data, and staff with

specialized expertise. Software packages called Geographic Information Systems provide for input, storage, retrieval, analysis, and display of geographical data. ARC/INFO is a GIS package that is the GIS software of choice for EPA.

B. What are geographical data?

Geographical data have a locational component that can be tied to a position on the earth. For example, data on public water supply wells are geographical data if locations for the wells are part of the data base. "Geo-based" data and "spatial" data are other ways of referring to geographical data.

C. Why use a GIS?

1. Location is a valid basis for analysis in EPA. Every environmental phenomenon or occurrence has a spatial component which may, in fact, contribute to an environmental problem. For example, the proximity of hazardous wastes to public water supply wells or aquifers may threaten the health of the population getting its water from those wells. The location of the hazardous wastes and wells near each other is a major factor contributing to a potential problem. If the hazardous wastes were in another location far from wells, aquifers, and population centers, then the likelihood of the hazardous wastes creating a health problem would be reduced.

   Because location is an important factor in environmental problems, EPA needs to use technology that can analyze and display geographical data in a meaningful way that aids in both the comprehension of complex environmental problems and decision-making about such problems. GIS is a technology that is designed to process, analyze, and display data with a locational component.

2. Present several brief examples of the use of GIS in EPA.

3. Other benefits of using GIS
   a. GIS adds new capabilities to EPA, since many spatial analysis techniques are too time-intensive to be done without an automated tool like GIS.
   b. GIS can be used as a technique for organizing geographical data. This provides for better data management.
   c. By using GIS as a data management tool, the quality, timeliness, and access to information improve.
   d. GIS increases productivity (e.g., in map production).

D. The concepts of geographical analysis that are automated by GIS are not new but have existed for years. GIS merely is a new technology that effectively automates the application of these concepts. The development of GIS has been based on developments in relational data base management systems, computer graphics, and personnel computers.

E. The concept of conducting spatial analyses within EPA is not a new idea. EPA has used spatial analysis with some existing systems written in-house, such as STORET. GIS greatly adds to capabilities of existing systems.

F. GIS differs from Computer-Aided Design (CAD) and mapping tools such as SASGRAPH. Neither CAD nor SASGRAPH deal with analyses of spatial data that depend on the relative locations of that data. These other tools have important uses, and it is essential to use the right tool for the right job.

G. GIS is a technology that can bring locational information about environmental problems to bear on the decision-making process.

II. Concepts of mapping and geographical analysis

This section of the course describes basic concepts of mapping and geographical analysis that generally are mentioned only indirectly in ESRI's "Introduction to GIS" course. Because GIS is a tool for geographical analysis, users of the technology must understand these fundamental concepts.

A. Basic mapping concepts

1. Scale
   a. Describe the difference between small-scale maps (maps that cover a large area) versus large-scale maps (maps that cover a small area).
   b. Present different methods of representing scales. These should include the scale bar on a map and the ratio notation (e.g., 1:24,000).
   c. List commonly-used scales of maps (1:24,000; 1:250,000; 1:1,000,000).

2. Resolution
   How features are represented on a map depends on scale. For example, the width of a river may be shown as a band with width on a large-scale map but as a line with no width on a small-scale map.

3. Accuracy
   The accurate placement of features on a map depends on scale, material of which the map is made, width of pen lines, etc.

4. Coordinate systems
   The purpose of coordinate systems is to tie positions on maps to specific locations on the earth. Describe several major coordinate systems.
   a. Latitude/longitude
   b. UTM
   c. Township/range

5. Map projections
   Because the earth is a three-dimensional sphere and most maps are two-dimensional planes, special methods have evolved over many years for representing the unavoidable distortions that occur when a three-dimensional object is represented in two dimensions. These methods for producing maps are called map projections. Since distortions are inherent in all maps, it is important to understand the basic classes of projections, their inherent inaccuracies, and when they should or should not be used. For the two classes of projections described below, examples should be given of an inappropriate use of the projections.
   a. Equal-area maps -- Sizes of areas are represented accurately, but shapes are distorted.
   b. Conformal maps -- Shapes are represented accurately, but sizes of areas are distorted.
   c. There are many types of equal-area and conformal map projections, as well as other classes of projections that are not used as frequently in the kinds of maps utilized by EPA.

B. Major types of maps

Identify major types of maps that are often used in environmental work.

1. Topographic maps
   These maps are produced by the U.S. Geological Survey and show transportation, hydrography, elevation, settlements, and other man-made features. The concepts of using contour lines to represent elevation and of deriving slope from this information should be explained.

2. Isarithmic maps can be used for other variables besides elevation (e.g., temperature, rainfall).

3. Thematic maps
   Maps can be used to show the spatial distribution of anything that varies over space.

C. Statistics and maps

1. Descriptive statistics, such as means, medians, and regression coefficients, are often represented on maps. Any statistic that can be calculated for mapped phenomena can also be mapped. The calculation of descriptive statistics does not depend on the location of the phenomena and can be calculated whether the location of the phenomena are known or not.

2. Spatial statistics are those statistics that are dependent on the location of phenomena. The area of spatial statistics is less developed than the area of descriptive statistics. Examples of spatial statistics include measures of spatial autocorrelation

D. Simplified explanation of topology

1. Spatial relationships between map features are shown implicitly on maps, and our minds interpret these relationships. These relationships include adjacency and connectivity.

2. Adjacency (or contiguity) refers to the relationship of two features being next to each other. For example, determining the counties bordering a polluted stream involves adjacency relationships.

3. Connectivity refers to a link between two map features. For example, finding the safest route for a truck carrying hazardous wastes between two sites involves connectivity relationships.

4. By mapping data, our minds can see spatial relationships that are too complex to understand by looking at tables of data.

5. In digital maps in a computerized data base, spatial relationships like adjacency and connectivity are represented by data structures that store these relationships, or topology.

E. Basic concepts of spatial analysis

1. Map overlay
Map overlay is one of the most basic methods of spatial analysis and has been done for years using transparent maps. Different variables are mapped on separate maps of transparent material. The maps are then overlaid on each other on a light table to determine where the boundaries of the maps match and which areas have specific values for the several variables. In his book Design with Nature, Ian McHarg, a well-known landscape architect, was one of the earliest advocates of

using this technique in planning. Several examples of using the overlay concept with environmental problems should be given in the course.

2. Buffer generation around points and lines
   A buffer is created around a point or line to identify an area associated with that point or line. The purpose of buffer creation may be to identify an area where particular activities may not occur. For example, a buffer may be identified around a wellhead to designate an area where landfills and other disposal activities are prohibited.

3. Location/allocation
   a. Locating a facility or series of facilities (or points) to best serve a target population (or area) is a common problem in geographical analysis. Typically, locations are chosen to minimize or maximize a set of variables, subject to constraints. For example, determining the locations of recycling drop-off sites could be done to maximize the accessibility of the surrounding population to those sites.
   b. Allocating areas to a set of existing facilities is the reverse situation from the location problem described immediately above. For example, several radon sample readings are obtained at different locations in a zip code area as part of a project to map sample radon readings. Allocation occurs when deciding which parts of the zip code area should be mapped as having which radon values.

   To summarize, the "location" problem starts with a known area and tries to find the best location for facilities in that area. The "allocation" problem starts with known locations for facilities and tries to distribute parts of an area to those facilities.

4. Network route finding
   This process tries to find the best route based on some criterion, such as minimizing distance or time traveled, subject to constraints. For example, it may be required to find the best route for transporting hazardous waste that minimizes distance but avoids population centers with greater than 100,000 persons by a distance of ten miles.

III. GIS concepts

A. Representation of data in a GIS
   The material in this section is intended to convey the level to which the structure of data in a GIS should be described in the course. A very basic and relatively non-technical approach is taken, since only basic information on data structure is required by students taking the course. Technical implementors that need more information on ARC/INFO's data structures will receive that instruction in the two-week ARC/INFO course.

1. A GIS combines locational (spatial) and descriptive (attribute) data about features that can be mapped.

2. A GIS contains many layers (or coverages) of different types of data for the same geographical area. Examples of layers that might be needed include topography, water features (hydrography), roads, land use and land cover, and special layers for the problem at hand, such as RCRA and Superfund sites.

3. The following three types of map information are represented in a GIS.
   a. **Map features** (e.g., counties, land use patterns, roads, streams, landfills, public water supply wells)
      Two major ways have evolved for representing map features in digital form:
      (1) Raster (or grid): A grid is placed over a map. Each cell is assigned a value based on the feature that occurs in that cell. A separate layer is coded for each type of data.
      (2) Vector (or arc/node): On a map, features can be described as areas, lines, or points. In the vector method of representation, these features are represented as polygons, arc, nodes, and points that are comprised of series of (X,Y) coordinates. The vector representation method is used by ARC/INFO.
   b. **Characteristics of map features** (e.g., the name of a county, type of crops grown, the type of road)
      On a map, characteristics of map features are represented by the type, size, color, shading pattern, and the like of the symbols used to designate the features. Text on maps also conveys feature characteristics. In ARC/INFO, characteristics of map features are stored in an INFO data base and are linked to the map features (or spatial information) by common identifiers in the data base (keys).
   c. **Spatial relationships between the map features** (e.g., adjacency and connectivity of features)
      On a map spatial relationships are represented implicitly, and our minds interpret those relationships. In ARC/INFO, spatial relationships are represented by special data files created for that purpose. These files store information on:
      (1) which polygons are on the left and right of each arc
      (2) which points (nodes) are the starting and ending points for an arc
      (3) which arcs make up the boundaries of each polygon
      By storing these relationships (i.e., topology), ARC/INFO is able to reproduce spatial relationships between map features.

4. A true GIS combines topology and attribute data with spatial features. A mapping package or CAD system does not store topological relationships.

5. As stated above, ARC/INFO uses the vector structure and has a module to convert data from its format into a grid structure. The course should briefly describe advantages and disadvantages of the vector and grid data structures.

B. Use of a relational data base management system in GIS

1. A relational data base management system is used in a GIS to store data that are attributes of geographic features. INFO is the relational DBMS used in ARC/INFO.

2. A relational DBMS uses basic concepts of Boolean algebra to retrieve data.
   a. Common operators are: EQ, NE, LE, LT, GE, GT, AND, OR, NOT
      The course should provide graphical examples of the uses of AND, OR, and NOT.
   b. In a relational DBMS, common identifiers (keys) are used to relate spatial and attribute data of features. Each feature has a key that uniquely identifies that feature. This key is repeated in every record that contains information about that feature.
   c. The course should provide examples of the use of operators to retrieve data in queries.

3. As described earlier in the course, the development of GIS has depended in part upon the development of relational DBMS's.

C. Phases of a GIS project

This section describes GIS through a problem-solving perspective. The basic phases of a GIS project are identified, and through those phases, the functions of a GIS are described. ESRI's "Introduction to GIS" treats the functions of a GIS independently rather than describing those functions in the context of applying GIS to a problem. As each of the project phases described below is discussed in the course, it should be illustrated with an actual EPA project that has utilized GIS.

1. Problem definition and planning
   a. This is the most important phase of a project, since the questions to be answered, the data to be acquired, and the general scope of the analyses to be done are defined in this phase. If the problem to be

addressed by GIS is poorly defined, the project will be unfocused and will risk time and cost overruns.

b. The "GIS Planning" course, which has been recommended as part of EPA's GIS curriculum, will address this phase of a GIS project.

2. Data acquisition / data capture / data input
   a. During the data acquisition phase, data for a project are located and acquired. The data that are needed for a project were determined in the problem definition and planning phase.
   b. Both spatial and attribute data for the project's planned analyses need to be acquired.
   c. Data acquisition is typically the most time-consuming phase of the project. If existing digital data files cannot be obtained, the data acquisition phase may require 90 percent of the entire project's time.
   d. Several methods of getting data include digitizing, scanning, acquiring existing data bases from other GIS's, and converting data with locational information from other data bases into GIS coverages. The course should briefly explain the processes of digitizing and scanning in a non-technical way.
   e. Prior to entering data into the data base, careful work needs to be done to create a data base structure that will permit easy and efficient retrieval and maintenance of the data. Data base design typically proceeds in conjunction with data acquisition activites and must be completed before data are actually input into the data base.
   f. Data that are input into the GIS data base must be verified and edited to correct errors. One technique of doing this is to map each data layer to see if the distribution of the data appears reasonable, based on the user's knowledge of the subject.
   g. Data standards and documentation must be considered during this phase. Data that are acquired or new data bases that are created through digitizing or scanning must comply with standards needed to effectively utilize that data (e.g., have a common geographical reference). Standard documentation for each data layer should also be prepared.
   h. Quality assurance/control issues also must be considered. The quality of data that is required for a specific project depends in part upon the scale of analysis for the project and the uses of the data. For example, analyses that may lead to legal actions with a Superfund site require data of much higher quality than a project that is examining ozone patterns in a metropolitan area. Data quality must also be balanced against the time and cost required to obtain high quality data.

3. Data base storage and management
   a. Problem definition and the data required for a project greatly impact the data base design. As mentioned above, the data base design must permit easy retrieval and maintenance of the data.
   b. Data base management includes routine operations of creating, deleting, updating, copying, and renaming files.
   c. Routine backups of the data base must be performed by the computer system staff.
   d. Data base security is an important part of data base management. Who will have access to what data and the level of access they will have (read only, read/write, read/write/delete, etc.) must be determined. The effort devoted to data security will vary by type of project (e.g., more security for a Superfund project which may result in legal action).
   e. Data archiving is another issue that must be addressed. The amount of data to be retained on-line or archived, the period of on-line retention, and the ease of accessing archived data must be weighed against the likelihood of needing archived data and costs of keeping data on-line.

4. Data manipulation and analysis
   a. This part of the project is the phase where the power of a GIS is applied to the data in performing analyses appropriate to the problem. The analyses to be done are dependent upon the problem that has been defined and the data that have been acquired.
   b. Data manipulation includes operations such as changes in scale and projections, edgematching, and erasing boundaries. The course should briefly describe some of these operations through diagrams and examples of when they would be used.
   c. Data analysis in a GIS applies those concepts of geographical analysis described earlier, such as overlays and buffer generation. Examples of using overlays and buffer generation should be given by both demonstrating these techniques in ARC/INFO and citing uses of these techniques in actual EPA projects.
   d. A large part of data analysis also consists of ad hoc, interactive user queries of both spatial and attribute data. The use of queries should also be demonstrated in ARC/INFO and through referencing query use in EPA projects.

5. Data display
   a. Data display consists of both maps and reports. Examples of a variety of the types of maps that can be produced with ARC/INFO should be shown.
   b. Data display products can be produced both at a terminal and as hard-copy. Brief reference should be made to the range of output

devices (e.g., graphic terminals, several types of plotters, graphic printers).

c. Although data display is listed as the fifth phase in a GIS project, data display may, in fact, occur throughout the project. Data may be mapped in the data acquisition phase as a method of verifying data quality. The first step in data analysis may be mapping various coverages to view spatial distributions and patterns of data. Typically, analysis and display operations will be done in coordination as the results of one analysis are displayed before another analysis is done.

6. Application of the results of data analysis to the original problem
This final phase of a GIS project seeks to answer the questions that were asked in the problem definition phase. The results are applied to any decision-making process that the project was designed to assist.

IV. Implementation of GIS at EPA

A. Use of GIS at EPA -- Reference the GIS case studies document, which describes numerous GIS applications throughout the agency.

B. How to get started with GIS

1. Reference the GIS handbook, which lists EPA resources that can provide help with GIS.

2. Reference other courses in EPA's GIS curriculum that are currently available.

C. GIS tools at EPA

1. ARC/INFO: EPA's GIS software of choice
List and briefly describe the various ARC/INFO modules.

2. Hardware platforms on which ARC/INFO is operational at EPA
   a. VAXs at NDPD and at the labs
   b. PRIMEs at the WIC and the regions
   c. Common types of graphics terminals and plotters in use at EPA

D. Data sources

1. Idenfity geo-based data readily available from EPA and other federal agencies.
   a. EPA data

b. USGS data -- Digital Line Graph (DLG) and Digital Elevation Model (DEM) data
c. Bureau of Census DIME and TIGER data files

2. EPA's data clearinghouse is a source of information about data.

B. OUTLINE FOR A COURSE IN GIS PLANNING

This appendix presents an annotated outline for a course in GIS Planning. This course is part of the recommended GIS curriculum for EPA and should be taken by both technical implementors (GIS teams and their managers) and end-users (environmental scientists and their managers).

Much of the outline is based on EMSL-LV's GIS Technical Memorandum 1-88, "GIS Project Planning and Data Set Selection". The Memorandum was written by Mason J. Hewitt, III and Eric N. Koglin of EMSL-LV and by Richard A. Dulaney of Lockheed Engineering and Management Services, Inc. Substantive comments on the need for a GIS planning course made by Tom Scheitlin of Unisys Corporation, GIS Technical Support at EPA's NDPD, have also been incorporated into the outline.

A Course in GIS Planning

I. Introduction -- importance of planning a GIS project

A. Because GIS projects can be very consumptive of time and resources, especially if lengthy data collection efforts are undertaken, planning a GIS project is critical to its success. By careful planning, resource requirements can be determined in light of available project funding.

B. Simpler technologies should be used for projects whenever those technologies will do the job. Basic guidelines and examples could be presented of when a GIS is not needed and a simpler technology, such as SASGRAPH, is preferable.

II. Life-cycle of a GIS project

A. Planning phase

Planning a project requires both end-users and GIS staff and a substantial time commitment from both groups. The level of involvement of end-users is especially important. With only limited involvement of end-users in the planning phase, projects run the risks of delays and failure because various data requirements or other project needs may go unconsidered until a much later stage in the project. As the following steps in the planning process are described, key decision points should be highlighted.

1. Define the objectives of the project. How GIS will support these objectives must also be stated clearly.

2. Define major decisions to be made and questions to be answered by the project. Based on these decisions, define the quality of data needed to make these decisions (Data Quality Objectives). Consideration also should be given to the spatial accuracy of data that are needed.

3. Define information needed for the project based on the objectives and decisions to be made. A matrix of project questions and decisions versus data needs may assist in this effort. Project staff also must have some plans regarding how the data will be used in the GIS to answer project questions. At this time a second matrix of data needs versus data sources should be constructed.

4. Determine the availability of data that are needed for the project. Categorize the data into three groups:
   a. Data you have
   b. Data someone else has
   c. Data that no one has

5. Determine whether the data that are available (data that you or someone else has) are adequate for the project. Project objectives, data quality objectives, and the project's timeframe, which may or may not allow time to acquire new data, must be considered in evaluating available data.

6. Analyze estimated project costs and the costs of the various types of information needed for the project. Based on these estimated costs and available funding, determine whether project objectives need to be revised in light of available funding and data. If so, recycle through the previous project planning steps.

7. Based on data that will be obtained for the project, define in more detail the analyses that will be performed in the project. If there are project questions where a method of analysis is not clear, define prototypes that may assist in developing a method of analysis.

B. Implementation phase

Although much of the work in the implementation phase is done by the GIS staff, end-users have a role in the various steps of implementation, and that role should be emphasized in the course. End-users have major responsibility for verifying data quality, reviewing and testing the design and operation of applications, providing direction in performing analyses, evaluating results, and drawing conclusions based on the analyses.

The activities of the GIS staff in the various steps of the implementation phase listed below should be described so that end-users have a good understanding of the life-cycle process of a GIS project. Key decision points should be stressed so end-users understand the implications of changing project scope, design, or data requirements at various points in the life of the project. At the same time, it must be recognized that as end-users become more familiar with GIS technology and it capabilities, end-users may wish to refine the scope of a project to utilize GIS capabilities that they did not fully understand during the project planning phase. If a project's scope is to be refined, some planning activities will have to be repeated, perhaps after implementation has already started. When refining a project's scope, careful consideration must be given to potential impacts on resources budgeted for the project and on estimated completion dates.

1. Data base design

2. Logical system design
   If the objective of a project is to develop an ongoing application, the end-users of that application should review all aspects of the user interface, including menus, data presentation screens and graphics, and methods to navigate through the application, as well as analytical operations to be performed by the application. End-users should understand the importance of contributing their comments at this stage of application development before numerous macros have been written. The GIS staff should understand the need for end-user review of the application design.

3. Data capture and automation

4. Review and production of maps for data quality assurance
   End-users need to participate in the review of GIS outputs produced for quality assurance.

5. Development and testing of the GIS system
   End-users should participate in testing and reviewing the system. This will typically require end-users to identify sample questions that can be used to test the system.

6. Production
   From this point onward, end-users access the GIS system and/or work with the GIS staff to conduct analyses directed towards the objectives of the project.

III. Demonstration of the project planning phase through examples

To assist end-users and GIS staff in understanding the project planning phase, three scenarios of the planning process should be presented in the course. The planning required for a small, a medium, and a large project should be described and contrasted. This will allow a comparison of the planning effort needed for different types of projects and the implications of that effort on required resources and budgets. If possible, these scenarios should be supported by examples of both successful projects and projects in which inadequate planning resulted in problems.

IV. Data set identification and selection

A. Identify sources of data that frequently are used in projects on environmental problems. Methods and resources for identifying data sources, such as OIRM's data clearinghouse prototype should be described.

B. Discuss important factors to consider in selecting the scale or source of base coverage data. Specific types of data to discuss include:

1. Digitial Line Graph data
2. Land use and land cover
3. Topography
4. Census geography
5. Demography

C. Provide lists of base ARC/INFO coverages that are available from EPA. Some indication of the quality of these coverages and their appropriate uses should be given.

C. LIST OF INTERVIEWEES

EPA HEADQUARTERS

Office of Information Resources Management, Program Systems Division

Joe Sierra	National GIS Coordinator
Ed Partington	Systems Integration Branch

Office of Administration and Resources Management, Washington Information Center

Sandra Gill	Contract support manager

Office of Human Resources Management, Human Resources Development Division

Kerry Weiss	Director

Office of Toxic Substances

Loren Hall	Exposure Assessment Branch

ENVIRONMENTAL MONITORING SYSTEMS LABORATORY -- LAS VEGAS

Spatial Analysis Laboratory

Mason Hewitt	Manager

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

NATIONAL DATA PROCESSING DIVISION

Contract Support

Tom Scheitlin	GIS Technical Support
Gene Costello	GIS Technical Support
Pat Straw	Manager, Training Support

ENVIRONMENTAL RESEARCH LABORATORY -- CORVALLIS

Contract Support

Denis White	Geographer
Andrew Herstrom	Geographer

REGION I

Information Management Branch

Michael MacDougall	Chief
Greg Charest	GIS Applications Manager

REGION III

Information Resources Management Branch

Robert Braster	Chief, Information Management Support Section

Contract Support

Douglas Freehafer	Programmer/analyst
Renee Gelblat	Programmer/analyst
David West	Programmer/analyst

REGION IV

Office of Integrated Environmental Analysis

George Collins	Chief
Phyllis Mann	Environmental Scientist
Jerry Sorenson	Environmental Scientist
Henry Strickland	GIS Coordinator

U.S. GEOLOGICAL SURVEY

GIS Research Laboratory

Jay Donnelly	Staff Geographer, ARC/INFO training

DEFENSE MAPPING AGENCY

Defense Mapping School

Capt. Bruce Donaldson	Management Technology Department

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE

James Henderson	Director, Customer Support and Training

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