To the Graduate Council:

I am submitting herewith a thesis written by Xiaoming Zhu entitled "Integration of GIS and Transportation Analysis: An Interface between ARC/INFO and FIELDS." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geography.

Bruce A. Ralston, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor
and Dean of The Graduate School

INTEGRATION OF GIS AND TRANSPORTATION ANALYSIS: AN INTERFACE BETWEEN ARC/INFO AND FIELDS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Xiaoming Zhu

August, 1992

ACKNOWLEDGEMENTS

First, I would like to thank the Department of Geography, the University of Tennessee, Knoxville for providing the opportunity and environment for me to continue my education.

I am indebted to my advisor, Dr. Bruce A. Ralston who has readily given his time in guidance for this research. I am also grateful to my committee members, Dr. Thomas L. Bell and Dr. John B. Rehder for their assistance and helpful comments during the completion of this study. In particular, I would like to thank Dr. Bell's thoughtful review and discussion about this study, as well as corrections of English grammar in the text of the thesis.

ABSTRACT

Integrating an existing transportation analysis package and a commercial Geographic Information System (GIS) is an efficient approach to enhance the analytical capabilities of transportation modeling software and extend the use of a GIS. This thesis presents an integrating system that links a stand-alone transportation package, the Food for Peace Inland Emergency Logistics and Distribution Simulation System (FIELDS), with a commercial GIS package, ARC/INFO.

The thesis explores the major components of the integrating system, including data transfer, display function, and user interface. In particular, a menu-driven interface for use in the ARC/INFO environment is developed. Through the interface, users can easily implement the integration of the GIS and the transportation analysis modeling package.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

TRANSPORTATION ANALYSIS AND GIS

Mathematical modeling has been a major tool in transportation analyses that are used to plan, evaluate, and predict the performance of transportation systems. Empirical analyses of transportation analysis require a large amount of spatial data as well as non-spatial data. Unfortunately, the lack of adequate data and well-developed graphic display capabilities limit the implementation of many transportation models.

Geographic Information Systems (GIS) are designed to handle spatial information (Star and Estes, 1990) and have powerful display and database management capabilities. However, GISs are general purpose information systems and most GIS packages are designed based on the principles of the relational databases. It is difficult for a GIS to handle sophisticated problems that require other data structures and complex models. Therefore, it is desirable to integrate GIS with particular transportation models that have not been developed in a GIS system.

This paper presents a prototype of an integrating system that links a popular commercial GIS software package, ARC/INFO, with a existing Linear Programming transportation modeling package, the Food for Peace Inland Emergency Logistics and Distribution Simulation System (FIELDS)

(Ralston and Ray, 1986). Before addressing the integration system, it is necessary to discuss the characteristics of transportation analysis and GIS.

1.1 TRANSPORTATION ANALYSIS

Most transportation analyses involve statistical methods or mathematical models that rely heavily on computer technologies. Thus, the quality of transportation analysis has improved with the development of computer technology. First, the development of computer technology allows the improvement of analytic tools. For example, GIS approaches, expert systems, and other planning databases are now available for transportation analysis (Lewis, Cook, and Minc, 1990). Secondly, today's high powered computers allow modelers to work on more complicated, multicomponent systems. The use of transportation models becomes more realistic for many users because microcomputers are now powerful enough to conduct the computations required in transportation analysis.

Transportation analysis usually involves geographical data modeling (Goodchild, 1991a), which is the process that converts complex geographical reality into a finite number of database records or features. The features have geographical expressions as points, lines, or areas, and possess descriptive attributes. In transportation analysis, these important geographic components include nodes, links, and areas. Nodes and links are the spatial features in transportation analyses. Attribute data, on the other hand, describe the non-spatial characteristics related to particular features.

Although mathematical modeling is a powerful tool in transportation planning, the predictions made through modeling may be unrealistic if the sample or observations are not sufficient enough for the models, the data are not accurate enough, or are out-of-date. Lack of adequate data is a major factor that limits the implementation of transportation models. Because transportation networks built for analysis are usually graphic abstractions reflecting spatial relationships associated with travel (O'Neill, 1991), collection of the data for transportation analyses involves many activities. Data for transportation analyses may come from a variety of sources at different geographic scales, utilizing different formats, and portrayed with different degrees of accuracy.

A major problem that is encountered in data collection is that spatial data may be recorded with respect to different reference systems. For example, existing locational data for building a regional network may have been measured from a variety of different map projections. The locational data have to be compiled within a common reference framework for further analyses (Simkowitz, 1987). Conversion to a common reference base is, in many cases, a time-consuming and costly process. The increasing application of

GIS may provide an impetus for data-sharing and data standardization efforts.

In brief, the development of computer technology in recent years has resulted in major advances in transportation modeling. There are increasing demands for better interaction between machine and modeler, better graphic display, and better database management capabilities. The models of today are designed for use on more powerful workstations or minicomputers with high quality graphic capabilities (Lewis, Cook, and Minc, 1990).

1.2 GEOGRAPHIC INFORMATION SYSTEM

A geographic information system (GIS) is an information system designed to work with data referenced by spatial or geographic coordinates. A GIS is both a database system with specific capabilities for spatially-referenced data, and a set of operations for working with the data (Star and Estes, 1990). GIS has been defined differently by many authors and there was for many years little agreement on what is a GIS and what it should do. In recent years, however, the definition developed by the National Center for Geographic Information and Analysis (NCGIA) has been widely accepted. A geographic information system is defined by the NCGIA as "a computerized data base management system for capture, storage, retrieval, analysis, and display of spatial (locationally defined) data." The definition gives a picture of an ideal GIS.

The analytical and modeling abilities of a GIS have been weak compared to its database management and display abilities. Goodchild (1991b) stated that the reality of GIS today is: "a database containing a discrete representation of geographic reality in the form of static, two-dimensional geometric objects and associated attributes, with a functionality largely limited to primitive geometric operations to create new objects or to compute relationships between objects, and to simple query and summary descriptions."

One main reason that a GIS does not typically have a strong ability for performing modeling is that GIS packages commonly use relational databases. The data structures of relational databases may not be compatible with the various data structures required by different mathematical models. Despite this shortcoming, the power of the graphic display and data management capabilities of GISs still attract the interest of modelers.

Database Management Functions

The main function of an information system is to process information from its primary sources and convert the data to the most effective format for users. Since a GIS is designed to handle information related to spatial locations, it has several general functions that can process data from various sources. One advantage of using a GIS to manage data, especially when dealing with transportation data, is that a GIS permits the integration of diverse data sets that are unrelated to each other, duplicative, and inconsistent (Simkowitz, 1987). A GIS may, in other words, serve as a bridge connecting various applications by a unifying data format. It is expected that more and more data from various sources will be stored in GIS format or a format compatible with that of major commercial GIS packages.

The trend toward a standardized data format will benefit geographic analysis. Traditionally, the input of the data in the form of a map or other graphic expressions has required manual digitizing. Input of existing geographical data in various forms on paper or film may involve tedious compilation and keyboard operations. In recent years, however, more data have been stored in digital form. Data input may be accelerated when the data are in a digital format that can be easily captured by computers. The need for continuous improvement in data conversion technology has been a major concern of the GIS industry. Converted data expressed in a standardized format extend the data sources that can be processed with a GIS.

Data conversion problems also exist among different GIS packages. Two types of GIS packages exist: vector-based and raster-based (O'Neill, 1991). The vector data model uses discrete line segments or points to identify locations. The raster data model, on the other hand, divides the entire study area into a regular grid of cells in a specified sequence. Most GIS packages are designed to use vector data because most conventional data are of this type. ARC/INFO is one such vector-based GIS package. However, accumulation of remotely sensed data has stimulated GIS vendors to improve their systems to accept raster as well as vector data.

Map Projections and Coordinate Systems

A GIS is capable of handling many commonly used map projections. It can establish an internally consistent system for recording and specifying object locations. After the establishment of a system, the user can determine the characteristics of any specified location in terms of the contents of each data layer in the system. GISs offers convenient tools to change map scales and contents. These systems also offer editing abilities that can correct location data.

Spatial Analysis

The major spatial analysis tools of current GISs are computer programs that manipulate data to create new information from the relationships among the data and the topological structure. Spatial manipulation gives the locations and contents of objects and will enable further processing of information (Nyerges and Dueker, 1988).

Spatial manipulation of both location and attribute data make GISs unique. The current status of the analytic capabilities of GISs is, however, still far from satisfactory. Most GIS packages use arithmetic and logic functions (Boolean operators) to perform spatial analysis. Users interested in complex analysis will find that the spatial analysis functions of existing GISs are not powerful enough to meet their needs.

Graphic Functions

A GIS can generate its graphic output with hardware devices such as printers, plotters and photographic equipment. In addition to the hard copy graphics that are printed on paper and film, GIS can also produce "soft copy" graphics. Soft copy images are transient images on a computer screen, displaying various kinds of maps and other graphics presenting analytical results (Star and Estes, 1990). Soft copy or temporary graphics displayed on the screen play an important role in assisting the user in reviewing his intermediate and final results. Intermediate results that are in soft copy form save time and lower the cost by reducing the needs for making hard copies. Decisionmakers also can benefit from high quality graphic presentations.

1.3 INTEGRATION OF GIS AND TRANSPORTATION ANALYSIS

1.3.1 The Purpose of Integration

Transportation modeling packages usually do not have powerful display systems to present effectively the resulting configuration of modeled outputs. GIS commercial packages, on the other hand, lack analytic and modeling capabilities. In order to add GIS power to transportation analysis, integrating the two types of software is necessary. Problems encountered in an integration attempt may stem from

1) The data structure in a GIS package that may be inappropriate for use with particular models;

2) Topological relationships in GIS packages that are based on physical network may be incompatible with non-physically-based logical entities used in network models;

3) The objectives and constraints used in modeling change from application to application.

Addressing these user problems requires programming. The strategy of programming is dependent on the nature of the particular project. Recent work uses FORTRAN (Kehris, 1990) and ARC Macro Language (Ding and Fotheringham, 1991) to integrate spatial analysis and GIS. Object-oriented programming languages could be used to develop re-usable sub-programs (classes) that allow easy access to the GIS database. The use of these reusable class programs would make it easier to update the modeling software (Ralston and

Zhu, 1991).

1.3.2 The Approaches to Integration

Several approaches to link transportation analysis and GIS are possible: 1) build display modules into the modeling package; 2) improve the analytical abilities of GIS software; and 3) develop stand-alone interface software.

The first approach is to provide functional integration, i.e., integration within one framework. It requires new data structures, sophisticated programming technology, and other advanced techniques to develop a GIS-transportation analysis system. Recently, attempts have been made to develop built-in display systems for some modeling tasks. For example, a computer display function was built into the Bangladesh Transportation Modeling System (Liu and Ralston, 1990). The advantage of these kinds of display systems is that they are developed for solving particular problems. As the result, an all-in-one system is created that does not have compatibility problems. The disadvantages of the all-in-one system are that sophisticated programming is involved and a relatively large amount of time and funding is required to develop such a system.

The second approach is to add transportation analysis abilities into existing GIS. Simkowitz (1987) referred to this concept as GIST (GIS for transportation research and analysis). Although only limited models can be adopted by existing GIS packages, this is a cost-effective method for users who would use these simple models.

The third approach is to develop stand-alone interface software that can bridge the gap between transportation analysis and GIS packages. This kind of interface can solve compatibility problems between GIS and transportation analysis packages for projects ranging greatly in size, and it requires less investment than the built-in approach of the all-in-one system. The stand-alone interface allows the GIS user to develop more sophisticated models than those found in commercial GIS packages. This approach has great potential and is expected to be widely used in the future. The integrating system discussed in this paper belongs to this category. Interfacing a GIS with a transportation package allows the user to avoid the difficulty in designing a data model that handles both GIS functions and transportation analysis (Shaw, 1991).

In summary, development of GIS in recent years makes it a powerful tool that can enhance transportation modeling. Integration between GIS and transportation models can be accomplished in many different ways. This paper uses the stand-alone interface approach to connect ARC/INFO and FIELDS.

CHAPTER 2

INTRODUCTION TO FIELDS

FIELDS (the Food for Peace Inland Emergency Logistics and Distribution Simulator) is a micro computer-based transportation analysis software package. It was developed by B. A. Ralston and J. J. Ray at the University of Tennessee for U.S. Agency for International Development (Ralston and Ray, 1987). This package determines the best use of existing transportation and storage facilities for food-aid distribution in Africa with a multi-period storage and distribution linear programming (LP) model.

Linear programming models are widely used to solve transportation problems. Most LP modeling software packages, however, do not have sophisticated graphic functions to display and edit a network and display analytical results. FIELDS is a well-developed LP model with graphic capability. The reason to choose it for the integrating study presented here is because this study primarily is aimed at integration between LP modeling software and a popular GIS commercial package. FIELDS is an ideal example to use to demonstrate this integration because it is handy and still in the process of improvement for potential use in the future.

2.1 LINEAR PROGRAMMING MODELS

The basic components of LP models are an objective function and a set of constraints. The objective function is the linear formula that mathematicaly expresses the goal. The constraints reflect the supplies, demands, and the physical limits of the distribution network for a transportation problem.

The objective of the FIELDS model is to find the route and shipping schedule of food aid so that demands are met at a minimal cost. There are three variables in the objective function: link flows, airdrops, and storage. Six constraints were applied to this model: port offtake, demands, storage availability, shipping capacities, truck constraints, and transshipment constraints. The FIELDS model is constructed based on these variables, constraints, and input data. The results from FIELDS include the quantity of food aid to be supplyed, to be shipped, the optimal solution of routing of food aid (by mode or combination of different modes), and schedule of delivery. Marginal economic analysis is also provided by interpretation of the LP output. This analysis can predict where it is most advantageous to increase storage capability, and how much savings can benefit by doing so. Based on the weather conditions and the transportation network in Africa, a single-commodity, multi-period LP model is developed by FIELDS. This model can handle up to eight time periods and three transportation modes—road, railroad, and waterways.

To construct the FIELDS LP model, certain information is required as input data. These data also need to be linked to ARC/INFO when integrating the two packages. The contents and formats of these input data files are explained in next section.

2.2 FIELDS INPUT

FIELDS requires three files as input data: a link file, a node file, and a port file. In order to better understand the integrating procedures, the contents of these files are described briefly below.

Link Data File

A link data file contains a list of links in a network, as well as relevant economic information about the link for each period. These data are called 'attribute data' in ARC/INFO. Usually, shape points that keep track of the starting position, ending positions of each link segment are kept in a link file. In FIELDS, links are defined as straight lines between two nodes. Thus, shape points data do not exist in a link file, and the position of a link is recorded by the coordinates of a pair of nodes in the node file. Appendix A1 presents an example of a link file used by FIELDS. Link data for all time periods are vertically appended to a single file. Each time period in the file is delimited by the word 'ENDDATA'.

In each period, there are eight fields in the link file. The fields are delimited by at least one space. Each field is described below following the order of their appearance in the file:

ANODE(A10): A name of "from node" for a link.

BNODE(A10): A name of "to node" for a link.

MODE(A2): A mode flag. It must have two capital letters: RD for road, RL for railroad, and WT for waterways.

ID(I6): The user-assigned identification for a link.

KM(F10.3): The length of each link in kilometers.

COST(F7.3): The cost per ton per kilometer for the period. It may change with time period.

CAPACITY(F7.3): The capacity of the link. If the link has unlimited capacity, it has -1 value. The values may change with period.

F_WAY(F2.0): The flag of the direction of the link. 0 represents a two way link, 1 represents a one-way link.

Node Data File

An example of a node file is given in Appendix A2. The node data file contains all the relevant information about each node in the network. In addition to attribute data, the latitude and longitude of each node are given in the node file. Like the link file, data for each time period are separated by an "ENDDATA" record. There are 13 fields in a node file.

NAME(A10): The name of the node.

ID(I6): User-assigned identification number for a node.

DEMAND(F10.3): Demand (supply) of a node. A negative value represents a supply node.

TNUM(F10.3): The number of local trucks. -1 indicates the number of trucks is unlimited.

ETSIZE(F7.3): The size of trucks. If the number of trucks is unlimited, the value is zero.

ETSETUP(F10.3): The cost per metric ton, per period for leasing extra trucks.

TRANSHIP(F2.0): Transshipment flag. 0 indicates that transshipments are allowed at the node. 1 indicates transshipments are prohibited at the node.

TRANSCOST(F7.3): The cost per ton of switching modes at that node.

CSTORCOST(F7.3): The cost per ton, per period.

CSTORCAT(F10.3): The storage capacity.

AIRCOST(F10.3): The cost of airdrop.

LAT(F7.3): The latitude of a node in decimal degree equivalent.

LONG(F7.3): The longitude of a node in decimal degree equivalent.

ARC/INFO requires a unique identification number for each link and node in order to relate attribute and location data (see Chapter 3). Therefore, in this study, an ID field is added to FIELDS link and node files by the author. An ID number is assigned to each link and node, and each number is unique in the data file. For example, in Appendix A-1, based on the unique characteristics of these IDs and identification of different transportation modes, link and node files from the FIELDS have the following ID convention:

Range of ID number	Represent Features
1000 - 1999	ROAD links (in link file)
2000 - 2999	RAIL links (in link file)
3000 - 3999	WATER links (in link file)
1 - n	NODES (in node file)

Port Data File

In addition to link and node files, a port data file is also used to provide the port information related to nodes. The port files carry the information about port offtake rates per period for each mode. Like other files, the periods are separated by the "ENDDATA" record. If a mode is not available at a port, its offtake rate is minus one (-1). Appendix A3 presents an example of a port file, which is described as follows:

NAME(A10): A port node name.

RD_RATE(F10.3): Offtake rate for roads.

RL_RATE(F10.3): Offtake rate for rail.

WT_RATE(F10.3): Offtake rate for waterways.

Because each port is also a node stored in the node file, physical network relationships between nodes and links can be built without port data. For example, as a port, ABIDJAN, Ivory Coast, appears in the port file with road, rail and waterway take-off rates. It also appears in the node file which provides the latitude, longitude and and other information related to ABIDJAN node. The LP mode reads the data related to the ABIDJAN from both the node file and the port file. The results of LP output are transferred to ARC/INFO, and displayed graphically.

2.3 FIELDS OUTPUT

The LP model generates a large volume of output. A report module of FIELDS generates a series of easy-to-read tables that describe the LP solution. The module also generates a graphic result file used with the graphics programs of FIELDS (See Appendix B). This file is used as input in the integrating system described in this paper to display the LP solution in ARC/INFO.

The report module also generates summary tables. PC ARC/INFO cannot generate a better text report than FIELDS.

Therefore, the integrating system is only designed to use ARC/INFO's graphic display capability.

The FIELDS graphic file is written based on the analysis of variables, constraints, and the interpretation of their marginal economic information (i.e. dual prices) in the solution. The file contains information about the solutions for each link and node in each period. The data format is similar to that of link and node files. However, this file includes all links and nodes solution information. Within this file, each time period data start with an arc data set by 'ARCDATA' line, then 'NODEDATA' line symbols the first line of node data set. 'ENDDATA' line is the last record for each time period data. Appendix B is a example of FIELDS graphic result file.

The values 0, 1, 2 in the data files are used to code the solution. As an example, a portion of the file is listed below.

```
ARCDATA
ABIDJAN    FERKE       1000    0    1    1
ABIDJAN    FERKE       2000    1    1    1
AGADEZ     APLIT       1001    0    1    0
...         ...        ...          ...
OFFSHORE   LOME        3010    2    1    0
OFFSHORE   PTHARC      3011    2    1    0
NODEDATA
```

ABECHE	001	1	0	2	0	0	-13.82	20.81
ABIDJAN	002	0	0	0	1	0	-5.38	-4.03
AGADEZ	003	1	0	0	0	0	-16.97	8.00
...	...	...	...	...	...		...	...

There are six items in the arc data set. The first three data items are ANODE, BNODE, and arc IDs. The next integer is the code of modes, 0 for road (RD), 1 for railroad (RL), and 2 for waterways (WT). The last two data items are FLOW and CAPACITY, representing the analysis results of flow and capacity of the link. The code 0, 1 have been assigned specific content for each mode:

FLOW: 0 - No flow is assigned to a link

1 - Flow is assigned to a link

CAPACITY: 0 - Zero dual price, indicating that there is no economic advantage to increase capacity.

1 - Non zero dual price, indicating an increase in capacity would lower total transportation cost.

"NODEDATA" marks the beginning of the node data. There are nine data items in the node data set. NAME and ID are the first two items matching the same items in the node file. The next five fields, contain single digit integers, and encode the LP results. The last two items are latitude and longitude of a node, matching the same items in node file.

The five fields related to the solution for a node are DEMAND, AIRDROP, STORAGE, TRANSSHIP, and TRUCK:

DEMAND: 0 - No demand at a node.
1 - Demand at a node.

AIRDROP: 0 - No airdrop at a node.
1 - Airdrop at a node.

STORAGE: 0 - No storage capacity at a node.
1 - Zero dual price, indicating current storage capacity is not fully used.
2 - Non zero dual price, indicating potential investment at a node can save total transportation cost.

TRANSSHIP: 0 - Intermodal transfers allowed at a node.
1 - Intermodal transfers not allowed at a node.

TRUCK: 0 - Need more trucks at a node.
1 - Do not need more trucks at a node.

In summary, this chapter is a brief review of FIELDS. This chapter, along with Chapter 3, will, it is hoped, assist the reader in understanding the data transfer and user interface between FIELDS and ARC/INFO.

CHAPTER 3

INTRODUCTION TO PC ARC/INFO

ARC/INFO is a popular GIS software package. It is a multi-purpose GIS used to automate, manipulate, analyze, and display geographic data in digital format. This chapter briefly introduces some basic concepts and functions in ARC/INFO that will be used to integrate ARC/INFO with FIELDS. The major sources of the information about ARC/INFO presented in this chapter come from publications of Environment System Research Institute Inc.(1990, 1991), the company that developed the system.

3.1 SUBSYSTEMS

There are versions of ARC/INFO for PC, VAX, and UNIX. Each version is designed to meet specific hardware and operating system requirements. PC ARC/INFO version 3.4D is used for this study. This ARC/INFO version contains a number of subsystems or modules. Each module has its own set of commands and functions. Logical groups of functions are organized within individual modules. This study involves following subsystems: the ARC module, the ARCPLOT module, the TABLES module, the macro programming language, and the ARCSHELL. Each will be described briefly:

ARC

ARC module is the main program environment in ARC/INFO. Most functions in ARC are commands that can be executed without graphic devices. The other ARC/INFO subsystems are interactive in nature and use graphics terminals and digitizers. Coordinate projection and transformation functions, data conversion for loading data into and out of ARC/INFO, and most of spatial analysis operations are performed in ARC environment.

ARCPLOT

ARCPLOT is a graphic module in ARC/INFO that can be used to create and query maps. Many options are available in ARCPLOT. A map can be composed and customized according to user-selected elements. ARC/INFO provides many symbols for displaying and plotting arc, point, and polygon features in ARCPLOT. The maps produced can be saved in plot files for making hard copies. ARCPLOT is used in the study of FIELDS and ARC/INFO integration to display, query, and make plot files.

TABLES

TABLES is a relational database management system (DBMS) used to store, maintain, integrate, manipulate, and update attribute data. In ARC/INFO these data files are called tables. The integration of graphic and tabular data in a single system is based on the principle of relational database design. The relational database accepts tabular data from virtually any source.

Since 1990, a commercial standard relational database, dBASE™ (III or IV) has been integrated into PC ARC/INFO. dBASE adds the power of a commercial DBMS to ARC/INFO, and also makes ARC/INFO good for business-oriented data processing. However, dBASE can only be performed in PC version of ARC/INFO. In order to easily convert the integrating system to VAX or UNIX version, this study does not involve dBASE functions, and all database operations are performed in ARC/INFO database module, TABLES.

SML - Simple Macro Language

Simple Macro Language (SML) is a simple programming language for building macros with some features of a high-level programming language such as expression evaluation, input and output handling, and directing program flow-of-control. SML allows access to any module of ARC/INFO and the DOS operating system without leaving the ARC environment. It provides a tool to integrate ARC/INFO with other existing packages. The integrating system for this paper is an example of a SML implementation.

ARCSHELL

ARCSHELL is a menu interface system that is a graphic version of command language. It organizes a large number of ARC/INFO functional capabilities for users. The menu system provides pathways through the software to accomplish particular tasks. ARCSHELL is an open system that has great flexibility for users to choose commands, parameters. It can help new users to understand ARC/INFO quickly. Experienced users can develop their own applications easily using the macro language and the ARCSHELL interface. In order to effectively use ARCSHELL, the user needs to have some basic knowledge of GIS and ARC/INFO. Although ARCSHELL is not used in the ARC/INFO-FIELDS interface, the interface is built based on the ARCSHELL design principle.

3.2 SPATIAL FEATURES AND COVERAGES

Spatial features are delimited geographic phenomena. They are points, arcs, and polygons in ARC/INFO. A point is a spatial object without area and length. Its spatial location is recorded as coordinate value (x,y). An arc is a line that is made up by a connected sequence of points. A polygon is a closed area bounded by one or more arcs. For example, a node in transportation network is a point feature, a link (road) is an arc feature, and a traffic zone is a polygon feature. The three spatial features are used to represent real phenomena on the earth.

In ARC/INFO, a thematic layer, or a coverage is used to group similar features in spatial database. A coverage is "A digital analog of a single map sheet forming the basic data storage in ARC/INFO" (ESRI, 1990). Coverages can be generated in several different ways in ARC/INFO: digitizing the existing map manuscript manually, converting certain existing digital format data from other sources, or importing digital data from an ASCII text file containing x, y coordinate data. The last approach is also suitable for digital format data because most digital data can be converted into ASCII text format. Once data are prepared in ASCII text format, the coverage can be built directly.

A coverage is stored as a set of data from which the user can create a desired view for a particular purpose (ESRI, 1990). Each coverage is composed of a set of files. Some files store spatial data and others attribute data. For example, when an arc coverage is created, a control point file (TIC), a boundary file (BND), and an arc coordinate file (ARC) are created. These files store locational data of the coverage. If the topology of the coverage is created, attribute files that store topology and attribute data will be added to the coverage based on spatial features.

3.3 TOPOLOGY OF FEATURES

Spatial features in a coverage are related to each other by locations and directions. The term 'topology' describes the relationships among spatial features. These relationships are expressed in ways similar to that of describing relative locations. For example, the type of relationships people may use to describe location include "to the right of", "next to", or "inside of". ARC/INFO describes the topological relationships among the features in a coverage in much the same way.

In ARC/INFO, BUILD and CLEAN are the commands to build topology. There are two major differences between the two. First, BUILD processes lines, points, and polygons, while CLEAN only processes lines and polygons. Second, BUILD can only recognize existing intersections, while CLEAN creates an intersection wherever lines cross one another. Thus, how to build topology depends on how a coverage is created (digitized or imported), what features are in a coverage (line, points, or polygon), and what topology (arc-node, arc-polygon) will be used for a particular assignment. For example, if a user wants to create a non-planar graph, he should use the BUILD command to build topology. Through topology construction, each feature is assigned an internal number determining arc connectivity and polygon contiguity. Then these values are recorded and stored in a feature attribute table.

Table 3-1 is an example of Arc Attribute Table (AAT), and Table 3-2 is an example of Polygon Attribute Table (PAT). Feature attribute tables are ARC/INFO database files

Table 3-1 Standard Template of AAT

FNODE#	TNODE#	LPOLY#	RPOLY#	LENGTH	Cover#	Cover_ID
1	3	1	3	4.3503	1	100
2	1	2	1	1.7424	2	101
7	5	4	5	0.8262	3	102
7	6	3	3	1.8668	4	103
...						

FNODE# Internal node number for the beginning of an arc (from node)
TNODE# Internal node number for the end of an arc (to node)
LPOLY# Internal number for the left polygon (the Cover# in a corresponding PAT)
RPOLY# Internal number for the right polygon (the Cover# in a corresponding PAT)
LENGTH Length of each arc, measured in coverage units
Cover# internal arc number (values assigned by ARC/INFO)
Cover_ID User_ID (values assigned by the user).

Table 3-2 Standard Template of PAT

AREA	PERIMETER	COVER#	Cover_ID
-21.25	16.58	1	1
2.04	4.57	2	2
3.54	7.45	3	3
0.89	1.89	4	4
...			

AREA Area of each polygon, measured in coverage units
PERIMETER Length of each polygon boundary, measured in coverage units
Cover# Internal polygon number (assigned by ARC/INFO)
Cover_ID User_ID (assigned by the user)

(Understanding ARC/INFO, ESRI, 1990)

associated with each feature type. Each table is created from a template of standard items. Although there are three types of features, only two templates exist because points and polygons share the same template. Constructing topology for a polygon coverage creates a polygon attribute table (PAT); for a line coverage, an arc attribute table (AAT); and for a point coverage, a point attribute table (PAT).

The PAT for a point coverage will have zero value for both area and perimeter, and the Cover# will represent internal point number instead of polygon number. The actual name of the coverage will substitute for 'Cover'. For example, if the name of a coverage is "MYROAD", the Cover# will be MYROAD#. The same principle applies to Cover_ID.

A coverage consists of topologically-linked and thematically-grouped geographic features, and their associated attribute data. It is a basic unit of storage and a digital model of a piece of landscape in ARC/INFO database. This topology is based on physical nodes and links which can be displayed. However, transportation network models often use graphs in which some nodes and links do not physically exist. Examples would include logical arcs and nodes needed to simulate intermodal transfers, delays at border crossings, and loading and unloading costs (Ralston and Zhu,1991). This is one reason that GISs do not have fully developed, sophisticated transportation models contained within them.

3.4 INTEGRATED DATA

The power of a GIS lies in the link between the graphic (spatial) data and the tabular (attribute) data. This linkage is built and maintained by a relational key in the related files. The key is in the form of numerical identifiers that are assigned by users or by the ARC/INFO system. For example, a coverage may consist of two related files, such as an ARC file and an AAT file. The Cover_ID in each file is the key item used to relate the two files, and each coverage ID number must be unique.

The coordinate and attribute records share the item Cover_ID. Cover_ID associates attributes with features. In ARC/INFO, the connection has three characteristics (ESRI, 1990):

1) A one-to-one relationship exists between features on the map and records in the feature attribute table.
2) The link between a feature and its record is maintained through the unique identifier assigned to each feature.
3) A unique identifier is physically stored in two places: in the files containing the x, y coordinate data and in the feature attribute tables with corresponding record.

Based on these relationships, any two tables can be connected as long as they share a common attribute. According to this relational database concept, attribute data provided by users can be added to feature attribute tables easily by selecting a common relational key.

The first step of adding attribute data to AAT or PAT tables is to use the 'DEFINE' command in the TABLES module. This command defines the format of an "item" for storing data. This procedure is similar to that of creating a data structure or data dictionary in most databases. The "item" is the term for a category of attribute in PC ARC/INFO. This term is also called "FIELD" in most database concepts. After defining each new item for a table, the 'ADD' command in TABLES is used to capture the data with the defined format. The data become records in an ARC/INFO database file or table. The last step is to use the 'JOINITEM' command in the ARC module to join this table with corresponding AAT or PAT by user_IDs.

The same concept is used to construct other relationships between tables. Fig. 3-1 illustrates the relationships among AAT, lookup table symbols, and features on a map. Lookup tables specify display symbols according to attributes. The lookup table in Fig. 3-1 is an ARC/INFO database file with at least two items, one is the same as an item in the feature table, the other is 'SYMBOL'. For each unique attribute value, there is a corresponding record in the lookup table with a specific symbol number. When a map is displayed with the ARCPLOT module, users can specify the item to be used to reference the symbol. Then ARCPLOT looks up the value of this item for each record to obtain the correct symbol number.

Now that the relevant structures and procedures for FIELDS and ARC/INFO have been discussed, the next two chapters focus on integrating the two systems.

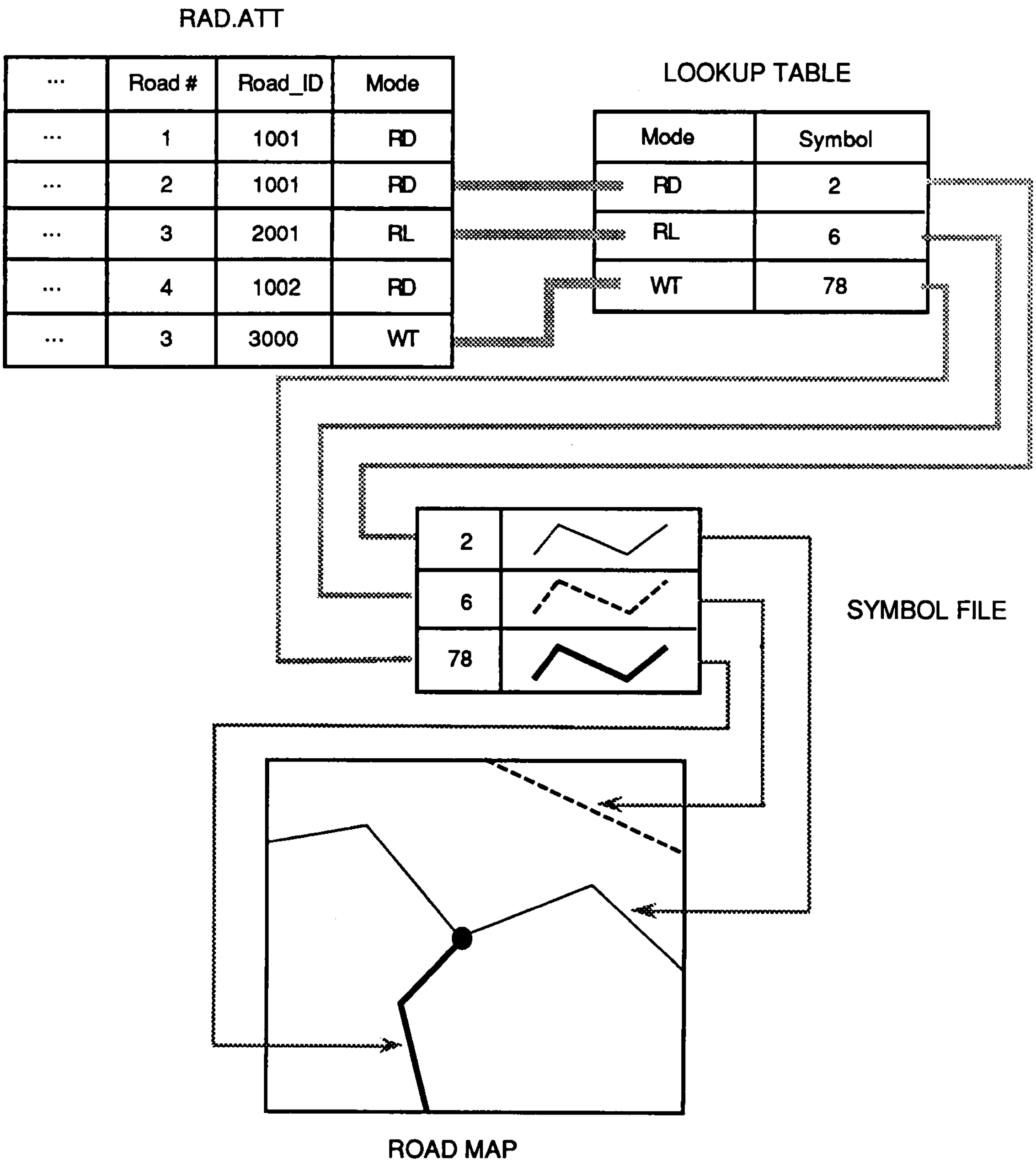

Figure 3-1
Relationships among AAT, Lookup Table,
Symbols, and Features on a Map

CHAPTER 4

INTEGRATION OF FIELDS AND ARC/INFO

Integrating FIELDS with ARC/INFO is done in the ARC/INFO the environment. That is, all commands begin within the ARC/INFO shell. The system consists of an ARC/INFO SML application program that includes ARC commands, ARCPLOT commands, TABLE commands, operating system (DOS) commands, and C programs. The relationships among the integrated components are shown in Fig.4-1.

To integrate ARC/INFO and FIELDS, four general objectives had to be addressed.

1) A linkage between ARC/INFO and FIELDS must be established to transfer topological relationships of the transportation network between the two software systems.
2) Routines to extract attribute data from both packages and transfer the data between the two packages had to be developed.
3) The tools for graphically displaying the analytical results from the FIELDS were built.
4) A menu-driven interface was created so that the user can directly deal with network coverages and attribute data without knowing any ARC/INFO commands.

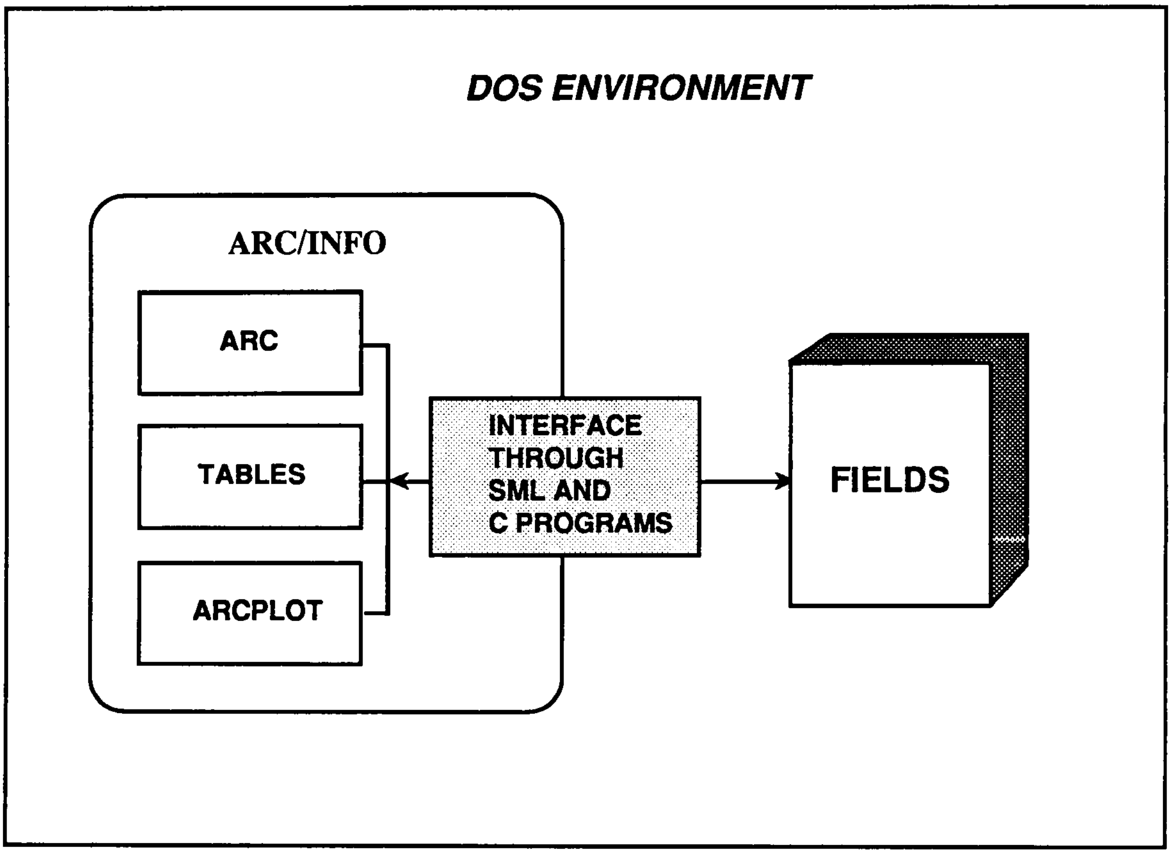

Figure 4-1

Interface Components Between ARC/INFO and FIELDS

This chapter will describe the technical procedures to achieve the first three objectives. The user interface will be discussed in chapter 5.

4.1 TOPOLOGICAL NETWORK OF FIELDS IN ARC/INFO

Transportation networks can be described through either graphs or matrices. Graphic based approaches characterize a network as a set of nodes connected by arcs. The matrix expression uses a connectivity matrix to represent network structure. In the connectivity matrix, rows are defined as origin nodes while columns are destination nodes. The matrix keeps track of the presence or absence of direct connections of each pair of nodes. This basic matrix can be used to derive additional data sets characterizing the properties of connections between nodes. These data can be used for further studies of network structures. In ARC/INFO, the topological relationships of a network are established based on graph theory. The topological relationships express the network structure and the analytical results related to the network. Topology is used to define explicitly spatial relationships between graphic features - generally nodes, arcs, and polygons. One main reason for developing the integration package between FIELDS and ARC/INFO is because ARC/INFO can build topological structures automatically when creating a coverage.

4.1.1 Location Data and User ID

Location data are the basic elements to build a network and topological relationships between the nodes and links in the network. Generally, the coordinate values of nodes and shape points of links are the locational data required to build a network. In FIELDS all links are treated as straight lines from A nodes to B nodes. Therefore, coordinate values of nodes are the only locational data needed. These data are presented in the form of longitude and latitude listed in last two columns in each node file (see Appendix A). Transfer of the coordinate data into ARC/INFO is the first step to integrate the two packages.

Since FIELDS' locational data are already in tabular ASCII format (in a node file), it is possible to transfer the FIELDS network structure into ARC/INFO simply by importing data from ASCII text files.

To make the data transfer efficient, it is important to keep in mind the following ARC/INFO concepts. One advantage of GIS is the connection between graphic (spatial) and tabular (descriptive) data. In ARC/INFO, the connection between spatial features and their attributes has three characteristics (ESRI, 1990):

1) A one-to-one relationship exists between features on the map and records in the feature attribute table.
2) The link between a feature and its record is maintained through the unique identifier assigned to each feature.
3) A unique identifier is physically stored in two places: in the files containing the x, y coordinate data and in the feature attribute table with the corresponding record.

In general, a unique one-to-one identifier is the key in building all the connections among graphic features, attribute data, and their locations. The identifiers can be assigned by users before inputting data to ARC/INFO, or created by ARC/INFO when generating a coverage. In an ARC/INFO data base, the identifiers are called User_ID, in attribute tables the User_ID is a numerical data item called Cover_ID. To be consistent with ARC/INFO, a link ID field is added to the FIELDS link file. Similarly, a node ID field is added to the FIELDS node file.

Since ARC/INFO stores locational data and attribute data separately, the first step of the integration is to build coverages and topologies in ARC/INFO by using locational data from FIELDS. The attribute data will be related to the corresponding features by link and node IDs later.

4.1.2 Arc Coverages and Topology

The integrating system uses the ARC/INFO 'GENERATE' command to build coverages by importing X, Y coordinate data (locational data) files. The GENERATE command requires the data files to follow a certain format. ARC/INFO requires each link's ID and its x, y coordinate values to build a coordinate file that creates a link coverage. The required data are kept in separated link and node files in FIELDS. The integrating system extracts the data from these two files by executing a C program (DEMOARC.C). Fig.4-2 shows the procedure employed from the extraction data to the creation of coverages. The data format required by the GENERATE command is also shown in the GEROAD, GERAIL, and GEWATER data files in this figure.

The DEMOARC.C program first processes starting node (A node) and ending node (B node) of a link in the link file. It then searches for the x, y values of the two nodes by matching the name of A and B nodes with the node names in the node file. Finally, it writes the link ID and x, y values of the A and B nodes to a new file in the format required by the ARC/INFO GENERATE command. Because the system builds separate link coverages for each mode, the C program delivers the output to three coordinate files according to each link's mode flag. In the link file, road, rail and water modes are distinguished by abbreviations RD, RL, and WT in a mode flag

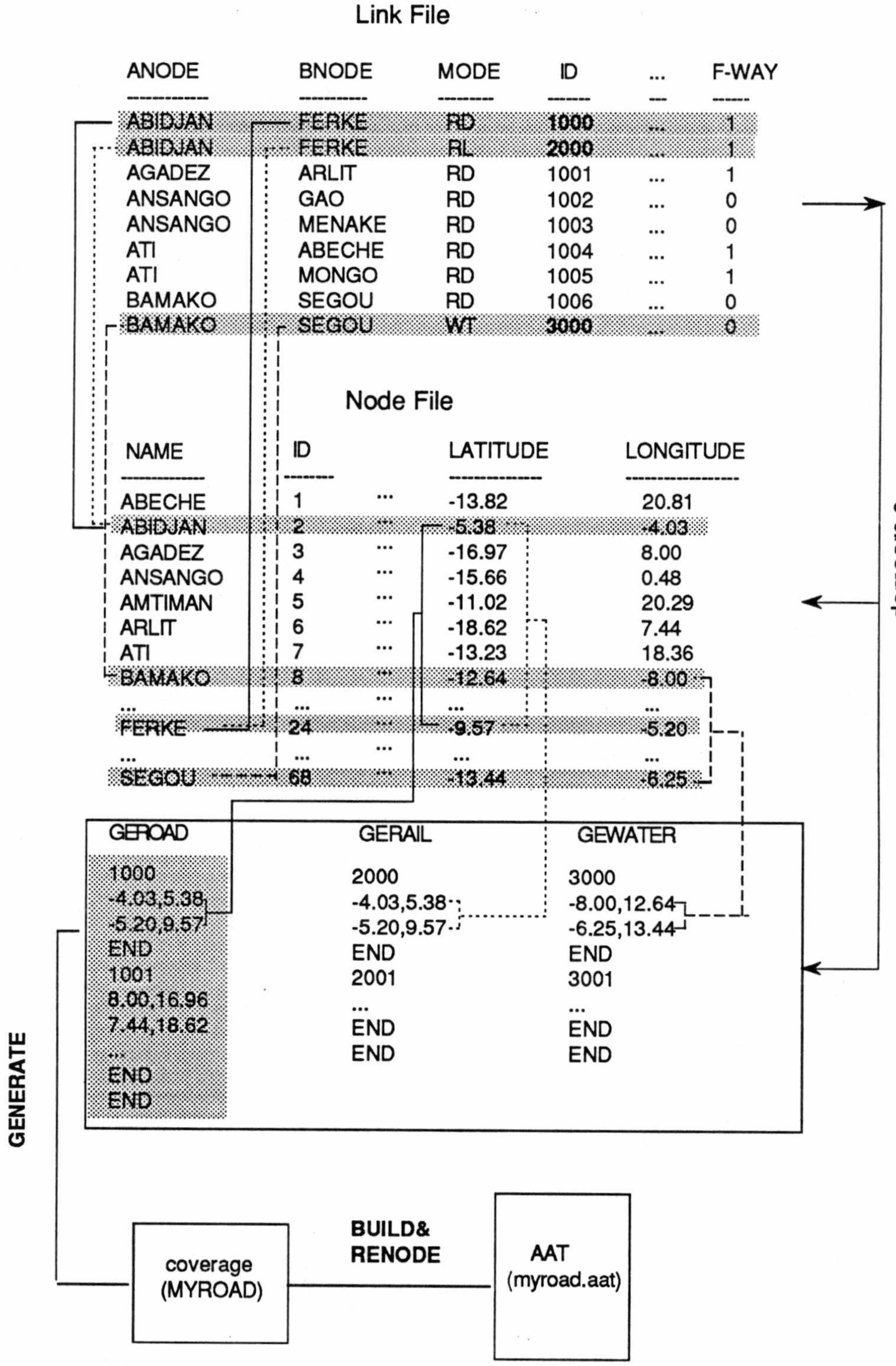

Figure 4-2

Creating A Link Coverage and Topology

field. The integration C program (i.e. DEMOARC.C) names the three files GEROAD, GERAIL, AND GEWATWER, and deletes these temporary names after coverages are created.

There are two reasons to build link coverages separately. First, in the FIELDS network, every link is a straight line connecting A and B nodes. Therefore, links of different modes connected by the same pair of nodes will overlap spatially if the entire network is built as a single coverage. By looking at the display map, users cannot identify an individual link. Consequently, users may be more confused when selecting particular link(s) on the screen in order to look at their attribute data (this overlap problem will be discussed in the last chapter). Secondly, it is more convenient to select a single mode layer for display and analysis of the result from FIELDS.

Using the three coordinate files as inputs, the system runs GENERATE command to build three link coverages. Once the coverages have been built, the next step is to build topology for these coverages. ARC/INFO has two commands to create topology and feature attribute tables automatically: 'BUILD' and 'CLEAN'. Either of the two commands can be used for line coverages. Based on graph theory, the CLEAN command creates intersections wherever lines cross one another. That is, all graphs are treated as planar. In transportation practice, however, where two links cross does not necessarily correspond to a node at the intersection. The crossovers could be an underpass of highway or railway. To avoid adding undesired nodes in the network, only the BUILD command with line option is used to create the topology and arc attribute table (AAT) for each coverage.

Usually, the topological connections between arcs and nodes are automatically generated as arcs are digitized, but the GENERATE command does not automatically calculate arc-node topology because it converts an ASCII text file of coordinates to create a coverage. For this reason, the 'RENODE' command is used to create arc-node topology for the coverage after running the BUILD command.

To build a link coverage and topology for FIELDS data in ARC/INFO involves execution of the following programs and commands in order (refer to Fig.4-2):

DEMOARC.C

GENERATE

BUILD

RENODE

The result is an arc coverage and corresponding arc attribute table (AAT). Table 4-1 is an example of AAT of a road coverage (MYROAD) created by the system.

An AAT contains seven standard items that represent topology and spatial measurements of the coverage. LPOLY# and RPOLY# have zero values in this table because the system

Table 4-1.

An Example of an Arc Attribute Table (AAT)

(MYROAD.AAT)

FNODE#	TNODE#	LPOLY#	RPOLY#	LENGTH	MYROAD#	**MYROAD_ID**
74	63	0	0	4.3503	1	1000
2	1	0	0	1.7424	2	1001
7	5	0	0	0.8262	3	1002
7	6	0	0	1.8668	4	1003
...						

Explanations:

FNODE#	Internal node number for the beginning of an arc (A node)
TNODE#	Internal node number for the end of an arc (B node)
LPOLY#	Internal number for the left polygon
RPOLY#	Internal number for the right polygon
LENGTH	Length of each arc, measured in coverage units
MYROAD#	Cover#, which is an internal arc number (values assigned by ARC/INFO). MYROAD is a coverage name.
MYROAD_ID	Cover_ID (values assigned by the user).

system will construct only arc-node topology. Cover_ID is a key item that represents the link identifiers assigned by the user. It is the matching ID when joining FIELDS attributedata to AAT. A boundary coverage is created in the same way that a link coverage is created.

4.1.3. Node Coverage and Topology

Nodes are locational origins and destinations of links in a transportation network. Nodes are related to links by their names in node and link files. Since analytical results from FIELDS contain information about nodes, such as demand of a node, storage of a node, etc., a node coverage is needed to display the information.

Building a node coverage is similar to building a link coverage. The procedure is illustrated in Fig. 4-3. First, the system executes a C program (DEMONOD.C) to construct an x, y coordinate file. The internal name of this file is GENODE. GENODE can be accessed by the 'GENERATE' command. Secondly, the GENERATE command is used to create a node coverage. The last step is to create a point attribute table (PAT) for the node coverage using the 'BUILD' command with point option.

Node file

NAME	ID	LATITUDE	LONGITUDE
ABECHE	1	-13.82	20.81
ABIDJAN	2	-5.38	-4.03
AGADEZ	3	-16.97	8.00
ANSANGO	4	-15.66	0.48
AMTIMAN	5	-11.02	20.29
ARLIT	6	-18.62	7.44
ATI	7	-13.23	18.36
BAMAKO	8	-12.64	-8.00
...	...	...	...
FERKE	24	-9.57	-5.20
...	...	...	...
SEGOU	68	-13.44	-6.25

DEMONOD.C

GENODE

```
1, 10.81, -13.82
2, 04.03, -5.38
3, 08.00, -16.97
4, 00.48, -15.66
5, 20.29, -11.02
6, 07.44, -18.62
7, 18.36, -13.23
8, -8.00, -12.64
... ... ...
24 05.20, -9.57
... ... ...
68 -6.25, -13.44
END
```

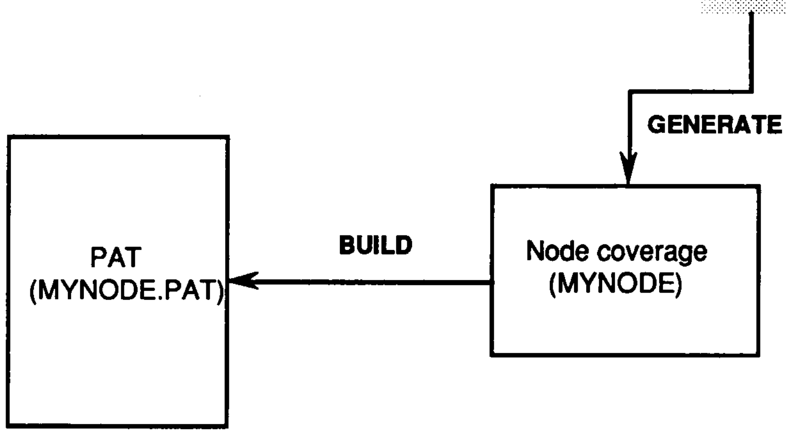

Figure 4-3

Creating a Node Coverage and Topology

Table 4-2 is an example of PAT table of the node coverage named MYNODE. Each PAT contains four standard items.

Because the node coverage is a point coverage, AREA and PERIMETER values are automatically set to zero. User_IDs are the node IDs assigned by the user in the node file: they are the key items used to relate nodes with links, and to relate node attribute data with the position of each node in the node coverage.

Once the coverages, the AATs, and the PAT are properly created, the next objective is to develop a linkage to transfer attribute data between the two packages.

4.2 CONSTRUCTION OF ATTRIBUTE DATA LINKAGE

Attributes describe characteristics of spatial features. Only after the connections between attributes and locations have been established, can a user query the map to display attribute information, or create a new map based on the topology information stored in the feature attribute table. Although the link and node coverages have been created, the AATs and PAT thus far contain only standard topology and measurements created by ARC/INFO. User attribute data have not been related or added. This section will discuss the transfer of attribute data between the two packages.

4.2.1 Adding Attribute Data of FIELDS to AATs and PAT

FIELDS attribute data are stored in link and node files.

Table 4-2
An Example of a Point Attribute Table (PAT)

MYNODE.PAT

AREA	PERIMETER	MYNODE#	MYNODE_ID
0	0	1	1
0	0	2	2
0	0	3	3
0	0	4	4
...			

Explanations:

AREA	Area of each polygon, measured in coverage units
PERIMETER	Length of each polygon boundary, measured in coverage units
Cover#	Internal point number (assigned by ARC/INFO)
Cover_ID	User_ID (assigned by the user)

Each file contains attribute data for up to eight time periods (see Appendix A1, A2). Most items in link and node files remain the same in different time periods, such as ANODE, BNODE, and MODE in link files, but some do change with period, such as COST and CAPACITY in link files. These items carry the information regarding the features of a link or node. They need to be related to the corresponding coverages. Because road, rail and water coverages are created separately, link attribute data have to be separated by mode before being added to the AATs. The data transfer from FIELDS to ARC/INFO is carried out in three steps using C programs, ARC commands, and TABLES commands. An example for transferring link attribute data to ARC/INFO is shown in Fig. 4-4. The first step for the data transfer is to execute a C program (DEMOAAT.C) to extract attribute data from a link file, then write to three attribute files, ROAD.DAT, RAIL.DAT and WATER.DAT. These data files are written in a format that can be used by the 'ADD' command in the TABLES module of ARC/INFO.

The second step is to use the 'DEFINE' command to define data structures for each extracted data file. The item name of 'IDs' must be the same as the name of 'COVER_ID' in the AAT file because it is the relational key. For example, if the road coverage name is 'MYROAD', a 'MYROAD_ID' must be used as the item name when defining the ARC/INFO file structure. After a data structure file is defined, the ADD

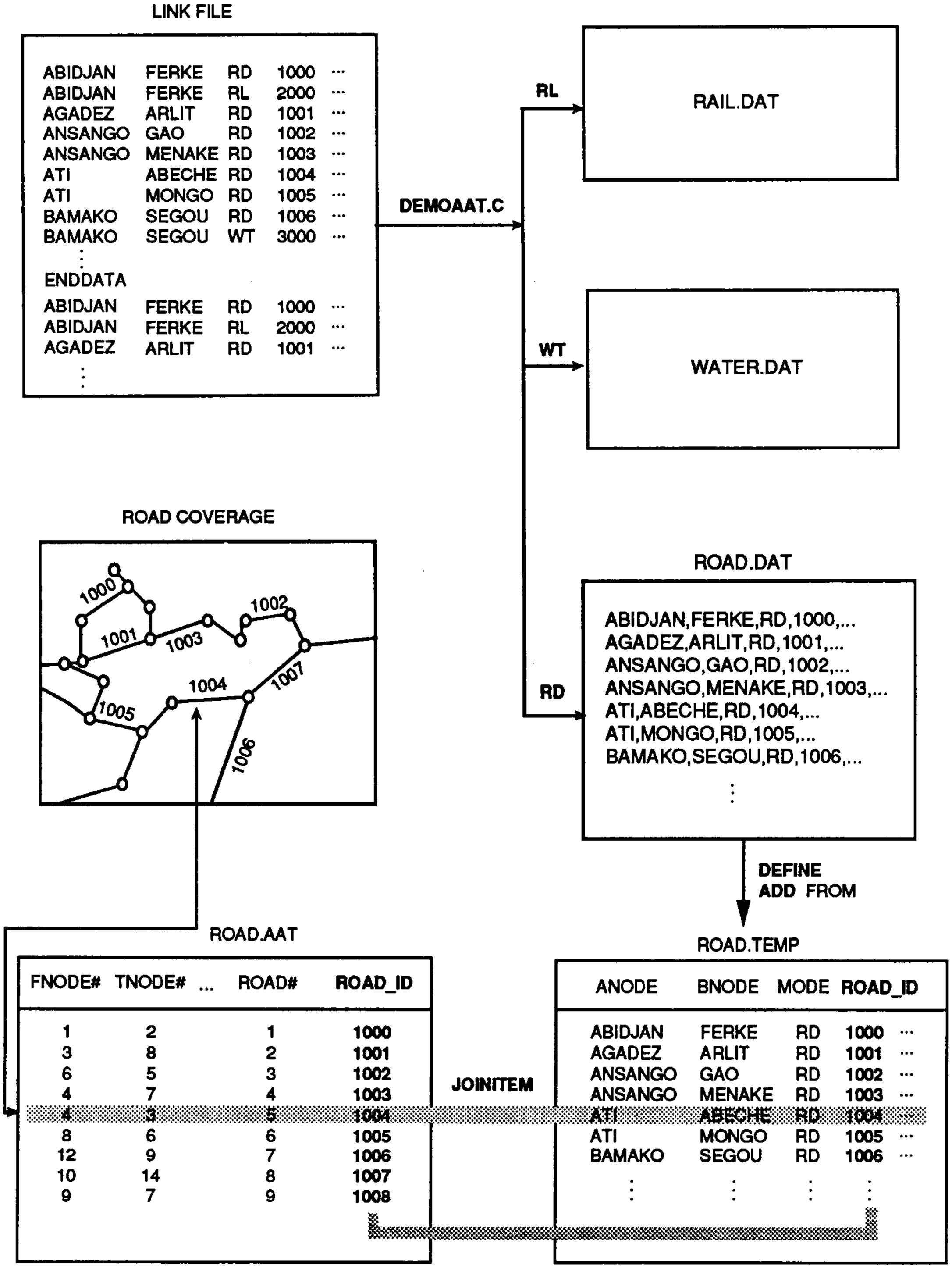

Figure 4-4

Transferring Link Attribute Data to ARC/INFO command with 'FROM' option will be used to add the records of 'ROAD.DAT' to this data structure file.

The last step is to join the attribute data file to the corresponding AAT file using the 'JOINITEMS' command. After execution of the JOINITEM command, the MYROAD.AAT file contains not only standard items, but also the entire road attribute data set from FIELDS. The relationships between links of the road coverage and their attribute data are also created by the system.

Rail, water, and node attribute data can be transferred to ARC/INFO with the same procedure. Node attribute data is extracted from a node file with a C program (DEMOPAT.C), then the data file (NODE.DAT) can be added to PAT of the node coverage.

The processes described above connects the attribute data of FIELDS with the corresponding ARC/INFO coverages. According to the ARC/INFO concept of a one-to-one relationship between a feature on the map and its attribute data, the user can select any link or node on the map, and look at its attributes immediately.

4.2.2 Extracting Data From ARC/INFO

Once transferred, FIELDS data can be displayed, queried, and edited in ARC/INFO. The user can add, delete, change links and nodes, and edit attribute data, then send the modified data back to FIELDS and re-run the model to get new results. Because FIELDS needs a link file and node file as input, sending data back to FIELDS requires extracting link file data and node file data from ARC/INFO. The following procedure is used to complete the data transfer from ARC/INFO to FIELDS.

1) Appending the three link coverages.

   Because FIELDS keeps all link data in one link file, the first step is to combine the three separate link data files in ARC/INFO to form a single file. The system uses the 'APPEND' command with line option to append road, rail, and water coverages to form a new coverage. A new AAT is created simultaneously. It contains all attribute data of links from the three AATs.

2) Extracting FIELDS attribute data from ARC/INFO.

   The AAT of the appended coverage contains the FIELDS attribute data and seven standard items assigned by ARC/INFO (Table 4-1). The 'PULLITEM' command in the ARC module can be used to extract the FIELDS attribute data. This command will extract the user specified items from the AAT, and store them in table format in an ARC/INFO database.

3) Converting data from table format to ASCII text format.

   The system uses the 'DUMP' command with fixed option to convert the file created in step 2 to an ASCII text format.

4) Rearrange data in FIELDS link file.

The last step is to rearrange the data to the original link file data format. Data for each period are appended vertically in the FIELDS link file (see Appendix A1), but horizontally when added to the AATs. The file created in step 3 still is in AAT format and needs to be rearranged. The system runs a C program (BACKLINK.C) to complete the data transfer.

The same procedure can be employed to send a node file back to FIELDS. Data are extracted directly from the PAT, then pulled out and converted into the ASCII text format. Finally, a C program (BACKNODE.C) rearranges the data in the node file format of FIELDS.

4.3 DISPLAY OF FIELDS RESULTS

An advantage of linking an external model with a GIS is to use the GIS' graphical capabilities. The importance of high quality visual presentation has been recognized because it allows decisionmakers to interact with the solution process and to visualize the modeled results displayed in map form. This visualization is especially important when large numbers of variables is involved. The modeling analysis of FIELDS generates a large volume of information (Ralston and Ray, 1987). One of the results generated by FIELDS is a graphic file that can be used to map various aspects of the optimal linear programming solution. This graphic file contains information about each link and node. The solutions are coded with integers, as described in Chapter 2. The integrating system uses these data to display the analytical results.

The steps used by the integration system are as follows:

1) Adding results to AATs and PAT

The results of the analysis are also the attribute information for links and nodes. To display the results on a map, the user needs to connect attribute data to AAT and PAT. The procedure is similar to that which relates link and node attribute data to AATs and PAT. Because the graphic file contains information about all link and node results, a single C program is written to generate three line files (based on mode) and a node file from the graphic file. Then 'DEFINE', 'ADD', and 'JOINITEM' commands are used to add these data to the three AATs and one PAT files.

2) Create lookup tables

To display the results, each code of solutions in the graphic file can be assigned a display symbol. Instead of storing display symbols in AATs or PAT, a set of lookup tables is created. Using the lookup tables reduces the redundancy of data storage and provides more flexibility by allowing more than one coverage to use one lookup table for display. Thus, a simple lookup table MODES.LUT, is used by all link coverages to display roads, rails, and waterways using assigned symbols (Table 4-3).

The connection between the lookup table and coverage features depends on the common key words that exist in both the lookup table and the AATs, such as 'MODES' column in Table 4-3. All link coverages with RD, RL, and WT mode flags in their AATs are displayed with symbols assigned in lookup table. Symbol 2 (red solid line), symbol 3 (green solid line), and symbol 4 (blue solid line) represent road, rail, and waterway, respectively.

Twelve lookup tables were generated to display the results of FIELDS (these tables are in a LOOKUP directory of the integrating system). Except the MODES.LUT, each table contains eight period values and symbols. Fig.4-5 shows the relationship between lookup tables and a coverage.

Table 4-3

A Lookup Table for Modes

(MODES.LUT)

MODES	SYMBOL
RD	2
RL	3
WT	4

ROAD.AAT

FNODE#	TNODE#	...	ROAD#	ROAD_ID	ANODE	BNODE	MODE		FLOW1	FLOW2 ...	CAPA1	CAPA2 ...
1	2	...	1	1000	ABIDJAN	FERKE	RD	...	1	1	1	0
3	6	...	2	1001	AGADEZ	ARLIT	RD	...	1	1	1	1
4	15	...	3	1002	ANSANGO	GAO	RD	...	0	1	0	0
4	7	...	4	1003	ANSANGO	MENAKE	RD	...	0	1	0	0
8	10	...	5	1004	ATI	ABECHE	RD	...	1	0	0	0
8	11	...	6	1005	ATI	MONGO	RD	...	1	0	0	0
9	12	...	7	1006	BAMAKO	SEGOU	RD	...	0	0	0	0
9	14	...	8	1007	BAMAKO	NARA	RD	...	1	0	0	0
9	7	...	9	1008	BAMAKO	NIORO	RD	...	0	0	1	1

MODES.LUT

MODE	SYMBOL
RD	2
RL	3
WT	4

FLOWROAD.LUT

FLOW1	FLOW2 ...	FLOW8	SYMBOL
0	0	0	1
1	1	1	6

CAPAROAD.LUT

CAPA1	CAPA2 ...	CAPA8	SYMBOL
0	0	0	1
1	1	1	6

Figure 4-5

Relationships Between Features and Lookup Tables

There are seven lookup tables for displaying link-related results:

MODES.LUT	three modes symbols
FLOWROAD.LUT	flow on roads for each of eight periods
FLOWRAIL.LUT	flow on rails for each of eight periods
FLOWAT.LUT	flow on rivers for each of eight periods
CAPAROAD.LUT	capacity on roads for each of eight periods
CAPARAIL.LUT	capacity on rail for each of eight periods
CAPAWAT.LUT	capacity on rivers for each of eight periods

Similarly, there are five lookup tables for displaying node-related results:

DEMAND.LUT	demands for each of eight periods
AIR.LUT	airdrop for each of eight periods
TRAN.LUT	transshipment for each of eight periods
TRUCK.LUT	truck numbers for each of eight periods
STORAGE.LUT	storages for each of eight periods

A lookup table for node coverage uses marker (for node and point features) symbols instead of line symbols to display node-related information. The lookup table seeks for the relating keys in a PAT instead of in an AAT.

With these lookup tables, the FIELDS results can be displayed. The next step is to design a user interface for presenting these results to the user.

CHAPTER 5

USER INTERFACE

5.1 INTRODUCTION

A user interface is the part of the computing system that allows a person using the computer access to the facilities offered by the computer (Thimbleby, 1990). In general, a user interface fits into two categories: a common user interface and user interface for particular packages. A common user interface primarily involves system development. The interface for particular packages is needed when two pieces of software cannot communicate directly with each other, and that communication is important. This paper discusses an interface of the second type, specifically the interface between FIELDS and ARC/INFO.

5.2 IMPLEMENTATION

The user interface developed to integrate FIELDS and ARC/INFO is a hierarchical, menu-driven system. Fig. 5-1 shows the structure of the menu hierarchy. Descriptions of each menu and its options are given below.

To initiate the system, the user types '@INTER' or '&RUN INTER' at the ARC prompt. For example, if the system and data files of FIELDS are loaded in a directory called 'TEMP' in the C drive, the command to start the system is:

(C:\TEMP)[ARC]**@INTER**

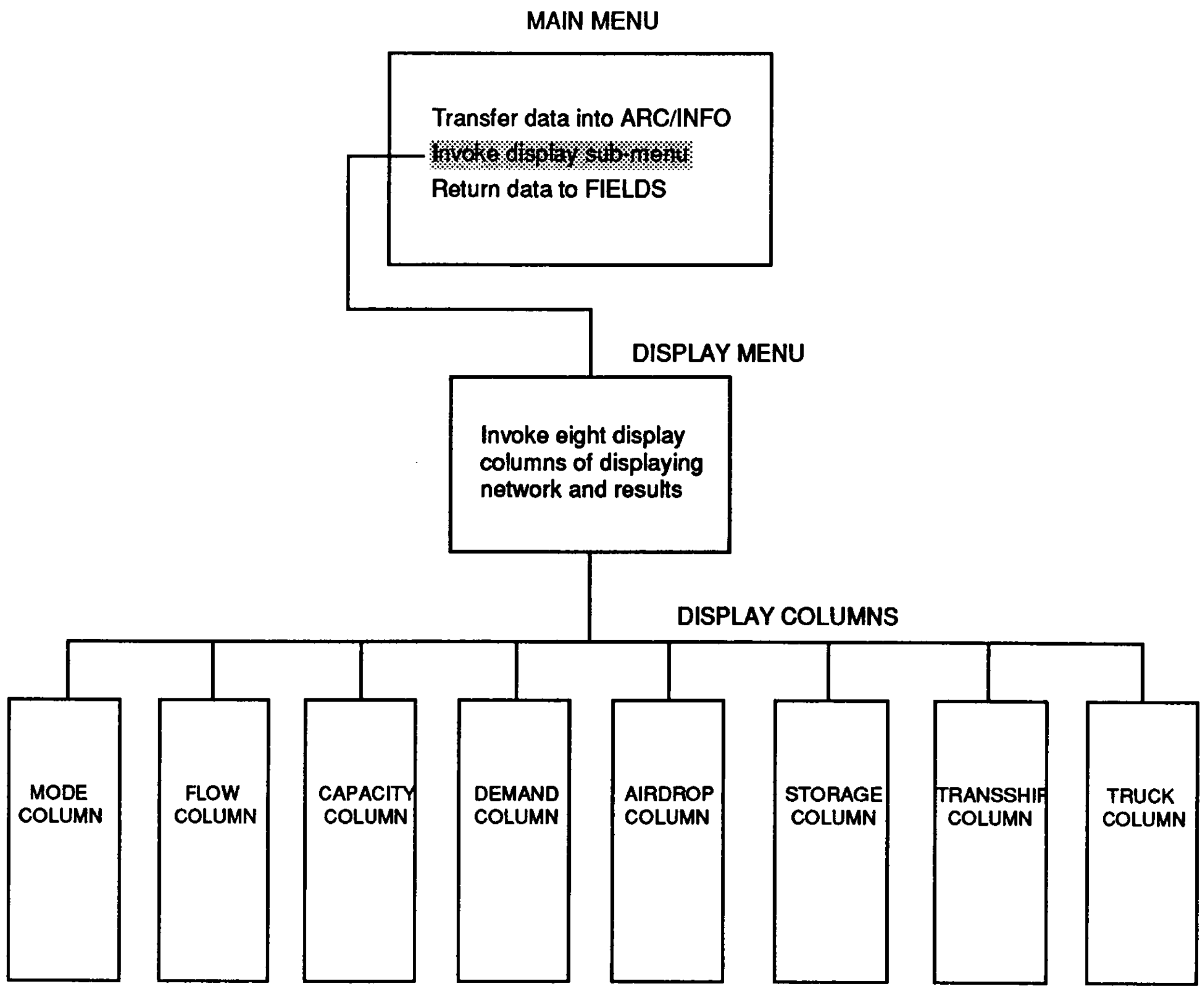

Figure 5-1

Structure of Menu System

The main menu (Fig.5-2) will appear on the screen. The main menu is the control center of the integrating system. All actions will be guided with a menu tree rooted in the main menu. When each selection is completed, the user will be returned to the main menu.

To select an option in the menu, the user moves the cursor to the desired number and presses the 'RETURN' key. While the computer is executing the selected option, messages reporting the progress appear on the screen. The messages appear in two colors. Messages in white are generated by ARC/INFO, while messages in yellow are issued by the application programs.

There are four options in the main menu. The first three options represent the three major groups of applications in this system. They are listed in the order that the various steps are to be executed. In other words, to complete the entire integration operation, the user has to go through the three options, from 1 to 3. The user also has to follow the order even if he or she is interested only in executing one of the options. For instance, if the user intends to look at the graphic results (option 2), he or she can ignore option 3, but has to select option 1 before using option 2. That is, data must be imported before they can be displayed.

INTEGRATING SYSTEM
FOR
FIELDS AND ARC/INFO

~~~~~~

MAIN MENU

1 --- Transfer FIELDS data into ARC/INFO
2 --- Display results of FIELDS
3 --- Return data back to FIELDS

4 --- QUIT

Figure 5-2

Main Menu
~~~~~~

As shown in Fig. 5-1, the menu tree is not typically hierarchical. Options 1 and 3 do not have sub-menus. Once a user selects either of these options, the system begins to work on selected application programs immediately and will return to the main menu when they are completed. In the process, the user will be asked to enter file names, and names of files and coverages that are created by the system. Option 2 has a set of sub-menus, each of which controls graphic display. Option 4 allows user to exit the system. The following sections describe each option in detail.

5.2.1 Option 1 - Converting FIELDS Data into ARC/INFO

This option executes programs which perform the following tasks.

1) It creates three link coverages (road, rail, water), one node coverage, and builds the topology for these coverages. In addition, a boundary line coverage is also created.
2) It transfer FIELDS attribute data to the corresponding Arc Attribute Tables (AATs) and a Point Attribute Table (PAT).
3) It transfer the results of FIELDS to corresponding AATs and PAT.

Fig. 5-3 shows a flow chart of option 1. When option 1 is selected, the system will automatically work on task one. The user is asked to enter the names of existing data files (the link file, the node file, and the graphic result file). Then the system builds the coverages and prompts the user to name each coverage created. As programs are executed, the system will frequently display information about the FIELDS data files and the ARC/INFO coverages. The procedure can be explained using the example link file (WADEMO.ARC) and node file (WADEMO.NOD). When the FIELDS arc file and node file are entered, the system will display the numbers of links and nodes:

The number of arcs is: 109

The number of nodes is: 79

Then, the system will create the coverages according to the arc and node files and ask the user to name the coverages. If the road, rail, water, and node coverages are named MYROAD, MYRAIL, MYWATER, AND MYNODE, the COUNT will be invoked to give the following messages:

Here is your road coverage information:

Counting coverage MYROAD...

Arcs: 86

Segments: 86

Nodes: 77

Polygons: 0

Label Points: 0

Here is your rail coverage information:

Counting coverage MYRAIL...

Arcs: 11

Segments: 11

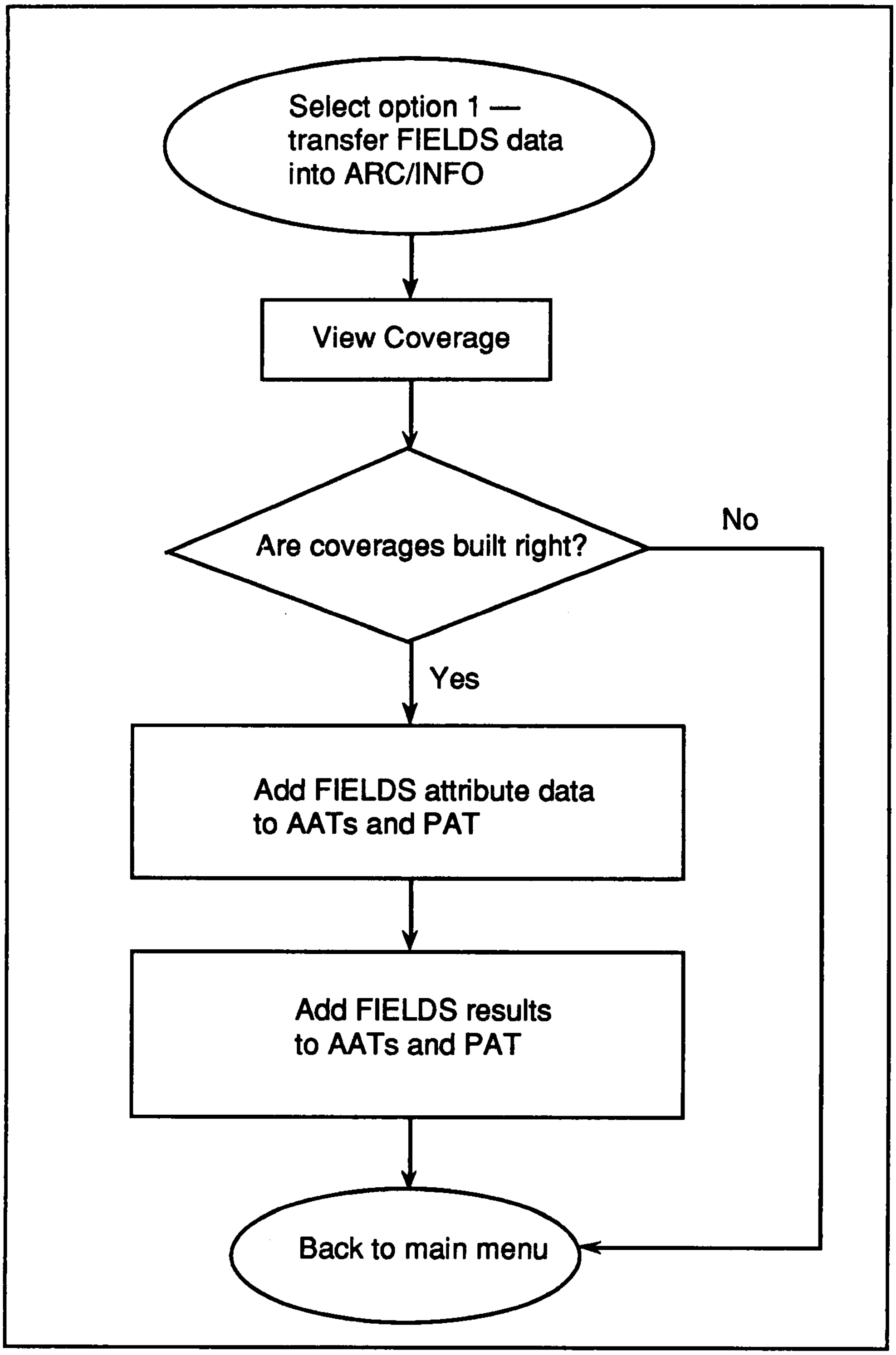

Figure 5-3

Flow Chart of Option 1.

Nodes: 16

Polygons: 0

Label Points: 0

Here is your water coverage information:

Counting coverage MYWATER...

Arcs: 12

Segments: 12

Nodes: 14

Polygons: 0

Label Points: 0

Here is your node coverage information:

Counting coverage MYNODE...

Arcs: 0

Segments: 0

Nodes: 0

Polygons: 0

Label Points: 79

Besides the number checking, the system displays the coverages created graphically with different symbols in the ARCPLOT module. This double checking gives the user an opportunity to locate problems at an early stage, and ensures that the original data of FIELDS has been accurately transferred into ARC/INFO.

After completion of the first task, the system gives the user a choice to continue or to exit the performance by displaying the message:

Do you want to continue to transfer FIELDS attribute data into ARC/INFO(Y or N)?

If the user enters Y(yes), the system will start to perform the second task, adding attribute data of FIELDS to AATs and PAT. The third task, transferring results of FIELDS to AATs and PAT, will be performed following a similar procedure. It will start automatically when the second task is finished. The user will then be prompted to enter names for the files to be generated in the process.

After the completion of option 1, the FIELDS data will have been transferred into ARC/INFO. The relations between attribute data and the features of the created coverages as well as the relations among the resulting codes, symbols, and features of the coverages will have been built.

5.2.2 Option 2 - Displaying Results of FIELDS

After option 1 in the main menu has been performed, option 2 can be selected to display the FIELDS results. This option consists of three steps: appending coverages, displaying results, and plotting maps. The following section briefly describes the procedure shown in Fig.5-4.

1) Appending Coverages

When Option 2 is selected from the display menu, the system performs the 'APPEND' command in the ARC module to append three separate link coverages (road, rail, and water) in to a single coverage (refer to Chapter 4.2.2). The user

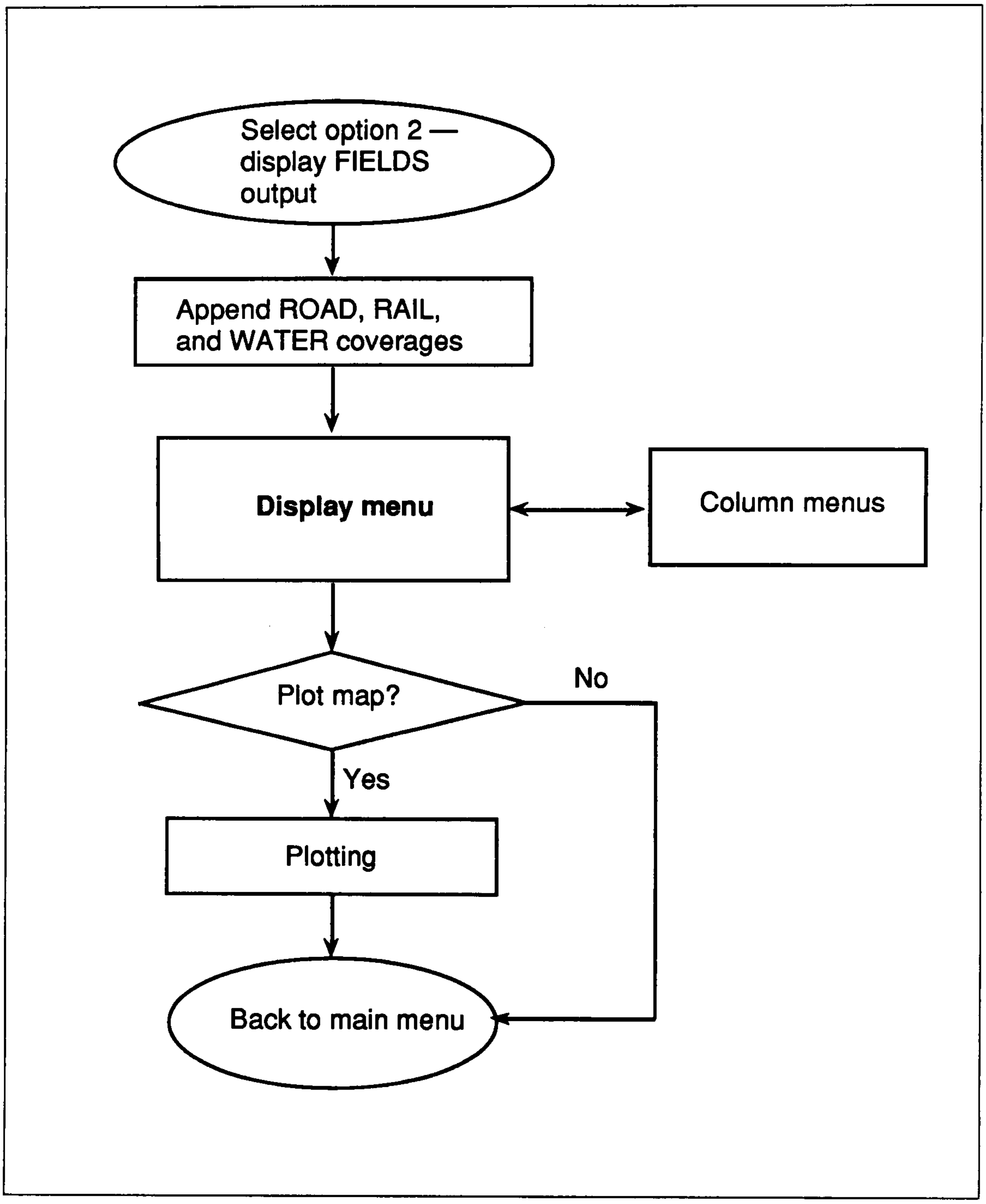

Figure 5-4

Flow Chart of Option 2.

will be prompted to give a name for the coverage being created. The appended coverage includes all links in the network. This coverage is used to display the entire network, and will also be used as a background when displaying the node-related information. In addition, an appended AAT is automatically created. This AAT contains all link attributes imported from FIELDS.

After the coverages have been appended, the display menu will appear on the screen.

2) Displaying Results

The display menu (Fig.5-5) lists eight options to display different components of the network. The user may select any option in the menu in any order. The 'MODE' option is used to view the network. The other seven options are used to view the FIELDS LP results. The functions of each option and the feature displayed in each option are listed in Table 5-1.

As shown in Fig. 5-4, each option in the display menu invokes a column menu when the option is selected. Each column menu contains options that represent different modes or time periods for the features to be displayed. When each option is selected from a column menu, four major activities take place: (1) the selected features are displayed. (2) a map file of the display is created; (3) more features may be added to the basic display; and (4) the attribute data for

DISPLAY MENU
~~~~~~~~~~~~~~~~
mode
flow
capacity
demand
airdrop
storage
transship
truck

QUIT

Figure 5-5

The Display Menu.

selected features are listed on screen. The following section will discuss each option in the display menu as well as its related column menu.

<u>The MODE option</u>

'MODE' is an option that provides the user an opportunity to view the network . When this option is selected from the display menu, a mode column menu appears (Fig. 5-6). This column provides four choices to display the network: network, road, rail, and water.

When the NETWORK is selected from the mode column, the column menu disappears and the entire network is displayed with geographic boundaries of the study area in the
~~~~~~~~~~~~~~~~

Table 5-1

Categories of Display Menu Option

OPTION	DISPLAY FEATURE	MAIN FUNCTION
Mode	arcs and node	view network
Flow	arcs	view LP results
Capacity	arcs	view LP results
Demand	nodes	view LP results
Airdrop	nodes	view LP results
Storage	nodes	view LP results
Transship	nodes	view LP results
Truck	nodes	view LP result

background. Road, rail and water modes are shown as links in different colors, nodes are highlighted by marker symbols, and a legend is placed on the map. Links of each mode are displayed with consistent symbols throughout the process. Road links are in red, railroad in green, and waterway in blue. During the display, the system creates a map composition file that contains all elements displayed on the screen. The map file is named automatically by the system, with the name of the selected option plus a '.MAP' extension. For example, 'NETWORK.MAP' is created when the 'NETWORK' option is selected. All map files can be sent to a plotter to create hard copies.

network
road
rail
water

QUIT

Figure 5-6

The Mode Column Menu.

After the network has been displayed on the screen, the system runs the 'IDENTIFY' command in ARCPLOT module and asks the user:

Do you want to know a certain node's information(Y or N)?

If the answer is Y, a cursor will appear on the screen. The user can move the cursor to a node, then press any alphanumeric key to select it. The attribute list of the selected node will be displayed in the text window on the screen. The user can repeat the process to select as many nodes as he or she wants. To exit the view and return to the column menu, the user needs to press the F1 key or enter '&RETURN'.

When the 'ROAD' option is selected from the column, only road links will be displayed, with geographic boundaries in the background. A road map file, 'ROAD.MAP' is created simultaneously. After the road links have been displayed, there are three options that can provide the user additional information.

- The user may look at any link attribute data of roads in the same way as he or she examined node attribute data. The prompt message is:

  Do you want to know a ROAD's information?

- After looking at the attribute data, the system can overlay the node coverage to the display. The prompt message is:

  Do you want NODE background?

- The user can also add the water and rail coverages to the mode and road link display. The prompt message is:

  Do you want other MODES background?

The 'RAIL' and 'WATER' options from the mode column have the same functions as the 'ROAD' option. After 'RAIL' or 'WATER' is chosen, attributes will be displayed, a map file will be generated, then the node coverage can be added. Likewise, the other coverages also can be superimposed.

Display of Arc-related Results (FLOW and CAPACITY options)

The 'FLOW' and 'CAPACITY' options in the display menu provide information about the arc-related results. Each option has a related column menu that has options for eight periods. Fig. 5-7 shows the FLOW and CAPACITY column menus. In these two menus, options 'FLOW1' to 'FLOW8' represent the flow assignment results of up to eight time periods, while 'CAPA1' to 'CAPA8' represent up to eight period capacity results. The time periods available in the options depend on the number of periods input by the user. If the input from FIELDS contains data from only two time periods, only FLOW1 and FLOW2 in FLOW column, and CAPA1 and CAPA2 in CAPACITY column can be selected.

Flow assignment shows to which links the flows are assigned. For example, when 'FLOW1' is selected, a color network map will be displayed with its boundaries. As usual, red, green, blue lines in the flow option represent roads,

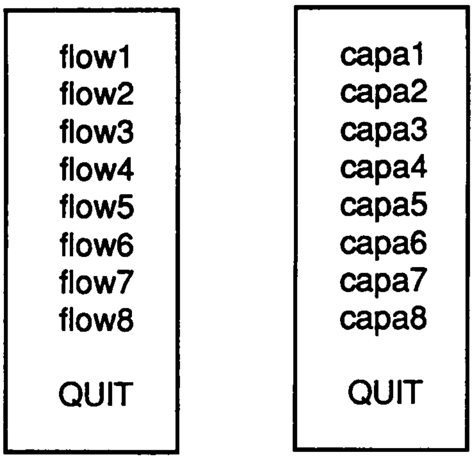

Figure 5-7

The Arc-related Column Menus.

railroads, and waterways respectively. White lines are the links without flow assignment. A legend is placed on the low-right of the display, and a map file called 'FLOW1.MAP' recording the map displayed on the screen is created. After viewing the display, the user may press the F1 key or type '&RETURN' to return to the 'FLOW' menu.

'CAPA1' to 'CAPA8' options in the column menu display the link capacity of each period in terms of dual prices. For any selected period, a map file is created for this option. White lines represent the links with zero dual prices. Red, green and blue links represent the road, railroad, and water links with non-zero dual prices. Non-zero dual prices means that if shipping capacities are increased on these links, the total transportation cost can be reduced.

Display of Node-related Results

Five options are designed to display node-related results in the DISPLAY menu: 'DEMAND', 'AIRDROP', 'STORAGE', 'TRANSSHIP', and 'TRUCK'. Each option is also related to a column menu that has options for eight periods (Fig.5-8). In each column menu, options available vary according to the time periods of input data. When an option is selected, a map file is created automatically.

When 'DEMAND' is selected from the DISPLAY menu, its column menu occurs on the screen with options for eight periods. After 'DEMAN1' is selected, the network map is shown on the screen. Nodes are displayed with two different symbols, representing the nodes with and without demands, respectively (Fig.5-9). As usual, the legend is placed on the lower right of the map. A map file named 'DEMAN1.MAP' is created simultaneously. Then the system prompts:

Do you want to know a certain node's attribute information?

If the answer is Y, a cursor will appear on the screen. After appropriate node has been selected, the attribute list of the node will be displayed in the text window on the screen. The user can select as many nodes as he or she wants until the answer is N.

When 'AIRDROP', 'STORAGE', 'TRANSSHIP', or 'TRUCK' options are selected, the procedure is similar to that described above. The legend of each map can explain its contents.

The user can go back to any column menu as well as display menu to reselect any options. After displaying the maps, plotting can be carried out.

deman1	air1	stor1	trans1	truck1
deman2	air2	stor2	trans2	truck2
deman3	air3	stor3	trans3	truck3
deman4	air4	stor4	trans4	truck4
deman5	air5	stor5	trans5	truck5
deman6	air6	stor6	trans6	truck6
deman7	air7	stor7	trans7	truck7
deman8	air8	stor8	trans8	truck8
QUIT	QUIT	QUIT	QUIT	QUIT

Figure 5-8

The Node-related Column Menus.

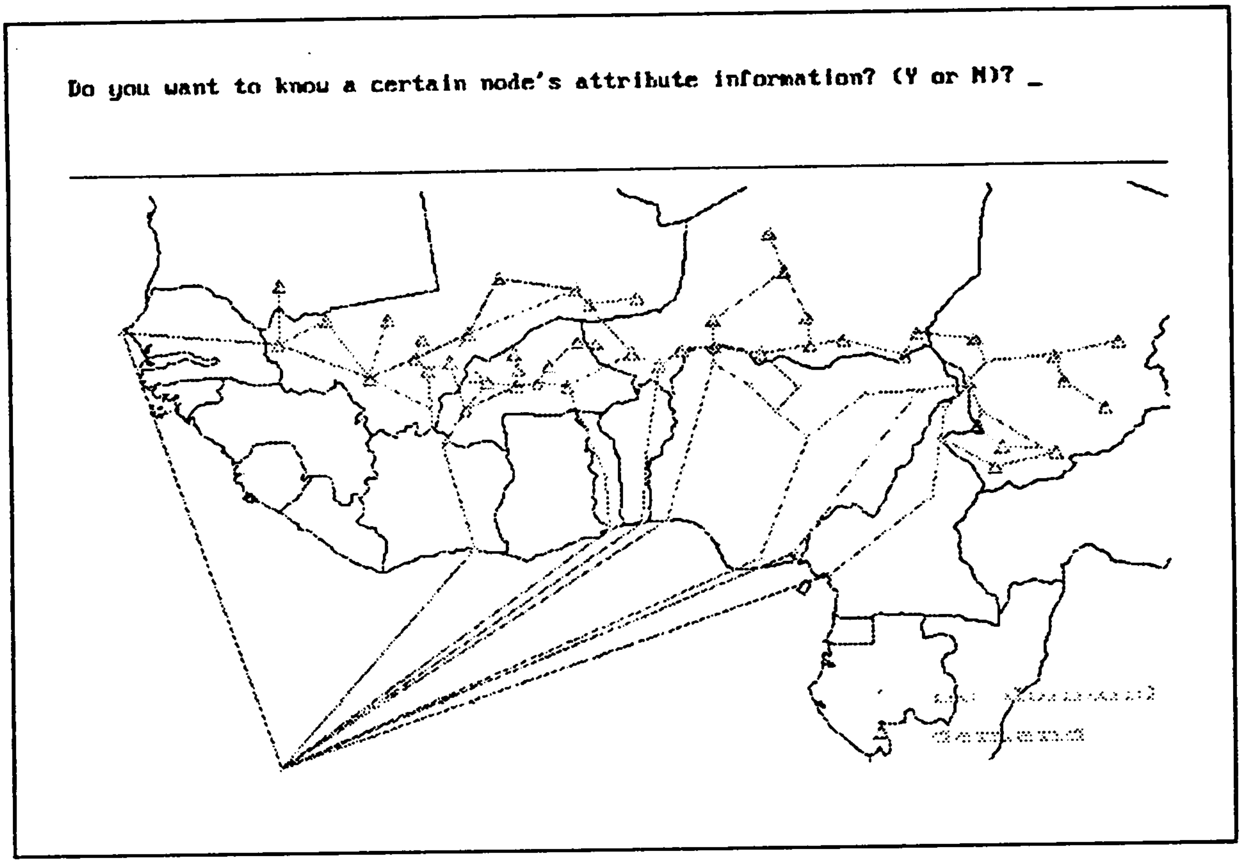

Figure 5-9

The Demand Map of Network

3) Plotting Maps

Plotting maps is the last step before leaving the display menu. Each option selected from the column menus has a map file. The system provides a list of available map files for the user. Before returning to the main menu, the user is given the option of plotting the maps created during the display process. The system will provide instructions for plotting and list the plot files with '.MAP' extension on the screen. Then the system will prompt:

Enter the name of plot file (with .MAP) or QUIT :

If the user has a plotter ready and intends to plot a map, the user will enter the map file name. The system will display the map first, then plot the map. The user can plot maps one at a time until entering 'QUIT' to leave the display menu.

If the user is not ready to plot maps or is not satisfied with the plot parameters provided by the system, the user can go back to the MAIN menu without plotting. The system will keep the map files in the current directory. The user can plot them out later using the ARC/INFO 'PLOT' command. The created plot files, however, will be automatically deleted when rerunning the system, or when reselecting an option from a column menu. In other words, the system only stores map files of the last application.

5.2.3 Option 3 - Returning Data to the FIELDS Format

This option converts data from the ARC/INFO format to FIELDS format. It is the reverse action of option one (refer to Chapter 4.2.2). There is no sub-menu related to this option. When the option 3 is selected, the system will extracts arc-related items from the AAT of the appended coverage, and extracts node-related items from the PAT of the node coverage. Then the items will be stored in two system files. The two files are rewritten with C programs in the format of the link and node files of FIELDS. The user is asked to enter names for the new link file and the node file, then the system runs the programs to complete the data transfer. If the user wants to overwrite the old files of FIELDS, he or she can enter the names of the existing files instead of new ones.

When the user is brought back to the main menu after this option is done, the whole integrating process is completed. The 'QUIT' option brings the user back to ARC prompt.

5.3 INTEGRATING SYSTEM DISKETTE

The diskette accompanying this document contains all the programs and data files of the integrating system. It is suggested that the system be loaded in an individual directory in a hard disk drive.

Six directories and other relevant files have been copied to the diskette:

CPROGRAM: Contains eight C programs and eight executable files

COLUMN: Contains eight SML programs for display of the results of eight categories

DEMODATA: Contains four example FIELDS data files for testing and demonstrate the system

LEGEND: Contains 13 legend files for different maps

LOOKUP: Contains 13 lookup tables for different modes and category results

MIXSML: Contains 34 SML sub-programs

In addition to the directories and the files under them, four demonstrating data files, eight executable C programs, and SML main programs of the system are also in the diskette. The main SML programs with 'SML', 'MNU', or 'DRV' name extensions. A file with an 'MNU' extension is mainly related to menu functions. A file with an DRV extension is an intermediate program used to drive another program.

By typing '@INTER' or '&run INTER', 'INTER.SML', the SML program used to start the system is invoked. 'DELETE.SML' is a utility program to delete the old coverages and files created by the system. This utility is used under two circumstances. One is when the user tests the system or practices using the system. By running 'DELETE.SML' the testing files and coverages created during the process will be automatically deleted. Otherwise the files and coverages created by the system will be kept for the user. Another situation is when the user makes mistakes or quits the system in the middle of the integrating process, the user can run the 'DELETE' utility to delete the unfinished files or coverages. However, it is suggested that the user manually check the current working directory when the second situation occurs. The utility function may not catch all unfinished files and coverages. To run this utility, the user enters '@DELETE' or '&RUN DELETE' at the ARC prompt.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This study has presented a system which integrates a GIS package, ARC/INFO with a stand-alone transportation analysis package, FIELDS. This integrating method bridges the two packages without modifying them. It is efficient, economic, and easy to use. The system consists of three basic components: the transfer of data from the FIELDS to ARC/INFO, the display of FIELDS LP results, and the transfer of data back to the FIELDS. The integration is implemented with programs written in C and in ARC/INFO SML. In particular, SML is a basic tool for this integration. The menu-driven interface developed in this study is also based on the SML.

This study is a prototype of the stand-alone integrating method. The method has several advantages:

(1) GIS as a spatial information system can provide adequate, standardized data required by transportation models. Integrating GIS with sophisticated models is a current trend because GIS provides common ground for data sharing.

(2) This type of integration systems enables sophisticated transportation models to take advantage of powerful GIS display capabilities. Because of the diversities in data structures of different models and involvement of non-planar

graphs in transportation analysis, it is difficult to expect GIS to accommodate all the models in the near future.

(3) A menu-driven interface can extend GIS and transportation analysis to users who do not have much GIS or modeling experience.

There are some assumptions and limits to this system about which users should be aware.

(1) The topology of a network is built based on physically existing nodes and links in ARC/INFO. In order to build the LP models, some logical nodes and links have to be created in FIELDS. For example, roads and railways connecting two cities are expressed as two physical link, and two logical link in FIELDS, but two physical links in ARC/INFO. The same situation may be encountered when a node is also a port. Thus, confusion may occur when a network involving two or more modes is built as one coverage. For example, if two or more links share the same line spatially, the user may not be able to retrieve the desired attribute data of particular link by selecting the line in display mode. In order to avoid this confusion, this study created separate coverages for each mode, and did not transfer port information to ARC/INFO.

(2) This is not a general purpose system. It is developed uniquely for PC ARC/INFO and FIELDS. However, the methodology and procedures used here can benefit other systems that integrate ARC/INFO and other types of transportation LP models.

A well-developed stand-alone integrating system can make a modeling package a decision support system. A decision support system is a framework for interacting, integrating analytical modelling capabilities, database management systems, and graphical display capabilities to improve decision-making processing. At present, the integrating system only allows users to examine visually the analytic results of FIELDS. Further research on the system will eventually allow users to interactively manipulate and observe the effects of different parameters on a transportation network.

BIBLIOGRAPHY

Ding, Y., and A. S. Fotheringham, 1991, "The Integration of Spatial Analysis and GIS: The Development of the STATCAS Module for ARC/INFO," National Center for Geographic Information and Analysis, SUNY Buffalo, Buffalo, NY.

ESRI, 1990, Understanding GIS: the ARC/INFO method, Redlands, CA.

ESRI, 1991, PC ARC/INFO GIS Concept Kit, Redlands. CA.

Goodchild, M. F., 1991a, "Integrating GIS and Environmental Modeling at Global Scales," GIS/LIS' 91 Proceedings, Vol.1, 117-127.

Goodchild, M. F., 1991b, "Spatial Analysis With GIS: Problems and Prospects," GIS/LIS' 91 Proceedings, Vol.1, 40-48.

Kehris, E., 1990, "A Geographic Modeling Environment Built Around ARC/INFO," Research Report No. 13, North West Regional Research Lab, Lancaster, UK.

Lewis, S., P. Cook, and M. Minc, 1990, "Comprehensive Transportation Models: Past, Present and Future," Transportation Quarterly, Vol. 44, 249-265.

Liu, C., and B. A. Ralston, 1990, The Bangladesh Transportation Modeling System, The International Bank for Reconstruction and Development, Washington, DC.

Loffman, R. S., 1987, User Interface for a Partially Incompatible System Software Environment with Non-ADP Users, [M.S. Thesis], Department of Computer Science, University of Tennessee, Knoxville. 211 p.

O'Neill, W.A., 1991, "Developing Optimal Transportation

Analysis Zones Using GIS," ITE Journal, December, 33-36.

Nyerges, T. L., and K. Dueker, (1988), Geographic Information Systems in Transportation, U.S. Department of Transportation, Washington, D.C.

Pascoe, R. T., and J. P. Penny, 1990, "Construction of Interfaces for Exchange of Geographic Data," International Journal of Geographical Information Systems, Vol. 4, 147-156.

Piwowar, J. M., E. F. LeDrew, and D. J. Dudycha, 1990, "Integration of Spatial Data in Vector and Raster Formats in a Geographic Information Systems Environment," International Journal of Geographic Information Systems, Vol. 4, 429-444.

Ralston, B. A., and J. Ray, 1986, The Food for Peace Inland Emergency Logistics and Distribution System, United States Agency for International Development, Washington, DC.

Ralston, B. A., and X. Zhu, 1991, "Interfacing Stand Alone Transport Analysis Software with GIS", GIS/LIS' 91 Proceedings, Vol.1, 209-218.

Ray, J., 1987, A Multi-period Linear Programming Model for Optimally Scheduling the Distribution of Food-aid in West Africa, M.S. Thesis. University of Tennessee, Knoxville. 103 p.

Shaw, S., 1991, "A GIS Approach For the Analysis of Hub-And-Spoke Structures of Airline Networks", GIS/LIS' 91 Proceedings, Vol.1, 199-208.

Simkowitz, H. J., 1987, "Design and Implementation of a

Geographic Information System for Transportation Research and Analysis," Journal of the Transportation Research Forum, Vol. XXX, 63-73.

Star, J., and J. Estes, 1990, Geographic Information Systems, Englewood Cliffs, NJ: Prentice-Hall, 303 p.

Thimbleby, H., 1990, User Interface Design, New York: ACM Press, 470 p.

APPENDICES

APPENDIX A

FIELDS INPUT DATA

APPENDIX A1

An example link file of FIELDS - WADEMO.ARC

ABIDJAN	FERKE	RD	1000	534.0	.077	15000.0	1
ABIDJAN	FERKE	RL	2000	530.0	.056	12500.0	1
AGADEZ	ARLIT	RD	1001	243.0	.077	-1.0	1
ANSANGO	GAO	RD	1002	95.0	.077	-1.0	0
ANSANGO	MENAKE	RD	1003	210.0	.077	-1.0	0
ATI	ABECHE	RD	1004	314.0	.200	-1.0	1
ATI	MONGO	RD	1005	154.0	.150	-1.0	1
BAMAKO	SEGOU	RD	1006	235.0	.077	-1.0	0
BAMAKO	SEGOU	WT	3000	228.0	.050	0.0	0
BAMAKO	NARA	RD	1007	377.0	.122	-1.0	1
BAMAKO	NIORO	RD	1008	432.0	.122	-1.0	0
BANFORA	BOBO	RD	1009	85.0	.077	-1.0	0
BANFORA	BOBO	RL	2001	85.0	.056	12500.0	0
BIRNIN	MARADI	RD	1010	250.0	.077	-1.0	0
BIRNIN	TAHOUA	RD	1011	122.0	.077	-1.0	0
BLA	SAN	RD	1012	100.0	.077	-1.0	0
BLA	SEGOU	RD	1013	88.0	.077	-1.0	0
BLITTA	KOUPELA	RD	1014	505.0	.077	-1.0	1
BOBO	KOUDOUGOU	RD	1015	291.0	.077	-1.0	0
BOBO	SAN	RD	1016	273.0	.077	-1.0	0
BOBO	KOUDOUGOU	RL	2002	247.0	.056	12500.0	0
BOBO	DEDOUGOU	RD	1017	173.0	.122	-1.0	0
BONGOR	LAI	RD	1018	148.0	.150	-1.0	0
CALABAR	MAIDUGURI	RD	1019	1067.0	.077	18750.0	1
COTONOU	PARAKOU	RD	1020	438.0	.077	25000.0	1
COTONOU	PARAKOU	RL	2003	438.0	.056	12500.0	1
DAKAR	KAYES	RL	2004	782.0	.056	20000.0	1
DEDOUGOU	NOUNA	RD	1021	57.0	.122	-1.0	0
DIFFA	NGUIGMI	RD	1022	170.0	.077	-1.0	0
DOGON	BIRNIN	RD	1023	145.0	.077	-1.0	0
DORI	TERA	RD	1024	90.0	.122	-1.0	1
DOSSO	DOGON	RD	1025	137.0	.077	-1.0	0
DOSSO	NIAMEY	RD	1026	138.0	.077	-1.0	0
DOUALA	NGOUND	RD	1027	1151.0	.077	1000.0	1
DOUALA	NGOUND	RL	2005	762.0	.056	37500.0	1
FERKE	OUANGOLO	RD	1028	44.0	.077	-1.0	1
FERKE	OUANGOLO	RL	2006	44.0	.056	12500.0	1
FIGUIL	LERE	RD	1029	38.0	.122	-1.0	1
FIGUIL	MORA	RD	1030	119.0	.077	-1.0	0
GAO	TOMBOUC	WT	3001	424.0	.050	0.0	0
GAO	TOMBOUC	RD	1031	424.0	.122	-1.0	0
GAYAM	SARH	RD	1032	50.0	.150	-1.0	0
GOURE	DIFFA	RD	1033	214.0	.077	-1.0	0
GUELENGD	BONGOR	RD	1034	83.0	.150	-1.0	0
GUELENGD	GAYAM	RD	1035	356.0	.150	-1.0	0
GUSAU	SOKOTO	RD	1036	220.0	.077	-1.0	0
JOS	POTISKUM	RD	1037	361.0	.077	-1.0	0
JOS	ZARIA	RD	1038	238.0	.077	-1.0	0
KANO	MARADI	RD	1039	266.0	.077	-1.0	0
KAYA	DORI	RD	1040	163.0	.122	-1.0	1
KAYES	BAMAKO	RL	2007	457.0	.056	20000.0	0
KAYES	KIFFA	RD	1041	281.0	.122	-1.0	1
KAYES	NIORO	RD	1042	251.0	.122	-1.0	0
KOUDOUGOU	OUAGA	RD	1043	86.0	.077	-1.0	0

KOUDOUGOU	OUAGA	RL	2008	97.0	.056	12500.0	0
KOUDOUGOU	DEDOUGOU	RD	1044	128.0	.122	-1.0	0
KOUDOUGOU	YAKO	RD	1045	79.0	.122	-1.0	0
KOUPELA	NIAMEY	RD	1046	372.0	.077	-1.0	0
KOUPELA	OUAGA	RD	1047	137.0	.077	-1.0	0
KOUSSERI	NDJAM	RD	1048	35.0	.077	-1.0	0
LAGOS	SOKOTO	RD	1049	1013.0	.077	-1.0	1
LAI	GAYAM	RD	1050	179.0	.150	-1.0	1
LERE	MOUNDOU	RD	1051	305.0	.122	-1.0	1
LOME	BLITTA	RD	1052	265.0	.077	15000.0	1
LOME	BLITTA	RL	2009	265.0	.056	10000.0	1
MAIDUGURI	KOUSSERI	RD	1053	200.0	.077	-1.0	0
MARADI	ZINDER	RD	1054	237.0	.077	-1.0	0
MASS	ATI	RD	1055	402.0	.122	-1.0	1
MASS	MAO	RD	1056	192.0	.122	-1.0	0
MONGO	AMTIMAN	RD	1057	251.0	.150	-1.0	0
MOPTI	GAO	RD	1058	588.0	.077	10000.0	0
MOPTI	TOMBOUC	WT	3002	400.0	.050	0.0	0
MORA	KOUSSERI	RD	1059	200.0	.077	-1.0	1
MOUNDOU	SARH	RD	1060	290.0	.122	-1.0	0
NDJAM	MASS	RD	1061	46.0	.122	-1.0	0
NDJAM	GUELENGD	RD	1062	156.0	.100	-1.0	0
NGOUND	FIGUIL	RD	1063	272.0	.077	-1.0	1
NGUIGMI	MAO	RD	1064	327.0	.200	-1.0	0
NIAMEY	ANSANGO	RD	1065	348.0	.077	0.0	0
OUAGA	KAYA	RD	1066	98.0	.122	-1.0	1
OUAGA	YAKO	RD	1067	78.0	.122	-1.0	0
OUANGOLO	BANFORA	RD	1068	88.0	.077	-1.0	0
OUANGOLO	ZEGOUA	RD	1069	126.0	.077	15000.0	0
OUANGOLO	BANFORA	RL	2010	88.0	.056	12500.0	0
PARAKOU	DOSSO	RD	1070	486.0	.077	-1.0	1
POTISKUM	MAIDUGURI	RD	1071	235.0	.077	-1.0	0
PTHARC	JOS	RD	1072	832.0	.077	18750.0	1
SAN	MOPTI	RD	1073	200.0	.077	-1.0	0
SEGOU	MOPTI	WT	3003	303.0	.050	0.0	0
SEGOU	NIONO	RD	1074	110.0	.122	-1.0	1
SIKASSO	BAMAKO	RD	1075	374.0	.077	-1.0	0
SIKASSO	BLA	RD	1076	203.0	.077	-1.0	0
SOKOTO	BIRNIN	RD	1077	93.0	.077	-1.0	0
TAHOUA	AGADEZ	RD	1078	403.0	.077	-1.0	0
TANOUT	AGADEZ	RD	1079	287.0	.122	-1.0	0
YAKO	OUIHA	RD	1080	73.0	.122	-1.0	1
ZARIA	GUSAU	RD	1081	184.0	.077	-1.0	0
ZARIA	KANO	RD	1082	172.0	.077	-1.0	0
ZEGOUA	SIKASSO	RD	1083	291.0	.077	-1.0	0
ZINDER	GOURE	RD	1084	166.0	.077	-1.0	0
ZINDER	TANOUT	RD	1085	160.0	.122	-1.0	0
OFFSHORE	ABIDJAN	WT	3004	1.0	.000	-1.0	1
OFFSHORE	CALABAR	WT	3005	1.0	.000	-1.0	1
OFFSHORE	COTONOU	WT	3006	1.0	.000	-1.0	1
OFFSHORE	DAKAR	WT	3007	1.0	.000	-1.0	1
OFFSHORE	DOUALA	WT	3008	1.0	.000	-1.0	1
OFFSHORE	LAGOS	WT	3009	1.0	.000	-1.0	1
OFFSHORE	LOME	WT	3010	1.0	.000	-1.0	1
OFFSHORE	PTHARC	WT	3011	1.0	.000	-1.0	1
ENDDATA							
ABIDJAN	FERKE	RD	1000	534.0	.077	15000.0	1
ABIDJAN	FERKE	RL	2000	530.0	.056	12500.0	1
AGADEZ	ARLIT	RD	1001	243.0	.077	-1.0	1
ANSANGO	GAO	RD	1002	95.0	.077	-1.0	0
ANSANGO	MENAKE	RD	1003	210.0	.077	-1.0	0
ATI	ABECHE	RD	1004	314.0	.200	100.0	1
ATI	MONGO	RD	1005	154.0	.150	0.0	1

BAMAKO	SEGOU	RD	1006	235.0	.077	-1.0	0
BAMAKO	SEGOU	WT	3000	228.0	.050	0.0	0
BAMAKO	NARA	RD	1007	377.0	.122	-1.0	1
BAMAKO	NIORO	RD	1008	432.0	.122	-1.0	0
BANFORA	BOBO	RD	1009	85.0	.077	-1.0	0
BANFORA	BOBO	RL	2001	85.0	.056	12500.0	0
BIRNIN	MARADI	RD	1010	250.0	.077	-1.0	0
BIRNIN	TAHOUA	RD	1011	122.0	.077	-1.0	0
BLA	SAN	RD	1012	100.0	.077	-1.0	0
BLA	SEGOU	RD	1013	88.0	.077	-1.0	0
BLITTA	KOUPELA	RD	1014	505.0	.077	-1.0	1
BOBO	KOUDOUGOU	RD	1015	291.0	.077	-1.0	0
BOBO	SAN	RD	1016	273.0	.077	-1.0	0
BOBO	KOUDOUGOU	RL	2002	247.0	.056	12500.0	0
BOBO	DEDOUGOU	RD	1017	173.0	.122	-1.0	0
BONGOR	LAI	RD	1018	148.0	.150	0.0	0
CALABAR	MAIDUGURI	RD	1019	1067.0	.077	18750.0	1
COTONOU	PARAKOU	RD	1020	438.0	.077	25000.0	1
COTONOU	PARAKOU	RL	2003	438.0	.056	12500.0	1
DAKAR	KAYES	RL	2004	782.0	.056	20000.0	1
DEDOUGOU	NOUNA	RD	1021	57.0	.122	-1.0	0
DIFFA	NGUIGMI	RD	1022	170.0	.077	-1.0	0
DOGON	BIRNIN	RD	1023	145.0	.077	-1.0	0
DORI	TERA	RD	1024	90.0	.122	0.0	1
DOSSO	DOGON	RD	1025	137.0	.077	-1.0	0
DOSSO	NIAMEY	RD	1026	138.0	.077	-1.0	0
DOUALA	NGOUND	RD	1027	1151.0	.077	1000.0	1
DOUALA	NGOUND	RL	2005	762.0	.056	37500.0	1
FERKE	OUANGOLO	RD	1028	44.0	.077	1000.0	1
FERKE	OUANGOLO	RL	2006	44.0	.056	12500.0	1
FIGUIL	LERE	RD	1029	38.0	.122	-1.0	1
FIGUIL	MORA	RD	1030	119.0	.077	-1.0	1
GAO	TOMBOUC	WT	3001	424.0	.050	0.0	0
GAO	TOMBOUC	RD	1031	424.0	.122	0.0	0
GAYAM	SARH	RD	1032	50.0	.150	-1.0	0
GOURE	DIFFA	RD	1033	214.0	.077	-1.0	0
GUELENGD	BONGOR	RD	1034	83.0	.150	0.0	0
GUELENGD	GAYAM	RD	1035	356.0	.150	0.0	0
GUSAU	SOKOTO	RD	1036	220.0	.077	-1.0	0
JOS	POTISKUM	RD	1037	361.0	.077	-1.0	0
JOS	ZARIA	RD	1038	238.0	.077	-1.0	0
KANO	MARADI	RD	1039	266.0	.077	-1.0	0
KAYA	DORI	RD	1040	163.0	.122	-1.0	1
KAYES	BAMAKO	RL	2007	457.0	.056	20000.0	0
KAYES	KIFFA	RD	1041	281.0	.122	0.0	1
KAYES	NIORO	RD	1042	251.0	.122	0.0	0
KOUDOUGOU	OUAGA	RD	1043	86.0	.077	-1.0	0
KOUDOUGOU	OUAGA	RL	2008	97.0	.056	12500.0	0
KOUDOUGOU	DEDOUGOU	RD	1044	128.0	.122	-1.0	0
KOUDOUGOU	YAKO	RD	1045	79.0	.122	-1.0	0
KOUPELA	NIAMEY	RD	1046	372.0	.077	-1.0	0
KOUPELA	OUAGA	RD	1047	137.0	.077	-1.0	0
KOUSSERI	NDJAM	RD	1048	35.0	.077	-1.0	0
LAGOS	SOKOTO	RD	1049	1013.0	.077	-1.0	1
LAI	GAYAM	RD	1050	179.0	.150	0.0	1
LERE	MOUNDOU	RD	1051	305.0	.122	-1.0	1
LOME	BLITTA	RD	1052	265.0	.077	15000.0	1
LOME	BLITTA	RL	2009	265.0	.056	10000.0	1
MAIDUGURI	KOUSSERI	RD	1053	200.0	.077	-1.0	0
MARADI	ZINDER	RD	1054	237.0	.077	-1.0	0
MASS	ATI	RD	1055	402.0	.122	100.0	1
MASS	MAO	RD	1056	192.0	.122	-1.0	0
MONGO	AMTIMAN	RD	1057	251.0	.150	0.0	0

MOPTI	GAO	RD	1058	588.0	.077	10000.0	0
MOPTI	TOMBOUC	WT	3002	400.0	.050	0.0	0
MORA	KOUSSERI	RD	1059	200.0	.077	-1.0	1
MOUNDOU	SARH	RD	1060	290.0	.122	-1.0	0
NDJAM	MASS	RD	1061	46.0	.122	-1.0	0
NDJAM	GUELENGD	RD	1062	156.0	.100	-1.0	0
NGOUND	FIGUIL	RD	1063	272.0	.077	-1.0	1
NGUIGMI	MAO	RD	1064	327.0	.200	0.0	0
NIAMEY	ANSANGO	RD	1065	348.0	.077	0.0	0
OUAGA	KAYA	RD	1066	98.0	.122	-1.0	1
OUAGA	YAKO	RD	1067	78.0	.122	-1.0	0
OUANGOLO	BANFORA	RD	1068	88.0	.077	-1.0	0
OUANGOLO	ZEGOUA	RD	1069	126.0	.077	15000.0	0
OUANGOLO	BANFORA	RL	2010	88.0	.056	12500.0	0
PARAKOU	DOSSO	RD	1070	486.0	.077	-1.0	1
POTISKUM	MAIDUGURI	RD	1071	235.0	.077	-1.0	0
PTHARC	JOS	RD	1072	832.0	.077	18750.0	1
SAN	MOPTI	RD	1073	200.0	.077	-1.0	0
SEGOU	MOPTI	WT	3003	303.0	.050	0.0	0
SEGOU	NIONO	RD	1074	110.0	.122	-1.0	1
SIKASSO	BAMAKO	RD	1075	374.0	.077	-1.0	0
SIKASSO	BLA	RD	1076	203.0	.077	-1.0	0
SOKOTO	BIRNIN	RD	1077	93.0	.077	-1.0	0
TAHOUA	AGADEZ	RD	1078	403.0	.077	-1.0	0
TANOUT	AGADEZ	RD	1079	287.0	.122	-1.0	0
YAKO	OUIHA	RD	1080	73.0	.122	-1.0	1
ZARIA	GUSAU	RD	1081	184.0	.077	-1.0	0
ZARIA	KANO	RD	1082	172.0	.077	-1.0	0
ZEGOUA	SIKASSO	RD	1083	291.0	.077	-1.0	0
ZINDER	GOURE	RD	1084	166.0	.077	-1.0	0
ZINDER	TANOUT	RD	1085	160.0	.122	-1.0	0
OFFSHORE	ABIDJAN	WT	3004	1.0	.000	-1.0	1
OFFSHORE	CALABAR	WT	3005	1.0	.000	-1.0	1
OFFSHORE	COTONOU	WT	3006	1.0	.000	-1.0	1
OFFSHORE	DAKAR	WT	3007	1.0	.000	-1.0	1
OFFSHORE	DOUALA	WT	3008	1.0	.000	-1.0	1
OFFSHORE	LAGOS	WT	3009	1.0	.000	-1.0	1
OFFSHORE	LOME	WT	3010	1.0	.000	-1.0	1
OFFSHORE	PTHARC	WT	3011	1.0	.000	-1.0	1

APPENDIX A2

An example node file of FIELDS - WADEMO.NOD

ABECHE	001	5300.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-13.82	20.81
ABIDJAN	002	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-5.38	-4.03
AGADEZ	003	5753.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-16.97	8.00
ANSANGO	004	1200.00	-1.0	0.0	0.0	00.2	3.65	5000.00	1000.00	-15.66	0.48
AMTIMAN	005	3055.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-11.02	20.29
ARLIT	006	3835.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-18.62	7.44
ATI	007	3763.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-13.23	18.36
BAMAKO	008	6000.00	-1.0	0.0	0.0	00.2	3.65	5000.00	1000.00	-12.64	-8.00
BANFORA	009	0.00	-1.0	0.0	0.0	00.2	3.65	5000.00	1000.00	-10.63	-4.68
BIRNIN	010	1915.00	-1.0	0.0	0.0	00.2	3.65	5000.00	1000.00	-13.77	5.28
BLA	011	2370.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-12.93	-5.79
BLITTA	012	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-8.34	1.04
BOBO	013	2593.00	-1.0	0.0	0.0	00.2	0.65	5000.00	1000.00	-11.21	-4.31
BONGOR	014	3710.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-10.29	15.39
CALABAR	015	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-4.98	8.32
COTONOU	016	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-6.37	2.43
DAKAR	017	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-14.70	-17.46
DEDOUGOU	018	1216.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-12.42	-3.48
DIFFA	019	2301.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-13.30	12.59
DOGON	020	1918.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-13.64	4.00
DORI	021	1388.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-14.03	0.02
DOSSO	022	1910.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-13.01	3.17
DOUALA	023	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-4.05	9.67
FERKE	024	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-9.57	-5.20
FIGUIL	025	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-9.74	13.96
GAO	026	7200.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-16.31	-0.03
GAYAM	027	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-9.34	17.86
GOURE	028	2301.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-13.97	10.27
GUELENGD	029	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-10.91	15.54
GUSAU	030	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-12.16	6.65
JOS	031	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-9.92	8.88
KANO	032	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-12.01	8.53
KAYA	033	1355.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-13.08	-1.09
KAYES	034	7200.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-14.10	-11.48
KIFFA	035	1182.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-16.63	-11.42
KOUPELA	036	1815.00	-1.0	0.0	0.0	00.2	3.65	5000.00	1000.00	-12.18	-0.37
KOUSSERI	037	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-12.06	15.03
KOUDOUGOU	038	1321.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-12.24	-2.35
LAGOS	039	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-6.47	3.43
LAI	040	3180.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-9.39	16.31
LERE	041	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-9.66	14.19
LOME	042	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-6.09	1.20
MAIDUGURI	043	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-11.84	13.18
MAO	044	3710.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-13.98	15.34
MARADI	045	1905.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-13.47	7.08
MASS	046	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-12.99	15.73
MENAKE	047	1320.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-15.91	2.33
MONGO	048	3180.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-12.16	18.70
MOPTI	049	1176.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-14.47	-4.21
MORA	050	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-11.02	14.14
MOUNDOU	051	3710.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-8.53	16.04
NARA	052	1194.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-15.13	-7.30
NDJAM	053	4505.00	-1.0	0.0	0.0	00.2	3.65	5000.00	1000.00	-12.13	15.09
NGOUND	054	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-7.31	13.60
NGUIGMI	055	1899.00	-1.0	0.0	0.0	00.2	3.65	5000.00	1000.00	-14.27	13.06
NIAMEY	056	4794.00	100.0	10.0	0.0	00.2	3.65	5000.00	1000.00	-13.54	2.10
NIONO	057	1215.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-14.25	-5.99
NIORO	058	1182.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-15.13	-9.65
NOUNA	059	1251.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-12.70	-3.89

OUAGA	060	3421.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-12.36	-1.54
OUANGOLO	061	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-9.93	-5.16
OUIHA	062	1286.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-13.57	-2.44
PARAKOU	063	0.00	100.0	32.0	0.0	00.2	3.65	1000.00	1000.00	-9.33	2.62
POTISKUM	064	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-11.70	11.04
PTHARC	065	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-4.80	6.99
SAN	066	2400.00	-1.0	0.0	0.0	00.0	5.65	200.00	1000.00	-13.28	-4.92
SARH	067	5300.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-9.14	18.38
SEGOU	068	1260.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-13.44	-6.25
SIKASSO	069	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-11.26	-5.67
SOKOTO	070	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-13.04	5.26
TAHOUA	071	5753.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-14.89	5.27
TANOUT	072	1937.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-14.96	8.87
TERA	073	959.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-13.96	0.75
TOMBOUC	074	7200.00	-1.0	0.0	0.0	00.2	3.65	200.00	1000.00	-16.83	-3.01
YAKO	075	1815.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-12.97	-2.28
ZEGOUA	076	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-10.48	-5.65
ZARIA	077	0.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-11.02	7.66
ZINDER	078	1931.00	-1.0	0.0	0.0	00.2	3.65	-1.00	1000.00	-13.79	8.99
OFFSHORE	079	0.0	-1.0	0.0	0.0	00.0	0.0	-1.00	0.0	4.00	-11.50
ENDDATA											
ABECHE	001	5300.00	0.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-13.82	20.81
ABIDJAN	002	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-5.38	-4.03
AGADEZ	003	5753.00	-1.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-16.97	8.00
ANSANGO	004	1200.00	-1.0	0.0	0.0	0 0.2	3.65	5000.00	1000.00	-15.66	0.48
AMTIMAN	005	3055.00	-1.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-11.02	20.29
ARLIT	006	3835.00	-1.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-18.62	7.44
ATI	007	3763.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-13.23	18.36
BAMAKO	008	6000.00	-1.0	0.0	0.0	0 0.2	3.65	5000.00	1000.00	-12.64	-8.00
BANFORA	009	0.00	-1.0	0.0	0.0	0 0.2	3.65	5000.00	1000.00	-10.63	-4.68
BIRNIN	010	1915.00	-1.0	0.0	0.0	0 0.2	3.65	5000.00	1000.00	-13.77	5.28
BLA	011	2370.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-12.93	-5.79
BLITTA	012	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-8.34	1.04
BOBO	013	2593.00	-1.0	0.0	0.0	0 0.2	3.65	5000.00	1000.00	-11.21	-4.31
BONGOR	014	3710.00	-1.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-10.29	15.39
CALABAR	015	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-4.98	8.32
COTONOU	016	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-6.37	2.43
DAKAR	017	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-14.70	-17.46
DEDOUGOU	018	1216.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-12.42	-3.48
DIFFA	019	2301.00	-1.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-13.30	12.59
DOGON	020	1918.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-13.64	4.00
DORI	021	1388.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-14.03	0.02
DOSSO	022	1910.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-13.01	3.17
DOUALA	023	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-4.05	9.67
FERKE	024	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-9.57	-5.20
FIGUIL	025	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-9.74	13.96
GAO	026	7200.00	-1.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-16.31	-0.03
GAYAM	027	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-9.34	17.86
GOURE	028	2301.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-13.97	10.27
GUELENGD	029	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-10.91	15.54
GUSAU	030	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-12.16	6.65
JOS	031	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-9.92	8.88
KANO	032	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-12.01	8.53
KAYA	033	1355.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-13.08	-1.09
KAYES	034	7200.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-14.10	-11.48
KIFFA	035	1182.00	-1.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-16.63	-11.42
KOUPELA	036	1815.00	-1.0	0.0	0.0	0 0.2	3.65	5000.00	1000.00	-12.18	-0.37
KOUSSERI	037	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-12.06	15.03
KOUDOUGOU	038	1321.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-12.24	-2.35
LAGOS	039	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-6.47	3.43
LAI	040	3180.00	-1.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-9.39	16.31
LERE	041	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-9.66	14.19
LOME	042	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-6.09	1.20
MAIDUGURI	043	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-11.84	13.18
MAO	044	3710.00	-1.0	0.0	0.0	0 0.2	3.65	200.00	1000.00	-13.98	15.34
MARADI	045	1905.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-13.47	7.08
MASS	046	0.00	-1.0	0.0	0.0	0 0.2	3.65	-1.00	1000.00	-12.99	15.73

MENAKE	047	1320.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-15.91	2.33
MONGO	048	3180.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-12.16	18.70
MOPTI	049	1176.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-14.47	-4.21
MORA	050	0.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-11.02	14.14
MOUNDOU	051	3710.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-8.53	16.04
NARA	052	1194.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-15.13	-7.30
NDJAM	053	4505.00	-1.0	0.0	0.0	0	0.2	3.65	5000.00	1000.00	-12.13	15.09
NGOUND	054	0.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-7.31	13.60
NGUIGMI	055	1899.00	-1.0	0.0	0.0	0	0.2	3.65	5000.00	1000.00	-14.27	13.06
NIAMEY	056	4794.00	100.0	10.0	0.0	0	0.2	3.65	5000.00	1000.00	-13.54	2.10
NIONO	057	1215.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-14.25	-5.99
NIORO	058	1182.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-15.13	-9.65
NOUNA	059	1251.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-12.70	-3.89
OUAGA	060	3421.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-12.36	-1.54
OUANGOLO	061	0.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-9.93	-5.16
OUIHA	062	1286.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-13.57	-2.44
PARAKOU	063	0.00	100.0	32.0	0.0	0	0.2	3.65	1000.00	1000.00	-9.33	2.62
POTISKUM	064	0.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-11.70	11.04
PTHARC	065	0.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-4.80	6.99
SAN	066	2400.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-13.28	-4.92
SARH	067	5300.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-9.14	18.38
SEGOU	068	1260.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-13.44	-6.25
SIKASSO	069	0.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-11.26	-5.67
SOKOTO	070	0.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-13.04	5.26
TAHOUA	071	5753.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-14.89	5.27
TANOUT	072	1937.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-14.96	8.87
TERA	073	959.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-13.96	0.75
TOMBOUC	074	7200.00	-1.0	0.0	0.0	0	0.2	3.65	200.00	1000.00	-16.83	-3.01
YAKO	075	1815.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-12.97	-2.28
ZEGOUA	076	0.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-10.48	-5.65
ZARIA	077	0.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-11.02	7.66
ZINDER	078	1931.00	-1.0	0.0	0.0	0	0.2	3.65	-1.00	1000.00	-13.79	8.99
OFFSHORE	079	0.0	-1.0	0.0	0.0	0	0.0	0.00	-1.00	0.00	4.00	-11.50

APPENDIX A3

An example port file of FIELDS

```
ABIDJAN        25000.00    15000.00       -1.00
CALABAR        20000.00       -1.00       -1.00
COTONOU        12000.00    20000.00       -1.00
DAKAR             -1.00    15000.00       -1.00
DOUALA          3000.00    30000.00       -1.00
LAGOS              0.00       -1.00       -1.00
LOME           15000.00    15000.00       -1.00
PTHARC         20000.00       -1.00       -1.00
ENDDATA
ABIDJAN        25000.00    15000.00       -1.00
CALABAR        20000.00       -1.00       -1.00
COTONOU        12000.00    20000.00       -1.00
DAKAR             -1.00    15000.00       -1.00
DOUALA          3000.00    30000.00       -1.00
LAGOS              0.00       -1.00       -1.00
LOME           15000.00    15000.00       -1.00
PTHARC         20000.00       -1.00       -1.00
```

APPENDIX B

FIELDS OUTPUT GRAPHIC FILE

APPENDIX B

An example of FIELDS output graphic file - FIELDS.GRA

```
2 west africa

ARCDATA
ABIDJAN    FERKE       1000    0 1 1
ABIDJAN    FERKE       2000    1 1 1
AGADEZ     ARLIT       1001    0 1 0
ANSANGO    GAO         1002    0 1 0
ANSANGO    MENAKE      1003    0 1 0
ATI        ABECHE      1004    0 1 0
ATI        MONGO       1005    0 1 0
BAMAKO     SEGOU       1006    0 0 0
BAMAKO     SEGOU       3000    2 0 1
BAMAKO     NARA        1007    0 1 0
BAMAKO     NIORO       1008    0 0 0
BANFORA    BOBO        1009    0 1 0
BANFORA    BOBO        2001    1 1 1
BIRNIN     MARADI      1010    0 0 0
BIRNIN     TAHOUA      1011    0 1 0
BLA        SAN         1012    0 1 0
BLA        SEGOU       1013    0 1 0
BLITTA     KOUPELA     1014    0 1 0
BOBO       KOUDOUGOU   1015    0 0 0
BOBO       SAN         1016    0 1 0
BOBO       KOUDOUGOU   2002    1 0 0
BOBO       DEDOUGOU    1017    0 0 0
BONGOR     LAI         1018    0 1 0
CALABAR    MAIDUGURI   1019    0 1 0
COTONOU    PARAKOU     1020    0 1 0
COTONOU    PARAKOU     2003    1 1 1
DAKAR      KAYES       2004    1 1 0
DEDOUGOU   NOUNA       1021    0 1 0
DIFFA      NGUIGMI     1022    0 1 0
DOGON      BIRNIN      1023    0 1 0
DORI       TERA        1024    0 1 0
DOSSO      DOGON       1025    0 1 0
DOSSO      NIAMEY      1026    0 1 0
DOUALA     NGOUND      1027    0 0 0
DOUALA     NGOUND      2005    1 1 0
FERKE      OUANGOLO    1028    0 1 0
FERKE      OUANGOLO    2006    1 1 1
FIGUIL     LERE        1029    0 1 0
FIGUIL     MORA        1030    0 1 0
GAO        TOMBOUC     3001    2 0 1
GAO        TOMBOUC     1031    0 1 0
GAYAM      SARH        1032    0 0 0
GOURE      DIFFA       1033    0 1 0
GUELENGD   BONGOR      1034    0 1 0
```

GUELENGD	GAYAM	1035	0	0	0
GUSAU	SOKOTO	1036	0	0	0
JOS	POTISKUM	1037	0	0	0
JOS	ZARIA	1038	0	1	0
KANO	MARADI	1039	0	1	0
KAYA	DORI	1040	0	1	0
KAYES	BAMAKO	2007	1	1	0
KAYES	KIFFA	1041	0	1	0
KAYES	NIORO	1042	0	1	0
KOUDOUGOU	OUAGA	1043	0	0	0
KOUDOUGOU	OUAGA	2008	1	1	0
KOUDOUGOU	DEDOUGOU	1044	0	1	0
KOUDOUGOU	YAKO	1045	0	0	0
KOUPELA	NIAMEY	1046	0	1	0
KOUPELA	OUAGA	1047	0	1	0
KOUSSERI	NDJAM	1048	0	1	0
LAGOS	SOKOTO	1049	0	0	0
LAI	GAYAM	1050	0	0	0
LERE	MOUNDOU	1051	0	1	0
LOME	BLITTA	1052	0	1	0
LOME	BLITTA	2009	1	1	1
MAIDUGURI	KOUSSERI	1053	0	1	0
MARADI	ZINDER	1054	0	1	0
MASS	ATI	1055	0	1	0
MASS	MAO	1056	0	1	0
MONGO	AMTIMAN	1057	0	1	0
MOPTI	GAO	1058	0	1	1
MOPTI	TOMBOUC	3002	2	0	1
MORA	KOUSSERI	1059	0	1	0
MOUNDOU	SARH	1060	0	1	0
NDJAM	MASS	1061	0	1	0
NDJAM	GUELENGD	1062	0	1	0
NGOUND	FIGUIL	1063	0	1	0
NGUIGMI	MAO	1064	0	0	0
NIAMEY	ANSANGO	1065	0	0	1
OUAGA	KAYA	1066	0	1	0
OUAGA	YAKO	1067	0	1	0
OUANGOLO	BANFORA	1068	0	1	0
OUANGOLO	ZEGOUA	1069	0	1	0
OUANGOLO	BANFORA	2010	1	1	1
PARAKOU	DOSSO	1070	0	1	0
POTISKUM	MAIDUGURI	1071	0	0	0
PTHARC	JOS	1072	0	1	0
SAN	MOPTI	1073	0	1	0
SEGOU	MOPTI	3003	2	0	0
SEGOU	NIONO	1074	0	1	0
SIKASSO	BAMAKO	1075	0	1	0
SIKASSO	BLA	1076	0	0	0
SOKOTO	BIRNIN	1077	0	0	0
TAHOUA	AGADEZ	1078	0	1	0
TANOUT	AGADEZ	1079	0	0	0
YAKO	OUIHA	1080	0	1	0
ZARIA	GUSAU	1081	0	0	0
ZARIA	KANO	1082	0	1	0
ZEGOUA	SIKASSO	1083	0	1	0
ZINDER	GOURE	1084	0	1	0
ZINDER	TANOUT	1085	0	1	0

OFFSHORE	ABIDJAN	3004	2 1 0
OFFSHORE	CALABAR	3005	2 1 0
OFFSHORE	COTONOU	3006	2 1 0
OFFSHORE	DAKAR	3007	2 1 0
OFFSHORE	DOUALA	3008	2 1 0
OFFSHORE	LAGOS	3009	2 0 0
OFFSHORE	LOME	3010	2 1 0
OFFSHORE	PTHARC	3011	2 1 0

NODEDATA

ABECHE	1	1 0 2 0 0	-13.82	20.81
ABIDJAN	2	0 0 0 1 0	-5.38	-4.03
AGADEZ	3	1 0 0 0 0	-16.97	8.00
ANSANGO	4	1 0 0 0 0	-15.66	0.48
AMTIMAN	5	1 0 2 0 0	-11.02	20.29
ARLIT	6	1 0 0 0 0	-18.62	7.44
ATI	7	1 0 0 0 0	-13.23	18.36
BAMAKO	8	1 0 0 0 0	-12.64	-8.00
BANFORA	9	0 0 0 0 0	-10.63	-4.68
BIRNIN	10	1 0 0 0 0	-13.77	5.28
BLA	11	1 0 0 0 0	-12.93	-5.79
BLITTA	12	0 0 0 1 0	-8.34	1.04
BOBO	13	1 0 1 1 0	-11.21	-4.31
BONGOR	14	1 0 2 0 0	-10.29	15.39
CALABAR	15	0 0 0 1 0	-4.98	8.32
COTONOU	16	0 0 0 1 0	-6.37	2.43
DAKAR	17	0 0 0 1 0	-14.70	-17.46
DEDOUGOU	18	1 0 0 0 0	-12.42	-3.48
DIFFA	19	1 0 0 0 0	-13.30	12.59
DOGON	20	1 0 0 0 0	-13.64	4.00
DORI	21	1 0 0 0 0	-14.03	0.02
DOSSO	22	1 0 0 0 0	-13.01	3.17
DOUALA	23	0 0 0 1 0	-4.05	9.67
FERKE	24	0 0 0 0 0	-9.57	-5.20
FIGUIL	25	0 0 0 0 0	-9.74	13.96
GAO	26	1 0 0 0 0	-16.31	-0.03
GAYAM	27	0 0 0 0 0	-9.34	17.86
GOURE	28	1 0 0 0 0	-13.97	10.27
GUELENGD	29	0 0 0 0 0	-10.91	15.54
GUSAU	30	0 0 0 0 0	-12.16	6.65
JOS	31	0 0 0 0 0	-9.92	8.88
KANO	32	0 0 0 0 0	-12.01	8.53
KAYA	33	1 0 0 0 0	-13.08	1.09
KAYES	34	1 0 0 1 0	-14.10	-11.48
KIFFA	35	1 0 2 0 0	-16.63	-11.42
KOUPELA	36	1 0 0 0 0	-12.18	-0.37
KOUSSERI	37	0 0 0 0 0	-12.06	15.03
KOUDOUGOU	38	1 0 0 1 0	-12.24	-2.35
LAGOS	39	0 0 0 0 0	-6.47	3.43
LAI	40	1 0 2 0 0	-9.39	16.31
LERE	41	0 0 0 0 0	-9.66	14.19
LOME	42	0 0 0 1 0	-6.09	1.20
MAIDUGURI	43	0 0 0 0 0	-11.84	13.18
MAO	44	1 0 0 0 0	-13.98	15.34
MARADI	45	1 0 0 0 0	-13.47	7.08
MASS	46	0 0 0 0 0	-12.99	15.73
MENAKE	47	1 0 0 0 0	-15.91	2.33
MONGO	48	1 0 2 0 0	-12.16	18.70

MOPTI	49	1 0 0 0 0	-14.47	-4.21
MORA	50	0 0 0 0 0	-11.02	14.14
MOUNDOU	51	1 0 0 0 0	-8.53	16.04
NARA	52	1 0 0 0 0	-15.13	-7.30
NDJAM	53	1 0 0 0 0	-12.13	15.09
NGOUND	54	0 0 0 1 0	-7.31	13.60
NGUIGMI	55	1 0 0 0 0	-14.27	13.06
NIAMEY	56	1 0 0 0 0	-13.54	2.10
NIONO	57	1 0 0 0 0	-14.25	-5.99
NIORO	58	1 0 2 0 0	-15.13	-9.65
NOUNA	59	1 0 0 0 0	-12.70	-3.89
OUAGA	60	1 0 0 1 0	-12.36	-1.54
OUANGOLO	61	0 0 0 0 0	-9.93	-5.16
OUIHA	62	1 0 0 0 0	-13.57	-2.44
PARAKOU	63	0 0 0 1 0	-9.33	2.62
POTISKUM	64	0 0 0 0 0	-11.70	11.04
PTHARC	65	0 0 0 1 0	-4.80	6.99
SAN	66	1 0 0 0 0	-13.28	-4.92
SARH	67	1 0 0 0 0	-9.14	18.38
SEGOU	68	1 0 0 0 0	-13.44	-6.25
SIKASSO	69	0 0 0 0 0	-11.26	-5.67
SOKOTO	70	0 0 0 0 0	-13.04	5.26
TAHOUA	71	1 0 0 0 0	-14.89	5.27
TANOUT	72	1 0 0 0 0	-14.96	8.87
TERA	73	1 0 2 0 0	-13.96	0.75
TOMBOUC	74	1 1 0 0 0	-16.83	-3.01
YAKO	75	1 0 0 0 0	-12.97	-2.28
ZEGOUA	76	0 0 0 0 0	-10.48	-5.65
ZARIA	77	0 0 0 0 0	-11.02	7.66
ZINDER	78	1 0 0 0 0	-13.79	8.99
OFFSHORE	79	0 0 0 0 0	4.00	-11.50

ENDDATA

ARCDATA

ABIDJAN	FERKE	1000	0 1 0
ABIDJAN	FERKE	2000	1 1 1
AGADEZ	ARLIT	1001	0 1 0
ANSANGO	GAO	1002	0 1 0
ANSANGO	MENAKE	1003	0 1 0
ATI	ABECHE	1004	0 0 0
ATI	MONGO	1005	0 0 0
BAMAKO	SEGOU	1006	0 0 0
BAMAKO	SEGOU	3000	2 0 1
BAMAKO	NARA	1007	0 1 0
BAMAKO	NIORO	1008	0 1 0
BANFORA	BOBO	1009	0 1 0
BANFORA	BOBO	2001	1 1 1
BIRNIN	MARADI	1010	0 0 0
BIRNIN	TAHOUA	1011	0 1 0
BLA	SAN	1012	0 1 0
BLA	SEGOU	1013	0 1 0
BLITTA	KOUPELA	1014	0 1 0
BOBO	KOUDOUGOU	1015	0 0 0
BOBO	SAN	1016	0 1 0
BOBO	KOUDOUGOU	2002	1 1 0
BOBO	DEDOUGOU	1017	0 0 0
BONGOR	LAI	1018	0 0 0
CALABAR	MAIDUGURI	1019	0 0 0

COTONOU	PARAKOU	1020	0 1 0
COTONOU	PARAKOU	2003	1 1 1
DAKAR	KAYES	2004	1 1 0
DEDOUGOU	NOUNA	1021	0 1 0
DIFFA	NGUIGMI	1022	0 1 0
DOGON	BIRNIN	1023	0 1 0
DORI	TERA	1024	0 0 1
DOSSO	DOGON	1025	0 1 0
DOSSO	NIAMEY	1026	0 1 0
DOUALA	NGOUND	1027	0 0 0
DOUALA	NGOUND	2005	1 1 0
FERKE	OUANGOLO	1028	0 1 1
FERKE	OUANGOLO	2006	1 1 1
FIGUIL	LERE	1029	0 1 0
FIGUIL	MORA	1030	0 1 0
GAO	TOMBOUC	3001	2 0 1
GAO	TOMBOUC	1031	0 0 1
GAYAM	SARH	1032	0 0 0
GOURE	DIFFA	1033	0 1 0
GUELENGD	BONGOR	1034	0 0 1
GUELENGD	GAYAM	1035	0 0 0
GUSAU	SOKOTO	1036	0 0 0
JOS	POTISKUM	1037	0 0 0
JOS	ZARIA	1038	0 1 0
KANO	MARADI	1039	0 1 0
KAYA	DORI	1040	0 1 0
KAYES	BAMAKO	2007	1 1 0
KAYES	KIFFA	1041	0 0 1
KAYES	NIORO	1042	0 0 1
KOUDOUGOU	OUAGA	1043	0 0 0
KOUDOUGOU	OUAGA	2008	1 1 0
KOUDOUGOU	DEDOUGOU	1044	0 1 0
KOUDOUGOU	YAKO	1045	0 0 0
KOUPELA	NIAMEY	1046	0 1 0
KOUPELA	OUAGA	1047	0 1 0
KOUSSERI	NDJAM	1048	0 1 0
LAGOS	SOKOTO	1049	0 0 0
LAI	GAYAM	1050	0 0 0
LERE	MOUNDOU	1051	0 1 0
LOME	BLITTA	1052	0 1 0
LOME	BLITTA	2009	1 1 1
MAIDUGURI	KOUSSERI	1053	0 0 0
MARADI	ZINDER	1054	0 1 0
MASS	ATI	1055	0 1 1
MASS	MAO	1056	0 1 0
MONGO	AMTIMAN	1057	0 0 0
MOPTI	GAO	1058	0 1 0
MOPTI	TOMBOUC	3002	2 0 1
MORA	KOUSSERI	1059	0 1 0
MOUNDOU	SARH	1060	0 1 0
NDJAM	MASS	1061	0 1 0
NDJAM	GUELENGD	1062	0 0 0
NGOUND	FIGUIL	1063	0 1 0
NGUIGMI	MAO	1064	0 0 0
NIAMEY	ANSANGO	1965	0 0 1
OUAGA	KAYA	1966	0 1 0
OUAGA	YAKO	1067	0 1 0

OUANGOLO	BANFORA	1068	0	1	0
OUANGOLO	ZEGOUA	1069	0	1	0
OUANGOLO	BANFORA	2010	1	1	1
PARAKOU	DOSSO	1070	0	1	0
POTISKUM	MAIDUGURI	1071	0	0	0
PTHARC	JOS	1072	0	1	0
SAN	MOPTI	1073	0	1	0
SEGOU	MOPTI	3003	2	0	0
SEGOU	NIONO	1074	0	1	0
SIKASSO	BAMAKO	1075	0	1	0
SIKASSO	BLA	1076	0	0	0
SOKOTO	BIRNIN	1077	0	0	0
TAHOUA	AGADEZ	1078	0	1	0
TANOUT	AGADEZ	1079	0	0	0
YAKO	OUIHA	1080	0	1	0
ZARIA	GUSAU	1081	0	0	0
ZARIA	KANO	1082	0	1	0
ZEGOUA	SIKASSO	1083	0	1	0
ZINDER	GOURE	1084	0	1	0
ZINDER	TANOUT	1085	0	1	0
OFFSHORE	ABIDJAN	3004	2	1	0
OFFSHORE	CALABAR	3005	2	0	0
OFFSHORE	COTONOU	3006	2	1	0
OFFSHORE	DAKAR	3007	2	1	0
OFFSHORE	DOUALA	3008	2	1	0
OFFSHORE	LAGOS	3009	2	0	0
OFFSHORE	LOME	3010	2	1	0
OFFSHORE	PTHARC	3011	2	1	0

NODEDATA

ABECHE	1	1	1	0	0	0	-13.82	20.81
ABIDJAN	2	0	0	0	1	0	- 5.38	-4.03
AGADEZ	3	1	0	0	0	0	-16.97	8.00
ANSANGO	4	1	0	0	0	0	-15.66	0.48
AMTIMAN	5	1	1	0	0	0	-11.02	20.29
ARLIT	6	1	0	0	0	0	-18.62	7.44
ATI	7	1	1	0	0	0	-13.23	18.36
BAMAKO	8	1	0	0	1	0	-12.64	-8.00
BANFORA	9	0	0	0	0	0	-10.63	-4.68
BIRNIN	10	1	0	0	0	0	-13.77	5.28
BLA	11	1	0	0	0	0	-12.93	-5.79
BLITTA	12	0	0	0	1	0	-8.34	1.04
BOBO	13	1	0	0	1	0	-11.21	-4.31
BONGOR	14	1	1	0	0	0	-10.29	15.39
CALABAR	15	0	0	0	0	0	-4.98	8.32
COTONOU	16	0	0	0	1	0	-6.37	2.43
DAKAR	17	0	0	0	1	0	-14.70	-17.46
DEDOUGOU	18	1	0	0	0	0	-12.42	-3.48
DIFFA	19	1	0	0	0	0	-13.30	12.59
DOGON	20	1	0	0	0	0	-13.64	4.00
DORI	21	1	0	0	0	0	-14.03	0.02
DOSSO	22	1	0	0	0	0	-13.01	3.17
DOUALA	23	0	0	0	1	0	-4.05	9.67
FERKE	24	0	0	0	0	0	-9.57	-5.20
FIGUIL	25	0	0	0	0	0	-9.74	13.96
GAO	26	1	0	0	0	0	-16.31	-0.03
GAYAM	27	0	0	0	0	0	-9.34	17.86
GOURE	28	1	0	0	0	0	-13.97	10.27

GUELENGD	29	0	0	0	0	0	-10.91	15.54
GUSAU	30	0	0	0	0	0	-12.16	6.65
JOS	31	0	0	0	0	0	-9.92	8.88
KANO	32	0	0	0	0	0	-12.01	8.53
KAYA	33	1	0	0	0	0	-13.08	-1.09
KAYES	34	1	0	0	0	0	-14.10	-11.48
KIFFA	35	1	1	0	0	0	-16.63	-11.42
KOUPELA	36	1	0	0	0	0	-12.18	-0.37
KOUSSERI	37	0	0	0	0	0	-12.06	15.03
KOUDOUGOU	38	1	0	0	1	0	-12.24	-2.35
LAGOS	39	0	0	0	0	0	-6.47	3.43
LAI	40	1	1	0	0	0	-9.39	16.31
LERE	41	0	0	0	0	0	-9.66	14.19
LOME	42	0	0	0	1	0	-6.09	1.20
MAIDUGURI	43	0	0	0	0	0	-11.84	13.18
MAO	44	1	0	0	0	0	-13.98	15.34
MARADI	45	1	0	0	0	0	-13.47	7.08
MASS	46	0	0	0	0	0	-12.99	15.73
MENAKE	47	1	0	0	0	0	-15.91	2.33
MONGO	48	1	1	0	0	0	-12.16	18.70
MOPTI	49	1	0	0	0	0	-14.47	-4.21
MORA	50	0	0	0	0	0	-11.02	14.14
MOUNDOU	51	1	0	0	0	0	-8.53	16.04
NARA	52	1	0	0	0	0	-15.13	-7.30
NDJAM	53	1	0	0	0	0	-12.13	15.09
NGOUND	54	0	0	0	1	0	-7.31	13.60
NGUIGMI	55	1	0	0	0	0	-14.27	13.06
NIAMEY	56	1	0	0	0	0	-13.54	2.10
NIONO	57	1	0	0	0	0	-14.25	-5.99
NIORO	58	1	0	0	0	0	-15.13	-9.65
NOUNA	59	1	0	0	0	0	-12.70	-3.89
OUAGA	60	1	0	0	1	0	-12.36	-1.54
OUANGOLO	61	0	0	0	0	0	-9.93	-5.16
OUIHA	62	1	0	0	0	0	-13.57	-2.44
PARAKOU	63	0	0	0	1	0	-9.33	2.62
POTISKUM	64	0	0	0	0	0	-11.70	11.04
PTHARC	65	0	0	0	1	0	-4.80	6.99
SAN	66	1	0	0	0	0	-13.28	-4.92
SARH	67	1	0	0	0	0	-9.14	18.38
SEGOU	68	1	0	0	0	0	-13.44	-6.25
SIKASSO	69	0	0	0	0	0	-11.26	-5.67
SOKOTO	70	0	0	0	0	0	-13.04	5.26
TAHOUA	71	1	0	0	0	0	-14.89	5.27
TANOUT	72	1	0	0	0	0	-14.96	8.87
TERA	73	1	1	0	0	0	-13.96	0.75
TOMBOUC	74	1	1	0	0	0	-16.83	-3.01
YAKO	75	1	0	0	0	0	-12.97	-2.28
ZEGOUA	76	0	0	0	0	0	-10.48	-5.65
ZARIA	77	0	0	0	0	0	-11.02	7.66
ZINDER	78	1	0	0	0	0	-13.79	8.99
OFFSHORE	79	0	0	0	0	0	4.00	-11.50

ENDDATA

VITA

Xiaoming Zhu was born in Xian, China on August 6, 1950. She worked for Shannxi Coal Exploration Company as a field assistant and a drafting person during 1970-1972.

In 1972, Xiaoming attended Peking (Beijing) University to study geology and graduated in 1975. She worked for Shannxi Coal Exploration Company as a geologist for geophysical exploration after graduating.

In 1978, Xiaoming entered graduate school in Peking University, and studied remote sensing at the Institute of Remote Sensing Technology and Applications in Peking University. She received the M.S.degree in 1981.

After working five years at the Professional Design Institute of the Ministry of Railroad of China, she entered the United States. In 1990, Xiaoming got the opportunity to study at the Department of Geography, University of Tennessee. She received her second M.S.degree in 1992.