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PLUS: A CONVERSATIONAL REGIONAL PLANNING TOOL

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FOREWORD

Manual manipulation of physical and socio-economic data required by the resource planner has been the common approach for many years. However, with the relatively recent advent of computerized data storage systems the planner has often had at his disposal more information than he could deal with manually. Not only has it frequently become physically impossible for him to synthesize the large amounts of data to which he has access, but he has also in many instances been constrained to superficial data analyses by the very magnitude of the information sets and the complexity of the relationships between the various data available to him.

The development of computer systems designed to allow the resource planner to analyse, synthesize and extrapolate the information and relationships contained within his data sets is a logical outgrowth of past data collection initiatives such as the Canada Land Inventory. In order that the masses of data gathered by such programs might be utilized in an optimum way, potential users required knowledge of, and access to, computerized planning systems which they might employ in their resource planning work. This paper describes one of the systems developed in response to this need, and presents several examples of practical problems and their solution through the use of the system. By so doing, the paper provides the reader with the opportunity to assess the efficacy of the system and the problems of its use.

AVANT-PROPOS

Pendant de nombreuses années, c'est manuellement, surtout, qu'étaient traitées les données physiques et socio-économiques requises par les planificateurs de ressources. Toutefois, avec la venue relativement récente des systèmes automatiques de stockage des données, cette méthode s'est révélée insuffisante; non seulement était-il souvent impossible, physiquement, de synthétiser la masse de données auxquelles on avait accès, mais il fallait se résoudre, dans de nombreux cas, à se limiter à des analyses superficielles, à cause de l'énormité même des ensembles de données et de la complexité des relations entre ces données.

Le perfectionnement des systèmes informatiques afin de permettre l'analyse, la synthèse et l'extrapolation de l'information et des relations contenues dans les ensembles de données est une conséquence logique d'initiatives passées de collecte de données comme l'Inventaire des terres du Canada. Pour utiliser de façon optimale la masse de données recueillies lors de programmes de ce genre, il fallait aux planificateurs de ressources une connaissance et l'accès des systèmes informatisés de planification qu'ils pouvaient employer dans leur travail. Ce rapport décrit un des systèmes mis au point à cette fin et apporte plusieurs exemples de problèmes pratiques et de leur solution par le système; le lecteur a ainsi le loisir de juger des problèmes se rapportant à son utilisation et de son efficacité.

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ABSTRACT

The geographic information system PLUS consists of two separate parts. The first, PLUS/X, operates in polygon mode and carries out data preparation for the second part, PLUS/2, which is a grid system. PLUS/X requires an expert user and a large computer, while PLUS/2 can be used by a layman with access to a mini-computer.

This paper sets forth the background which led to the development of PLUS, presents the logic which defined its hybrid nature, describes the principal functions of the system and presents nine practical problems and the steps necessary to resolve them through the use of PLUS.

RÉSUMÉ

Le système PLUS d'information géographique comprend deux parties distinctes. La première, PLUS/X, fonctionne en mode polygone et fait la préparation des données pour la seconde partie, PLUS/2, qui est un système à quadrillage. PLUS/X est réservé aux experts et aux gros ordinateurs tandis que PLUS/2 est accessible aux profanes ayant accès aux mini-ordinateurs.

Ce rapport explique l'origine du système PLUS, présente la logique qui a déterminé sa nature hybride, en décrit les principales fonctions et présente neuf problèmes pratiques et les étapes nécessaires à leur solution par le système.

TABLE OF CONTENTS

		PAGE
	FOREWORD	i
	ABSTRACT	ii
	TABLE OF CONTENTS	iii
	LIST OF FIGURES	vi
	PREAMBLE	vii
I	INTRODUCTION	1
	BACKGROUND	1
	POTENTIAL USER CONCERNS	5
	DESIGN CONSTRAINTS OF THE PLUS SYSTEM	6
II	THE PLUS SYSTEM AS DEVELOPED	8
	PLUS X	8
	PLUS/2	11
	Data types in PLUS/2	14
	PLUS/2 coverage names	16
	The PLUS/2 Functions	16
	PLUS/2 Functions: Housekeeping	17
	1) Starting a session (RESTART)	17
	2) Assistance to the user (HELP)	18
	3) Listing the maps in the system (COVERAGES)	18
	4) Displaying maps (DISPLAY)	19
	5) Deleting a coverage (DELETE)	20
	6) Terminating the session (STOP)	20

TABLE OF CONTENTS (CONT'D.)

PAGE

PLUS/2 FUNCTIONS: Creating New Files 21

1) Input by the user (CREATE) 21

2) Recoding a file (RECODE) 22

3) Recoding a file (RETYPE) 22

4) Creation of lines (LINES) 22

5) Creation of strips (STRIPS) 23

6) Creating a mask (POLYGON) 23

7) Overlaying two maps to produce a composite (OVERLAY) 24

8) Numerical combination of two maps to create a third (COMBINE) 24

PLUS/2 Functions: Tabulation and Analysis 25

1) Simple tabulation of a map (TABULATE) 25

2) Crosstabulation of two maps (CROSSTAB) 25

3) Tabulate with respect to distance (DTAB) 26

4) Tabulate with respect to contiguity (CONTIG) 26

5) Analysis of Variance (ANOVA) 27

6) Regress two numeric files (REGRESS) 27

7) The identification of minimum paths (ROUTE) 27

PLUS/2 - General Operation 28

III WORKED EXAMPLES 30

Problem 1: Making a Map 35

Problem 2: Tabulating agricultural capability 42

Problem 3: Determining the amount of class 2 land which has an average water table depth of 12" - 30" ... 42

Problem 4: Determining the amount of class 2 land within 10 miles of Stuartburn 44

TABLE OF CONTENTS (CONT'D.)

PAGE

Problem 5: Determining a numerical relationship between agricultural capability and water table depth to allow one to be prediated from the other 46

Problem 6: Predicting hay yields 46

Problem 7: Determining the amount of class 2 agricultural land flooded in the spring flood of 1970 52

Problem 8: Determining the amount of agricultural land affected by the construction of a divided highway 52

Problem 9: Identifying a least-cost route for a pipeline where cost is defined as the cost of agricultural land that would be disturbed during construction 54

SUMMARY 64

LIST OF FIGURES

		PAGE
1.	The Multiplier Identifier Format	10
2.	Data Input to PLUS - Roseau River Study	11
3.	The Functions of PLUS/2	17
4.	Roseau River Basin Study Area Conventional and PLUS/2 Representations	31 - 32
5.	Starting a PLUS/2 Session and DISPLAYing a Coverage	34 - 41
6.	TABULATE, RETYPE and CROSSTABulate a Coverage	43
7.	Tabulate According to Distance (DTAB)	45
8.	RETYPE and REGRESS Two Numeric Coverages	47
9.	COMBINE Two Numeric Coverages	49 - 51
10.	CROSSTABulate a POLYGON Coverage	53
11.	Build LINES and STRIPS for DISPLAY	55 - 58
12.	DISPLAY of a ROUTE Within a POLYGON	60 - 63

PREAMBLE

During recent years several computer systems have been developed with the general aim of facilitating land use planning. In September, 1972, Dr. Jay Beaman (Parks Canada) and Dr. J.H. Ross (Lands Directorate) conducted a cursory review of existing practices in the computerized land use planning field. Following this review a decision was taken to investigate the problems and prospects of a system which would incorporate the strengths and avoid the weaknesses of the then extant systems.

Accordingly, preliminary discussions were held with Dr. M.F. Goodchild (University of Western Ontario) to study further the technical feasibility of such a system. These discussions led to the report, "A Position Paper on Geographic Data Processing", written by Dr. Goodchild under commission to Parks Canada, in which the conceptual framework of the system which has come to be known as PLUS (PLANNING LAND USE) was set forth.

Subsequently in response to the evident need for a comprehensive, yet comprehensible, computerized land use planning system, the Lands Directorate retained Dr. Goodchild to develop necessary algorithms and programs, and to test the system in a real world case. This report discusses the PLUS system as it presently exists. It presents only a general view of the system. The technical details are treated in Goodchild, M.F., PLUS X DOCUMENTATION, Macrogeographic Systems Workshop, University of Western Ontario, 1976.

INTRODUCTION

This introductory paper is intended to explain the types of questions PLUS may be used to investigate, why it is efficacious to use a computerized land use planning system, and how such a system might be employed in a planning exercise. First, however, it will be necessary to examine the types of data planners usually have at their disposal, and the form of these data.

BACKGROUND

The data involved in land use planning are generally provided in map form - or as tables or listings which can readily be given spatial expression. These data may be expressed as point data (for example the population of a city located at the intersection of two geographic coordinates), line data (for instance a number of data points indicating the course of a stream or hydro line), or as areal data (for example the information that the area enclosed by an outline of data points is all suitable for growing a certain crop). In addition to these three data types it should be noted that each type may be subdivided into either numeric or alphanumeric classes. The former involves those data which may be measured or counted accurately (e.g. the population density of an area), while the latter class is concerned with those data which are coded nominally (i.e., the classes are named - e.g., "on a river", "good for growing a certain crop", etc.).

Point and line data types can be reduced to polygon data sets by considering the points as polygons having no area and the lines as long polygons having almost no width. Line and polygon data sets may be reduced to point data by treating the lines of series of closely spaced points and the polygons as dense areas of points. The question of which course to follow becomes one of efficiency in computer processing and manipulation of the data.

The mechanical handling of these three data types in an optimal fashion necessitates a common data structure. Three basic structures have been used in past automated planning systems: the point, grid and polygon systems are quite well known. Each will be discussed briefly below.

1) Point Systems - Point information systems deal with geographic data by referencing the central point of each land parcel and ascribing the characteristics of the parcel to that point. Information is retrieved for specified areas by inspecting each parcel's centroid to determine whether it lies within the area of interest or not. In this case the actual location of any phenomenon lying within the parcel is lost. One knows only that it lies somewhere within the parcel.

2) Areal Systems - Areal systems can be further subdivided into fixed grid and polygon schemes. Each is treated separately below.

a) Fixed grid systems subdivide the planning area by superimposing an arbitrary rectangular grid. Data are then recorded on the basis of this grid, each grid cell being assigned the attributes which it overlies, be they point, line, or areal in nature.

The chief advantages of the grid structure are that a) once data is gridded there is no need to retain its absolute location, its sequence sufficing, b) the data observations (i.e., same grid cell for different map coverages are spatially coincidental, and c) data manipulation and comparison become relatively inexpensive to conduct because no location data need to be processed. Computer memory requirements for this type of system are generally small. The main disadvantages of the fixed grid approach are that a) the boundaries of areas can be represented only by a Manhattan-type line approximating the edge of the area (lines and points being equally imprecisely denoted), and once the data have been gridded they cannot be disaggregated to decrease the planning scale, but may only be aggregated. Several grid systems are presently in use; MLMIS* and LUNR** are examples.

b) Polygon systems are those which store and manipulate areal data by referencing the geographic coordinates of the boundaries which outline the data. Data are generally recorded by manually digitizing the boundaries of polygons, although some systems, most notable CGIS, utilize drum scanners to automate the digitizing process.

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* The Minnesota Land Management Information System.

** The New York Land Use and National Resource Information System.

The chief advantages of the polygon system are that 1) it is more accurate (i.e., the original polygon boundary can be replicated almost perfectly from its digitized image), and 2) the data are independent of input scale, orientation and projection.

Polygon data have the disadvantages that: 1) they are expensive to manipulate because the locational information belonging to each polygon must always be dealt with mathematically, and 2) that they generally require large amounts of computer memory for even relatively simple manipulations. Several extant polygon systems provide examples, notably CGIS*, and PIOS**.

In spite of certain methodological difficulties it is evident that computerized land use planning systems have a great deal of potential. Existing systems have the ability to efficiently manipulate and display large amounts of data. Their chief disadvantages are the cost of data input, and their general incomprehensibility to the non-computer-expert land use planner***.

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* The Canada Geographic Information System.

** The San Diego Comprehensive Planning Organization Polygon Information Overlay System.

*** For a comprehensive treatment of several geographic information systems readers are referred to Tomlinson, R.F., et al., Computer Handling of Geographical Data, UNESCO Press, Paris, 1976.

POTENTIAL USER CONCERNS

It is a self evident, but nevertheless often unrecognized, truth that the design of any computer system must take into account the needs, desires, abilities and resources of the potential user group at which it is aimed. A fundamental part of the work undertaken before the PLUS system was designed consisted of reviewing the expressed concerns of several land use planners. This review revealed that a great number of their concerns could be met by a system which would respond to such questions as;

A) How much land of characteristic A (define any characteristic desired - e.g. having a slope ranging from 10 to 15 percent) is located within our planning region; where is this land?

B) How much land is type A on one coverage (e.g. depth to water table) and type B on another coverage (e.g. suitability for septic tanks); and where is it?

C) Is there any consistent relationship between any two coverages A and B - i.e. if we know the characteristics of one coverage, can we predict those of the other?

D) Given that we know that a certain functional relationship between coverages A and B will interact in such a fashion as to produce result C, can we predict the characteristics of C (e.g. knowing that the CLI agriculture capability index and the amount of nitrogen added to the soil are related in a specific way, can we predict the yield of certain agricultural crops)?

The review of potential users revealed that there was generally a low degree of sophistication in computer-concerned matters, and that any system to be used by this group would have to be very simple to operate.

It was also found that the level of resources which might be committed to a land use planning exercise was generally not very high. Many of the people contacted expressed the opinion that they felt that computerized planning would be too expensive. This feeling was often based on their knowledge that computers were expensive to operate.

DESIGN CONSTRAINTS OF THE PLUS SYSTEM

To ensure that PLUS would meet the basic objectives of the land use planner without exceeding his constraints, a set of basic requirements for the system was defined. The seven most important of these are outlined below:

1) The system had to be based on polygon storage of raw data in order to overcome the inherent inflexibility of grid storage. Additionally, because the final data manipulation was to be performed on a grid basis (to minimize costs) the system must have the capability of accepting pre-gridded data.

2) The system had to be flexible as far as the scale, projection, orientation, coordinate system and subject of the input data were concerned.

3) The system had to be usable by planners with limited computing background.

4) The system had to be capable of handling point, line and areal data types.

5) The system had to facilitate the statistical analysis of landbased data in order that inherent relationships might be modelled for later use.

6) The system had to be operable on equipment which might be used by land use planners where large computer installations are not available.

7) The system had to be able to utilize existing data banks as well as to integrate locally collected data.

THE PLUS SYSTEM AS DEVELOPED

It soon became evident that it would be impractical to design a system which met all these requirements and was simple enough for the non-expert computer user. Accordingly, the system was divided into two separate parts. PLUS X performs all the operations necessary to convert input polygon data to grid data at the required scale and orientation. PLUS/2 is an interactive program which permits relatively unsophisticated users to direct the computer to manipulate, combine and map their data in a number of different ways.

PLUS X cannot be run on a small computer as PLUS/2 can be, nor can it be run by a non-skilled user. PLUS X is not discussed in depth in this paper. Readers are asked to refer to PLUS X: DOCUMENTATION (op.cit.) for a detailed discussion.

PLUS X

The purposes of PLUS X are to accept input data in polygon, line or point formats, to perform the necessary scale transformations and coordinate rotations, and to output the data in a grid format, at any scale or orientation requested.

In order to perform these duties the system is subdivided into a number of subsections, each of which performs a specific task in this data reduction. As noted above, data can be input as point, line, or polygon; the point data can be allocated directly to their appropriate grid cells, but the line data (treated here as long, thin polygons) and polygon data require some manipulation.

Polygon data are generally input to PLUS X in a format referred to as 'image-/centre' (IC). In the IC format all the polygons for a given subject coverage are input, followed by a list describing the characteristics of each polygon and the coordinates of one point within it. This IC data is checked for accuracy, edited if necessary, and may then be numerically gridded. It may also be converted into the Pairwise Contact (PC) mode for data storage for future use. The PC data structure, which consists of the lines forming the edges of each polygon and the identities of the areas which the edges separate, is more efficiently stored and manipulated than IC data.

Polygon data obtained from data banks (such as the C.G.I.S. data bank) to date have been input to PLUS X in the PC data mode. The form of future polygon data input will be determined on the merits of each case. Either form of input (either IC or PC) is acceptable.

Polygon data of the PC type is again checked for correctness, and then either put into temporary storage or allocated directly to the designated grid. At this point the gridded data is easily mapped with one of the standard printer mapping packages, (e.g. SYMAP) or used in several different analysis packages. For example, by merely recoding the data one might use multiple regression or factor analysis packages to investigate relationships among different map coverages.

The gridded data output from PLUS X is written in such a way as to minimize the amount of storage space required. The format used is referred to as "multiplier identifier". The first record in each data file (sometimes referred to as a coverage or map) contains information which identifies the grid size and information type. The second and subsequent records consist of a multiplier (the number of times the following classification is repeated on that row of the grid) and the classification itself. (See Figure 1).

Figure 1 - The Multiplier Identifier Format

Record#	Mult.	Identifier
00020	16	1
00030	24	2
00040	11	1
.	.	.
.	.	.
.	.	.

It should be noted that it is not the purpose of PLUS to create large data storage banks. The aim of the system is rather to use information now available and to supplement this with locally produced data. (Data which have been coded will be retained for future use if deemed necessary, but no large data banks are anticipated). An indication of the wide range of data which can be processed by PLUS X can be gained from Figure 2 which enumerates some of the data processed for the Lands Directorate's Roseau River Basin Study.

Figure 2 - Data Input to PLUS - Roseau River Study

Data Name	Data Type	Data Scale	Source
CLI Agriculture	polygon	1:250,000	C.G.I.S.
CLI Forestry	polygon	1:250,000	C.G.I.S.
CLI Recreaton	polygon	1:250,000	C.G.I.S.
Depth of Water Table	polygon	1:126,720	Canada Agriculture
Surface pH	polygon	1:125,720	Canada Agriculture
MCIC	point	no scale	Manitoba Crop Insurance Corp.
Forest Inventory	polygon	1:63,360	Manitoba Gov't.
Water Balance	polygon	1:126,000	Canada Agriculture
Census	polygon	1:250,000	Statistics Canada

PLUS/2

PLUS/2 recognizes a variety of commands to display geographic data in map form, to tabulate those data, to cross-tabulate by distance from fixed point, to combine map coverages in a full array of mathematical and logical operations, and to permit analyses of the correspondences between maps in the system. Further, the modular form of programming used in the system permits new commands and capabilities to be added as they become necessary.

The use of the grid data structure has two considerable advantages. First, any map coded by grid cells can be displayed on simple devices like teletypewriters, video screens and computer printers. Other more elegant data structures would require either line plotters or extensive computing in order to display the data. Second, the grid form allows operations like overlaying and combining maps to be done quickly and cheaply. Although there is some loss of accuracy, particularly if the grid is coarse, there is a great advantage in the fast computer response to the user's commands.

PLUS/2 does not make great demands on computer memory as it stores nearly all of its data on inexpensive and readily available disk units.

PLUS/2 is an example of interactive computer use, in which the user (the land-use planner) makes decisions and provides commands while the program is actually running in the computer. It is possible for many other people to be using the same computer at the same time, probably in entirely different ways. The only requirements are some kind of terminal, a teletype for example, a telephone and the computer's telephone number. Standard telephone lines are adequate for the transmission of the terminal's dialogue with the computer.

While the teletype produces a permanent copy of the terminal input and output, there are advantages to the TV screen, or CRT terminal, in its greater speed and silent operation. The costs are comparable, and equipment now available allows the standard television set to be used in conjunction with a special keyboard. With equipment the size of a briefcase, the user can be in touch with a computer and data sets thousands of miles away simply by dialing the appropriate telephone number.

He is also free to work in the location of his choice and at the time he chooses. He may, for example, work from his own home at night when computer time is less expensive.

Timesharing is now a common form of operation for both small and large computers. Some small systems operate only in this mode. Other larger systems may offer timesharing in conjunction with more conventional batch operations, in which jobs are submitted to the computer as bundles of cards. In batch operations, the user has no way of interacting with the computer between the submission of the job and the return of the output.

Programming languages are rather different in batch and timesharing. Most small systems offer a variety of BASIC as the principal (sometimes the only) programming language, yet the version of BASIC available on large systems is often too limited for a large and complex program like PLUS/2. Rather, timesharing operation of large systems is more often through a standard language such as PL/1 and FORTRAN. Consequently, PLUS/2 has been developed in two parallel versions, BASIC for mini-computers, the PDP-11 or HP2000 for example, and PL/1 for large systems such as the IBM 360 series. One advantage of this arrangement is that the large system version can be operated in batch mode as easily as in timeshare, assuming that the batch user can provide all of the answers to PLUS/2's questions in advance, in the correct order.

Data types in PLUS/2

Geographic data is notorious for its variety of form. Even if the field is narrowed to polygon-type maps, in which the area is partitioned into zones of common value or type, the classification of each zone can take many forms. For example soil maps may be classified according to the name of the soil in each zone while census maps may contain strictly numerical classifications such as demographic totals. In each case the set of operations and manipulations is rather different. PLUS/2 narrows the range of options by recognizing two types of maps and treating them separately. 'Numeric' maps are those in which the classifications are numerical and suitable for algebraic manipulation. These maps can be arithmetically combined in any of a number of ways. On the other hand "Alphanumeric" maps have classifications which may be either alphabetic, numerical or a mixture of both. On these, arithmetic operations would make no sense. For example, the data of a map showing census tracts by identification number could not be validly multiplied by those of another map showing agricultural capability because, although the former has numerical classifications, the resulting numbers would have no numerical significance. The census map would be classified as an alphanumeric file in PLUS/2, and the system would not allow the user to perform operations reserved for numeric files.

Another distinction between alphanumeric and numeric files is that in the former case the system assumes that the number of possible codes is limited. If the user asks for a display of an alphanumeric file, the system will represent every code it finds in the file in a distinct manner by using a different symbol on the map it forms on the screen or printer. But as there is no theoretical limit to the number of different codes in a numeric file, the program will ask the user to define ranges for the map, and a different symbol will be used to display each range, rather than each code.

Most geographic data is 'intensive', that is, the value or code attached to a zone is assumed to be typical of all points within that zone. The demographic data collected by the census takes a rather different, 'extensive', form. If the number of persons resident in a census tract is used as the classification code for that tract, it is certainly not a code which is true of all points within the tract; rather, its value depends on the physical size of the tract. However, the total can be divided by the area of the tract to form a density, which is an intensive parameter. PLUS/2 draws no explicit distinction between the two data types. It assumes that all coverages will be of the intensive variety, so that the contents of each cell are true of that cell and do not depend on the area of the zone containing the cell.

PLUS/2 coverage names

PLUS/2 uses names in referring to individual map coverages. The names of existing coverages must be established prior to the computer session, while new files created during the session can be given new three-character names. For some computers, the user will be able to select names for new coverages with complete freedom, while other installations will require that the names be selected from a limited list.

The PLUS/2 Functions

As noted above, the PLUS/2 program is made up of a number of discrete subprograms, each of which performs a specified task. These subprograms, referred to here as functions, are activated when the user enters a "command". The computer interprets the command and initializes the required function. These functions may be divided into three groups to facilitate discussions. The "housekeeping" functions are those which querry the user about the data, print of maps requested, and provide various forms of assistance. The "create" functions allow the user to generate new coverages in a variety of ways. The last group, the "tabulation and analysis" functions allow the user to perform a variety of analyses on his data. Each function of these groups is discussed separately below.

Figure 3 - The Functions of PLUS/2

Housekeeping	Create	Tabulation and Analysis
COVERAGES	CREATE	ANOVA
DELETE	COMBINE	CONTIG
DISPLAY	LINES	CROSSTAB
HELP	OVERLAY	DTAB
RESTART	POLYGON	REGRESS
STOP	RECODE	ROUTE
	RETYPE	TABULATE
	STRIPS	

PLUS/2 Functions: Housekeeping

1) Starting a session (RESTART)

The PLUS/2 program must always have certain basic information about the data files at its diposal, the number and size of the grid cells, and the way in which maps produced are to be printed. In order to communicate this information to the program the user types in the command RESTART and responds to the questions posed. If the user wishes to continue a previous session without redefining the parameters he may specify any one of the other functions when prompted by the program.

2) Assistance to the user (HELP)

Once the user has initiated a command, the system is programmed to request (as explicitly as possible) whatever information it needs, one item at a time. An incorrect response to a request will usually cause the printing of message containing more detail on possible responses. In this way, the system requires the absolute minimum skill on the part of the user. The only occasion on which the PLUS/2 system is not capable of helping the user to provide the information is when the system is acutally waiting for a command. Because the set of possible commands is likely to be increased from time to time, the system is programmed to provide details on those commands that it currently recognizes whenever the user types HELP when asked for a command.

3) Listing the maps in the system (COVERAGES)

The use of this function by typing 'COVERAGES' causes a list of all of the coverages known to the system at that point in a session to be shown. This will include all those coverages declared to exist during setup, and any new files created by overlaying, generating polygons, etc. during the session The coverages are listed by name, since this is the way in which the user refers to them throughout a session, by the number assigned internally, and by type. The latter may sometimes appear as unknown, especially early in a session, since the system will only discover the type of an existing file by using it in some operation.

4) Displaying maps (Display)

The system generates maps by following the user's instructions, allocating a symbol to each grid cell in the file, and printing or forming that symbol in the appropriate location on a sheet of paper or a CRT screen. The grid data structure has a clear advantage here because the sequence of cells is the conventional printer sequence, so symbols can be fed to the printer or CRT in the order in which they occur in the file.

The use of a single symbol and print position to display each cell imposes certain restrictions on the display process. First, the grid array must fit within the dimensions of the screen, or paper.

For teletypes or CRT's this will usually restrict the display to 70 or 80 columns, and on CRT's to perhaps 20 or 30 rows. Rather than limit the size of map the system can handle, maps are 'paged' if the numbers of rows and columns are too great for a simultaneous display. During setup, the user is asked to specify the numbers of rows and columns in the grid, and also the numbers of rows and columns that can be displayed in one page. If necessary, the system will then set up a standard paging system and inform the user of the numbers of pages, overlaps between pages and so on. When displayed, the row and column notations will refer the user to the full grid rather than the section currently displayed. Of course, all other commands are carried out on the full grid.

Secondly, classification codes on maps will often be much more elaborate than can be denoted by a single symbol. Again this imposes restrictions on the DISPLAY command. For all other purposes, codes can be as elaborate as the user wishes. The effect on DISPLAY depends on the type of map. If the coverage being displayed is alphanumeric, the character used to determine the map symbol will be in a specified location in each code. If the file specified in the DISPLAY command is numeric, however, the user will be asked to supply numeric ranges for the DISPLAY operation. Each range will be given a user-selected symbol, so that the maximum number of possible ranges is limited to the number of distinct symbols available on the keyboard.

5) Deleting a coverage (DELETE)

To PLUS/2, the action of deleting a file by typing 'DELETE' simply erases the file name from its records. The user is permitted to use the deleted name for some new file he creates, in which case the name will be restored to PLUS/2's table of known files. All of these operations are quite independent of the physical existence of files on the computer's disk unit. However, in most computer systems, using an old file name for a new file will result in the physical replacement of the old coverage by the new version.

6) Terminating the session (STOP)

This function terminates a user session by returning control from PLUS/2 to the computer monitor. When a STOP command is executed, the list of files kept by PLUS/2 during a particular run is deleted. However, the actual files remain in the computer system. PLUS/2 will not protect a user from overwriting a file unless that file is specifically defined during each terminal session.

PLUS/2 Functions: Creating New Files

1) Input by the user (CREATE)

Files can be placed in the system in any of a number of ways. The most common is to load files directly onto disk by the use of some aspect of the PLUS/X package. However, PLUS/2 will generate files directly through program commands. Typing CREATE allows the user to enter the contents of a file through his terminal. The system adds such things as the header information to create a standard file, and stores it on the computer disk. The user specifies the coverage row by row from the top left hand corner, by indicating so many cells of one type, so many of another.

The system ensures that each row contains the correct number of cells, and allows the user to correct an entry that appears to contain an error.

Once the file is complete, the system returns to command mode, and the user might then display the new map to check for errors, or use it in any recognized function.

2) Recoding a file (RECODE)

This function allows any existing (old) file to be recoded to some new file with a different classification system. If the old file is alphanumeric, every time a new classification is encountered, the user is asked to supply whatever he wishes that classification to become in the new file. If the old file is numeric, the user establishes ranges, each one having some new symbol or value in the new file.

3) Recoding a file (RETYPE)

This function allows the classification type of any file to be changed from numeric to alphanumeric, or vice versa, without going through the RECODE function. The individual characters in the file are not changed, only their type is altered.

4) Creation of lines (LINES)

It is often desirable to create a coverage containing the routes of such lineal features as roads, pipelines or hydro lines. This function allows the user to do just this, and produces a special file which contains information describing the line. This file is of a special type (line) and can only be input to the STRIPS function. It <u>cannot</u> be displayed, tabulated, etc.

5) Creation of strips (STRIPS)

Line files created by function LINES are input to the STRIPS function to yield coverages in which the routes described by the line have known widths. For example, a lines file describing a major highway can be input to STRIPS and assigned a specific width. The file output by STRIPS (either alphanumeric or numeric) can then be displayed, tabulated, etc.

6) Creating a mask (POLYGON)

There are many occasions on which the user might wish to ask a question concerning some part of the study area. Sometimes the subarea might be defined in one of the coverages and questions such as how much land of type x lies in district y can often be answered by a crosstabulation. Often, however, the subarea of interest is not available in an existing file. Suppose that the user was interested in the amount of land of type x occurring in an Indian reservation in the study area, but had no coverage identifying the reservation specifically. The answer would be to generate a specific coverage giving the outline of the reservation. To do this, the POLYGON function asks the user to specify the outline of the area as a series of points, denoting the vertices or corners of the area in clockwise order. The system will then generate a coverage showing the polygon as cells with some symbol provided by the user, and showing the rest of the map as zeroes. The user can then crosstabulate this mask with the appropriate coverage to answer his questions, or combine the mask with some other attribute in one of the other functions.

7) Overlaying two maps to produce a composite (OVERLAY)

This function generates the logical combination of two alphanumeric maps. The system scans the two maps and, for every new combination of the two classifications, the user is asked to provide a new classification for the new map.

8) Numerical combination of two maps to create a third (COMBINE)

The COMBINE function parallels OVERLAY but performs algebraic instead of logical combinations. The most common form of combination asks for some variety of numerical aggregation of two maps to produce a third. First, each of the existing maps can be algebraically transformed up to a maximum complexity represented by:

$$(xw + a)^p$$

where x is the initial value
w is a weight
a is an added constant
p is a power

In addition, the result can be recoded into a number of ranges, each with a new value. The user can select from these options, or use all of them on each map independently.

Second, the resulting values can be combined in a number of ways. They can be added or multiplied, or the system can select the value which is greatest or that which is least, or one value can be used as a mask on the other to answer such questions as 'what are the areas and values of this map for which the other map has a value greater than x?'

PLUS/2 Functions: Tabulation and Analysis

1) Simple tabulation of a map (TABULATE)

This function provides the user with a summary of the types of land indicated on a specified map. For example, a map of agricultural capability could generate a summary of the area according to the categories of capability found on the map. As the user will already have defined the physical dimensions of each cell in appropriate geographical units, the system is able to tabulate the file in terms of both the numbers of cells and their physical area.

Alphanumeric and numeric maps are treated differently. If the file is alphanumeric, there will be an entry in the tabulation for each and every classification found in the map. If numeric, the user will be asked to specify ranges, and will be given a tabulation of the land falling into each range. For example, if the agricultural capability index is regarded as numeric and runs from 1 to 7, the user might define the ranges as 0 - 1.9, 2 - 3.9 and 4 - 7.0 and receive a table with three separate entries.

2) Crosstabulation of two maps (CROSSTAB)

Invoking this function by typing CROSSTAB gives a summary of all of the combinations of characteristics that occur when two maps are overlain. One might, for example, ask how much land of agricultural capability 3 occurs in census tract 5, and obtain the result by cross tabulating the two coverages. The program will generate a table in which there is one row for every classification found on one map, and one column for each classification found on the other. At the intersection of the row labelled capability 3 and the column for census tract 5, the user would find the number of cells which have both characteristics. The table also shows totals and measures of the degree of interdependence of the two coverages, specifically, chi square and Cramer's C.

3) Tabulate with respect to distance (DTAB)

This function is designed to answer questions such as "how much land of capability 3 occurs within 10 miles of Plusville?" The user types DTAB, provides the name of the coverage, the location of some point of interest, and a set of distance ranges, say 0 - 10 miles, 11 - 20 miles and greater than 20 miles. The system produces a table showing the classifications of the map in rows, and the categories of distance in the columns. The appropriate intersection of row and column gives the number of cells of that type found within that distance range.

4) Tabulate with respect to continguity (CONTIG)

The basic tabulations pay no attention to the contiguity of the areas tabulated. The results tell the user how much land of each type occurs, but do not indicate whether that land occurs in a single block or in small fragments or isolated cells. The user might investigate this aspect by displaying the map, or by contiguity tabulation, (type CONTIG) in which the program generates a list of all contiguous blocks of each class. To limit the length of the list, the user can indicate that he is interested only in certain values, or only in blocks of a certain minimum area.

5) Analysis of Variance (ANOVA)

In the analysis of geographic relationships it is often necessary to investigate the relationship between a numeric dependent variable (coverage) and an alphanumeric independent variable. This type of analysis is performed by the ANOVA function.

6) Regress two numeric files (REGRESS)

Running somewhat parallel to the crosstabulation function, but meaningful only for numeric files, is the regression function (type REGRESS). It provides an analysis of the degree to which the characteristic measured by one map is correlated with another. For example, the user might have maps of land value and agricultural capability, and by the use of this function answer questions about the way in which capability influences land value in the area. The function allows for the fact that maps may often be incomplete by asking the user whether there are specific values that indicate missing data.

7) The identification of minimum paths (ROUTE)

The planner if often faced with the task of determining the minimum cost path between two points in his study area. Function ROUTE performs this analysis on a numeric file, presents the "cost" of the minimum route, and gives the user the option of creating a map coverage indicating the route.

PLUS/2 - General Operation

The general operation of PLUS/2 is perhaps best understood through the description of a typical session. In the first step the user phones the computer and establishes himself as a bona fide customer by entering his account number and password during the login procedure. Next the user runs the PLUS/2 program. The initial response of the program is to print out a page banner and then ask for instructions. It does this by typing "COMMAND?", indicating that it is ready to perform any of the functions described above.

If the user is continuing a previous session he may proceed with his work. If, on the other hand, he wishes to define new coverages or start working with a new study area he must reset the program parameters by executing the RESTART function. During the execution of this function the program asks for information on the available maps of the area (coverages), the grid system in use, and the dimensions of the display area. Once complete, RESTART leads into the command mode which is the central state of the PLUS/2 system. Because of the information solicited in the RESTART phase, the system is able to carry out commands in which maps are referred to simply by name, and to display and manipulate these maps with minimal further information. After executing a function, the system returns to the command mode, except for the instruction STOP, which produces a return to the computer's monitor mode. Before leaving the terminal, the user would normally execute the logoff procedure in which the computer performs accounting calculations and closes down the session.

In normal circumstances, a typing error in an entry from a terminal would cause the termination of the program and a return to monitor mode. However, PLUS/2 is programmed so that the majority of such errors can be trapped. Instead of terminating completely, the program returns to command mode so that the user can simply try the step again. In effect, the system substitutes the command mode as the idle state in place of the computer's monitor mode. Only the most severe errors can cause a termination of the program.

III

WORKED EXAMPLES

In the next few sections, several typical problems are posed and solved by PLUS/2 in the context of a real study area. The area lies in the Roseau River Basin in Southeastern Manitoba, bounded by the 49th parallel to the south and the Red River to the West, and covering an area measuring 84 miles in an east - west direction by 18 miles north - south (see Figure 4). More precisely, the area is defined by the boundaries of townships 1 through 3, ranges 2 through 15 east of the principal meridian.

PLUS/2's study areas are conventionally rectangular. This is a reflection of the fact that the number of grid cells is not terribly important to the cost of computing, whereas the use of a non-rectangular boundary certainly is. It is much cheaper to manipulate the extra cells necessary to fill out a rectangle, than to add the complications of an irregular outline. Similarly, since costs are rather unresponsive to the number of grid cells in both PLUS/X and PLUS/2, it is usually wise to use a fine, high - resolution grid in order to maximize accuracy.

However, other factors may also be important in deciding on the size of the basic grid cell. In the case of this particular example, there are advantages in arranging the grid cell network to coincide with the land survey, so that when planning uses by grid cell one is the same time planning by quarter sections. There is one slight complication, in that the land survey is slightly offset between townships 2 and 3. This offset was followed in the preparation of the data to maintain the correspondence between grid cells

Figure 4

Roseau River Basin Study Area

Conventional and PLUS/2 Representations

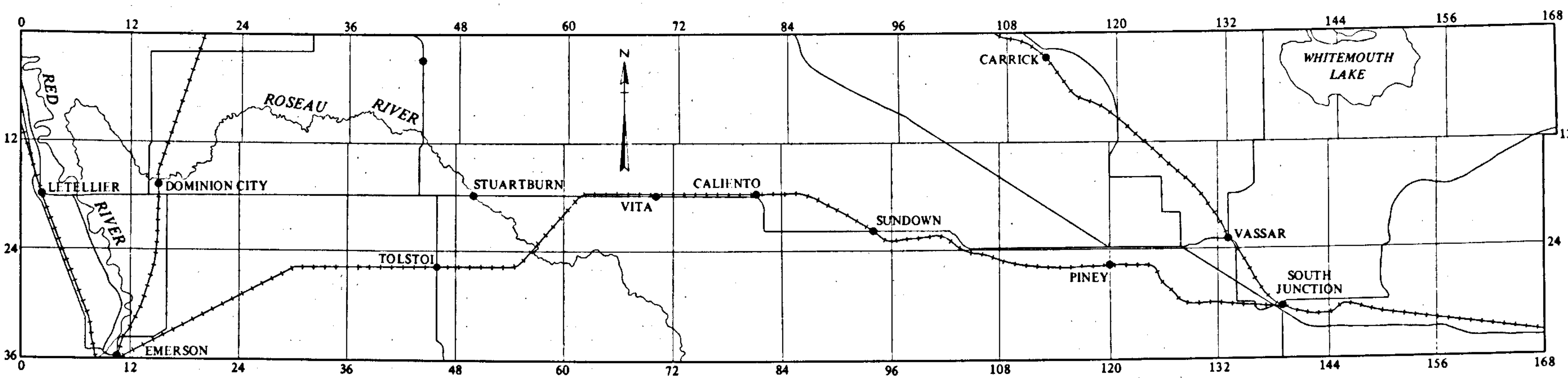
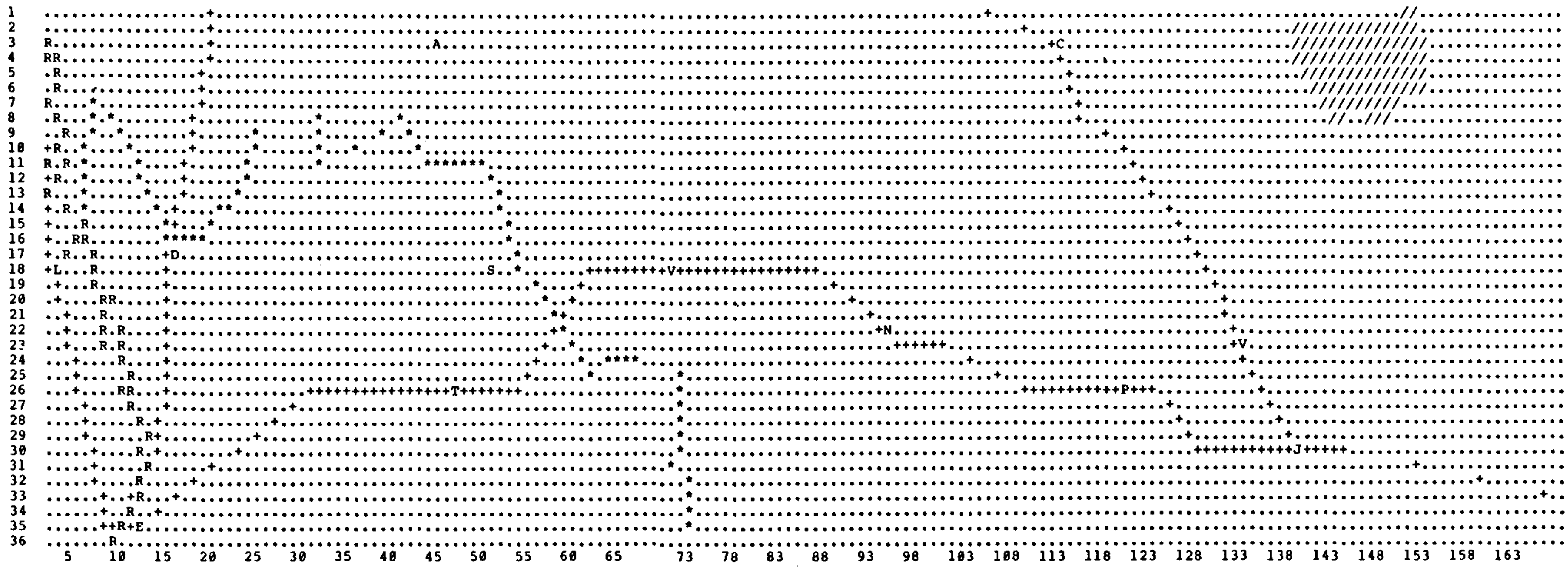


Figure 4 (con't.)

Roseau River Basin Study Area

Conventional and PLUS/2 Representations (cont.)



LEGEND

R = RED RIVER

* = ROSEAU RIVER

\+ = RAILWAY

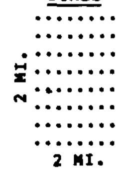
COMMUNITIES

L = LETELLIER   A = ROSA   V = VITA   P = PINEY

E = EMMERSON   T = TOLSTOI   N = SUNDOWN   V = VASSAR

D = DOMINION CITY   S = STUARTBURN   C = CARRICK   J = SOUTH JUNCTION

SCALE



(The scale of this figure is 56% of the computer output scale) and quarter sections, though it will not appear in the PLUS/2 displays.

Using quarter sections as grid cells gives a study area of 36 rows and 168 columns, or 6048 cells in all, a total of 1512 square miles. All of the data used in the study was drawn from existing maps and computer data banks to demonstrate the feasibility of PLUS/X's approach to compatibility problems, and fed into PLUS/2. The full list of data sources is given as Figure 2 above, although only two coverages are used for the purposes of the discussion below. One, here referred to as AGRI, is derived from the Canada Land Inventory index of agricultural capability. This information was obtained directly from the data files of the Canadian Geographic Information System through elements of the PLUS/1 package. The second file, SOIL, represents the depth to water table. It was digitized from manuscript maps provided by the Department of Agriculture, and converted to a grid structure for PLUS/2, again by elements of PLUS/X.

The sample session printout (Figures 5 - 12) shows exactly what would occur at a CRT or teletype terminal. The responses of the user are shown underlined to distinguish them from those messages produced by the computer.

The first few entries comprise the RESTART part of the session. Much of the information is needed for displays or tabulations, and in this case the system determines that to display a 36 by 168 grid on screen with only 24 by 60 print positions will require six pages of display, overlapping by 12 rows and 6 columns. So the top left page (referred to as page row 1 column 1) will cover columns 1 - 60 and rows 1 - 24, page row 2 column 2 will cover columns 55 - 114, rows 13 - 36 and so on. (See Figure 5).

Figure 5 -- Starting a PLUS/2 Session and DISPLAYing a Coverage

```
**************************************************************
*                                                            *
*       PLUS/2 BASIC VERSION          (12 JUNE 74)           *
*                                                            *
**************************************************************

FOR HELP USE HELP COMMAND

COMMAND ?RESTART
DEFINE THE AREA TO BE WORKED WITH AS A RECTANGULAR GRID
NUMBER OF ROWS ?36
NUMBER OF COLUMNS ?168
NUMBER OF CELLS 6048
HEIGHT OF EACH CELL ?.5
WIDTH OF EACH CELL ?.5
NUMBER OF ROWS ON ONE PAGE ?24
NUMBER OF COLUMNS ON ONE PAGE ?60
DISPLAYS ARE PAGED INTO 2  ROWS AND 3  COLUMNS
ENTER THE NAMES OF ALL EXISTING FILES. END THE LIST WITH 'EN
D'
NAME OF FILE NUMBER 1  ?AGRI
FILE AGRI TYPE ALPHA
NAME OF FILE NUMBER 2  ?SOIL
FILE SOIL TYPE NUMERIC
NAME OF FILE NUMBER 3  ?END
FINISHED FILE DEFINITIONS
```

The user names files AGRI and SOIL as existing prior to the session, and ends the list and the RESTART section by typing END. The system is then in the command mode, and will return to this point should the user make an error, through a typing mistake, using a name for a new file that is already in use, attempting to regress an alphanumeric file, and so on.

Problem 1 - Making a Map

For the first problem (see Figure 5), the user simply wishes to display the C.L.I. agricultural capability. The command DISPLAY is entered and the system responds by requesting the name of the file to be mapped. The user responds by naming file AGRI.

The system then asks which page is to be displayed. Page 1, 1 is selected, and PLUS/2 forms a map of rows 1 - 24 and columns 1 - 60. Since this is an alphanumeric display, the symbols used are those actually appearing in the coverage file. AGRI has a single character code; for more complex codes, the symbol used would be that appearing in some specific position of each code, for example the left-most.

The user goes on to display two more pages, row 1 column 2 (the upper middle part of the map) and row 2 column 3 (the lower right). In the latter case the right-hand part of the display is all zeroes, since agricultural capability coverage was only available for one of the two map sheets covering the study area.

When preparing a printer map the user must always consider the visual impression that the map will convey to his audience. Although the computer

Figure 5 -- Starting a PLUS/2 Session and DISPLAYing a Coverage (cont.)

```
COMMAND ?DISPLAY
NAME OF FILE FOR DISPLAY ?AGRI
FILE TYPE ALPHA
ENTER ROW AND COLUMN FOR DISPLAY PAGE ?1,1

 1    222233322333332222333322222332335544444445555555555055500006
 2    222233322333333332333322222224444444444455555555550550000
 3    222223322333333333333322222224444444444445555555555000000
 4    222223323333333333333333222222255444444444445555555000005500
 5    222223223333333333333332222222254444444444445555000000055500
 6    222223322333333333333322222222244544444444445555000000000000
 7    222223322233333333333332222222224455444444444555000000000000
 8    222222233333333333333222222222222455544444444545000000000000
 9    222222222223333333333233322322222444434444455544450000000000
10    222222222223333333333332222332323334443555555440500000000000
11    222222222223333333333322222223323444444353555555550000000000
12    222222222223333333333333332232322355444444445555555500000000
13    222222222223323333332333322323322554444444445555555555550005
14    222222222222222223332233332222333334445544444445555555555555
15    222222222222222222223222333222333333344455444443555555555555
16    222222222222222222232223233232333333333444554444443555555555
17    222222222222222222233332233333333333344444445444445555555555
18    222222222222222222233333232333333333333444444445444355555555
19    222222222222222222233333332335533333333354444454444355555555
20    222222222222222233333332333223553333333444544455544443555555
21    222222222222222333333323332233333333334444455545444444355555
22    222222222222222233333332332333333333334444444445444444445555
23    222222222222222233333333332333333333355544544545445544355555
24    222222222222222233333333322233333333544544544554545544445555
          5    10   15   20   25   30   35   40   45   50   55   60
```

Figure 5 -- Starting a PLUS/2 Session and DISPLAYing a Coverage (cont.)

```
NEW PAGE - YES OR NO ?YES
ENTER ROW AND COLUMN FOR DISPLAY PAGE ?1,2

 1   550006665550555555555566666660606660000000000400066066066666
 2   550000665550055555555555500600060666600000046000006066060046
 3   000000566555500555555666500000060666600000006666666660660004 46
 4   005500055650000005555666000000006606666000006066666666006066 6
 5   055500050050000000555555000000006006666000000666066660000060 6
 6   000000000005000000055500550000060666606000666660006000660 50
 7   000000000000000000000550500000066660666660066006066666666005 5
 8   000000005000505505555555005500066660030060666000600666606550
 9   000000055555555555555550550000666603306656660000666606060 0
10   000000005555555555555550000000666603035060530004444446660 05
11   00000005555555555555555505500360033005600606060444444446555
12   00000005555555555555555000000033000000000000006666444444445006
13   55000500555555555555555555000000000000000000006666654444440000
14   55555500555555555455555555550000000000000000006650054444444606
15   555555550555555555455555555550000000000660000064400444444444666
16   55555555505555555455555555555000000056544400066004444444446666
17   555555555005555555555555555550000045555564400060004640545666 6
18   555555555550555555555555555550000034555545444006002260055666 66
19   5555555555500555555555555555000000554454660000600000645566666
20   55555555555505555555555555550000005545540000000060006645566666
21   555555555555055555555555555550003355550500000060000605666665
22   5555555555550055555555555555500055555505000050060006665666665
23   355555555550000555555555555555000555555555555555506666656666 5
24   4455555555500000555555555555505000055555555550000000666666666 6
       59   64   69   74   79   84   89   94   99  104  109
```

Figure 5 -- Starting a PLUS/2 Session and DISPLAYing a Coverage (cont.)

```
NEW PAGE - YES OR NO ?YES
ENTER ROW AND COLUMN FOR DISPLAY PAGE ?2,3

 13  440000666600000000000000000000000000000000000000000000000000
 14  444606666600000000000000000000000000000000000000000000000000
 15  444666666600000000000000000000000000000000000000000000000000
 16  446666666600000000000000000000000000000000000000000000000000
 17  456666666500000000000000000000000000000000000000000000000000
 18  566666665500000000000000000000000000000000000000000000000000
 19  566666655500000000000000000000000000000000000000000000000000
 20  566666554400000000000000000000000000000000000000000000000000
 21  666665554400000000000000000000000000000000000000000000000000
 22  666665544400000000000000000000000000000000000000000000000000
 23  566665544400000000000000000000000000000000000000000000000000
 24  666666544400000000000000000000000000000000000000000000000000
 25  666666444400000000000000000000000000000000000000000000000000
 26  060444555500000000000000000000000000000000000000000000000000
 27  000000005500000000000000000000000000000000000000000000000000
 28  000000000000000000000000000000000000000000000000000000000000
 29  000000660000000000000000000000000000000000000000000000000000
 30  000006600000000000000000000000000000000000000000000000000000
 31  000066606200000000000000000000000000000000000000000000000000
 32  000066666200000000000000000000000000000000000000000000000000
 33  000066622200000000000000000000000000000000000000000000000000
 34  000006620000000000000000000000000000000000000000000000000000
 35  000000002400000000000000000000000000000000000000000000000000
 36  000000224400000000000000000000000000000000000000000000000000
       113  118  123  128  133  138  143  148  153  158  163
```

offers one a selection of over sixty characters, the choice of which to assign to each category in order to maximise visual impact is by no means a simple task. This is particularly true when one cannot use the computer's ability to overprint (i.e. print two or more characters in the same place) to obtain differing shades of black. In preparing maps for publication the user may wish to prepare colour separations or to enhance the computer output by the manual insertion of boundaries. For working documents, on the other hand, it will often be sufficient to choose display characters which maximise the visual impact between classifications. If characters which retain the implicit progression or intensification of the coverage being mapped can be chosen the impact of the final map is further enhanced.

The file AGRI, for example, contains categories which may be RECODEd as follows:

Category	New Code
2	$
3	#
4	*
5	/
6	-
0	.

This choice of symbols yields a map (see Figure 5) which, when DISPLAYed, increases the visual contrast between categories while at the same time retaining (through decreasing density) the implicit progression of agricultural capability.

Figure 5 -- Starting a PLUS/2 Session and DISPLAYing a Coverage (cont.)

```
COMMAND ?RECODE


NAME OF COVERAGE TO BE RECODED ?AGRI
FILE TYPE ALPHA
WHAT IS THE NEW FILE TYPE TO BE ?ALPHA
NAME OF THE FINAL FILE ?AGRI1
OPENING FILE IN POSITION 3
NEW SYMBOL OR VALUE FOR 2 IS  ?$
NEW SYMBOL OR VALUE FOR 3 IS  ?#
NEW SYMBOL OR VALUE FOR 5 IS  ?/
NEW SYMBOL OR VALUE FOR 4 IS  ?*
NEW SYMBOL OR VALUE FOR Ø IS  ?.
NEW SYMBOL OR VALUE FOR 6 IS  ?-

COMMAND ?DISPLAY


NAME OF FILE FOR DISPLAY ?AGRI1
FILE TYPE ALPHA
ENTER ROW AND COLUMN FOR DISPLAY PAGE ?1,1

 1   $$$$###$$#####$$$####$$$$$##$##//*******//////////.///...-
 2   $$$$##$$#########$####$$$$$$$$***********///////////.//....
 3   $$$$$##$$##################$$$$$$$$************///////////......
 4   $$$$$##$##################$$$$$$$$//***********//////....//..
 5   $$$$$#$$##################$$$$$$$$$/************////.....///..
 6   $$$$$##$$#################$$$$$$$$$$**/**********////..........
 7   $$$$$##$$$################$$$$$$$$$$**//*********///...........
 8   $$$$$$$##############$$$$$$$$$$$$$*///********/*/..........
 9   $$$$$$$$$$$$##########$###$$#$$$$$****#****///***/..........
 1Ø  $$$$$$$$$$$$$############$$$$$##$#$###***#//////**./..........
 11  $$$$$$$$$$$$###########$$$$$$$$##$#******#/#////////.........
 12  $$$$$$$$$$$$###############$$#$#$$#//********////////........
 13  $$$$$$$$$$$$$##$########$####$$#$##$$//*********//////////.../
 14  $$$$$$$$$$$$$$$$$###$$####$$$$#####***//******//////////////
 15  $$$$$$$$$$$$$$$$$$$#$$$###$$$#######***//*****#/////////////
 16  $$$$$$$$$$$$$$$$$$#$$$#$##$#$########***//******#///////////
 17  $$$$$$$$$$$$$$$$$$$$####$$###########******/*****//////////
 18  $$$$$$$$$$$$$$$$$$$#####$#$############*******/****#/////////
 19  $$$$$$$$$$$$$$$$$$$$#######$##//#######/*****/****#/////////
 2Ø  $$$$$$$$$$$$$$$######$###$$#//#######***/**///****#///////
 21  $$$$$$$$$$$$$$$######$###$$##########*****///*/******#/////
 22  $$$$$$$$$$$$$$$#######$##$##########*********/********/////
 23  $$$$$$$$$$$$$$$$##########$##########///**/**/*/**//**#/////
 24  $$$$$$$$$$$$$$$$#########$$########/**/**/**//*/*//****////
         5    1Ø   15   2Ø   25   3Ø   35   4Ø   45   5Ø   55   6Ø

NEW PAGE - YES OR NO ?NO
```

Figure 5 -- Starting a PLUS/2 Session and DISPLAYing a Coverage (cont.)

```
COMMAND ?RECODE
NAME OF COVERAGE TO BE RECODED ?AGRI
FILE TYPE ALPHA
WHAT IS THE NEW FILE TYPE TO BE ?ALPHA
NAME OF THE FINAL FILE ?AGRI2
OPENING FILE IN POSITION 4
NEW SYMBOL OR VALUE FOR 2 IS  ?H
NEW SYMBOL OR VALUE FOR 3 IS  ?H
NEW SYMBOL OR VALUE FOR 5 IS  ?.
NEW SYMBOL OR VALUE FOR 4 IS  ?.
NEW SYMBOL OR VALUE FOR Ø IS  ?.
NEW SYMBOL OR VALUE FOR 6 IS  ?.
FILE CREATED
```

```
COMMAND ?DISPLAY
NAME OF FILE FOR DISPLAY ?AGRI2
FILE TYPE ALPHA
ENTER ROW AND COLUMN FOR DISPLAY PAGE ?1,1

  1  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH...........................
  2  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH.............................
  3  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH.............................
  4  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH............................
  5  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH...........................
  6  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH...........................
  7  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH...........................
  8  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH..........................
  9  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH....H......................
 1Ø  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH...H....................
 11  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH......H.H.................
 12  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH..........................
 13  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH..........................
 14  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH.........................
 15  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH..........H.............
 16  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH...........H...........
 17  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH.......................
 18  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH...........H..........
 19  HHHHHHHHHHHHHHHHHHHHHHHHHHHHH..HHHHHHHH...........H.........
 2Ø  HHHHHHHHHHHHHHHHHHHHHHHHHHHHH..HHHHHHH.............H........
 21  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH................H......
 22  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH.......................
 23  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH.................H.....
 24  HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH........................
         5   1Ø   15   2Ø   25   3Ø   35   4Ø   45   5Ø   55   6Ø

NEW PAGE - YES OR NO ? NO
```

Another technique maximising the visual impact of a map is to differentiate only between those classifications of importance to the project. If, for example, one is only interested in the location of "high quality" and "low quality" agricultural land, he might choose to portray CLI classes 1-3 as "H" and the rest as "." by running function RECODE on file AGRI and DISPLAYing the results (see Figure 5).

Problem 2: Tabulating agricultural capability

To determine the amount of each class of agricultural land in the study area, (see Figure 6) the user tabulates the AGRI coverage through the TABULATE function. The system finds seven categories, which are listed in the order PLUS/2 encounters them, beginning with class 2 agriculture and ending with category "6".

The tabulation is given in three forms, by number of cells, percentage of the total, and by physical area. During RESTART, the user gave the size of each cell as ½ mile by ½ mile, so the physical area will be in units of square miles. Thus we know, for example, that 742 quarter sections, (12.26% of the study area) or 185.5 square miles are of class 2 agricultural capability, etc.

Problem 3: Determining the amount of class 2 land which has an average water table depth of 12"-30".

This question can be handled by the CROSSTAB function (Figure 6). Inspection of the file SOIL shows it to be numeric. Since CROSSTAB requires the files to be alphanumeric, SOIL is RETYPED as alphanumeric file SOILA. The user then executes function CROSSTAB on files AGRI and SOILA. In the output,

Figure 6 -- TABULATE, RETYPE and CROSSTABulate a Coverage

```
COMMAND ?TABULATE
NAME OF FILE TO BE TABULATED ?AGRI
FILE TYPE ALPHA
TABULATING FILE TYPE ALPHA
LEVEL          NAME          TOTAL CELLS     PERCENT
 1              2               742            12.2685
 2              3               596            9.8545
 3              5               1158           19.1468
 4              4               587            9.70569
 5              0               2609           43.1382
 6              6               356            5.88624

COMMAND ?RETYPE
NAME OF FILE TO RETYPE ?SOIL
FILE TYPE NUMERIC
NAME OF THE NEW FILE ?SOILA
FILE COMPLETE

COMMAND ?CROSSTAB


NAME OF FIRST FILE IN CROSSTAB ?AGRI
FILE TYPE ALPHA
NAME OF SECOND FILE ?SOILA
FILE TYPE ALPHA
CROSSTABULATION - AGRI IN ROWSSOILA IN COLUMNS
      3     0     4     5     1     2
2      215   74    67    372   8     6     742
3      106   126   162   197   1     4     596
5      262   227   48    500   3     118   1158
4      104   173   74    213   3     20    587
0      603   586   377   222   0     821   2609
6      61    83    98    28    0     86    356

       1351  1269  826   1532  15    1055  6048


CHISQUARE STATISTIC 1668.75 WITH 25 DF
```

the categories are listed in the order that they are encountered. The tabulation shows that of the 742 cells of class 2 agricultural capability, 215 have a depth to water table of code 3 (12"-30"). For another 74 cells depth data is unavailable, 67 cells have a depth of water table of code 4 (greater than 30"), etc. Totals are given around the edge of the table with a grand total in the bottom right corner.

At the bottom of the table are statistics to test whether a relationship exists between capability indices and depth to water table. Cramer's statistic is a measure of the strength of such a relationship. A value of 1.0 indicates a perfect relationship and 0.0 indicates no relationship. Depth to water table, then, is to some extent capable of predicting agricultural capability and vice versa.

<u>Problem 4: Determining the amount of class 2 land within 10 miles of Stuartburn</u>

PLUS/2 can handle this problem by a request for a distance tabulation (see Figure 7). The user runs DTAB on file AGRI. The distance ranges 0-10 miles and 10-100 miles are established and the labels of <" 10" and " 10"> to be used in the table.

Since Plus/2 does not function on a coordinate system, the location of Stuartburn must be specified by a row and column number. The system will assume the point lies at the center of the cell and will measure distance to the centre of all other cells. Stuartburn is located at row 18 column 50.

The tabulation shows that only 9 of the 742 cells of class 2 agricultural land lie within 10 miles of Stuartburn. The majorority of the land in this

Figure 7 -- Tabulate According to Distance (DTAB)

```
COMMAND ?DTAB

NAME OF FILE FOR DISTANCE TABULATION ?AGRI
FILE TYPE ALPHA
DISTANCES ARE IN GEOGRAPHIC UNITS. NUMBER OF RANGES ?2
SPECIFY THE UPPER LIMITS OF EACH RANGE, THEN THE
NEW SYMBOL OR VALUE FOR EACH RANGE
LIMIT AND SYMBOL OF RANGE Ø  ?1Ø,<1Ø
LIMIT AND SYMBOL OF RANGE 1  ?1ØØ,>1Ø
ENTER ORIGIN POINT AS ROW AND COLUMN NUMBER ?18,5Ø
CROSSTABULATION - DISTANCES IN COLUMNS, COVERAGE IN ROWS
            <1Ø  >1Ø
2             9    733  742
3           142    454  596
5           483    675  1158
4           4Ø2    185  587
Ø           156   2453   26Ø9
6            1Ø    346  356
           12Ø2   4846
```

area is class 4 and 5 with 402 and 483 cells respectively.

Problem 5: Determining a numerical relationship between agricultural capability and water table depth to allow one to be predicted from the other

To look at the numerical relationship between depth to water table and agricultural capability (see Figure 8), the user uses the 'REGRESS' function. Since both variables in a regression must be numeric the user RETYPEs AGRI as AGRIN, and then executes function REGRESS. He specifies zero as a missing data code in both files so that the organic soils and empty cells do not affect the analysis.

The result is that the y variable, SOILN, can be predicted from the value of the x variable, AGRIN, by the equation

$$y=4.5728-0.1430\ x$$

In other words, the greater the agricultural capability index, the less the depth to water table. But the relationship is very weak, with a correlation of only .183, indicating that a mere 3.35% of the variation in depth to water table is predictable from a knowledge of agricultural capability. The t-statistic gives a test of the statistical significance of the analysis, which was based on 2756 of the 6048 cells available, the others missing either x or y values, or both.

Problem 6: Predicting hay yields

Suppose that past experience had shown that hay yields expressed in thousands of lbs. per acre could be predicted by the following equation: Y=3+.5 (AGRI)+.4 (SOIL). (This particular equation is not based on any facts but is

Figure 8 -- RETYPE and REGRESS Two Numeric Coverages

```
COMMAND ?RETYPE

NAME OF FILE TO RETYPE ?AGRI
FILE TYPE ALPHA
NAME OF THE NEW FILE ?AGRIN
FILE COMPLETE

COMMAND ?REGRESS

NAME OF THE X VARIABLE ?AGRIN
FILE TYPE NUMERIC
NAME OF THE Y VARIABLE ? SOIL
FILE TYPE NUMERIC
ENTER MISSING DATA CODES FOR X AND Y ?0,0
REGRESSION EQUATION    Y   =   4.57284   +  -0.143034  X
CORRELATION 0.183094  R SQUARED 3.35233E-2
T STATISTIC FOR TEST OF R 9.77371
WITH 2754 DF
X SUM  10695 MEAN 3.88062
Y SUM 11073 MEAN 4.01778
SUM X SQ 46629 VARIANCE 1.85984 DEVIATION 1.36376
SUM Y SQ 47617 VARIANCE 1.13503 DEVIATION 1.06538
SUM XY 42237
NUMBER OF POINTS 2756
COMPUTE RESIDUALS ?NO
```

similar to one that might be derived from a statistical analysis and is used here only as an example). On the basis of this equation, the user wants to know how many contiguous areas of at least 1920 acres are likely to produce more than 6,500 lbs. of hay per acre.

This is an example where two files have to be numerically combined to produce a composite which, when tabulated, will show the desired results. The planner will first combine AGRIN (the numeric version of AGRI) and SOIL to form HAY, (see Figure 9). The program will ask for the desired options for each file. For file AGRIN, the added constant will be 3, the power 1 and the weight .5 while for file SOIL, the added constant will be 0, the power 1 and the weight .4.

It will be noted that while defining the options for the combination the user can code the new values into relevant ranges. Since a recode is not necessary in this example, the value 0 is given to this option. To obtain a file of predicted yields, the two values are now added together to complete HAY.

To display HAY, only two ranges will be used since the planner is only interested in areas where the predicted yield is greater than 6,500 lbs. per acre. Thus, range 1 will have an upper limit of 6.5 and will be symbolized by a 1. The upper limit for range 2 will be 9 and will be symbolized by 2. Page 1, 1 is used for the display. A clearer map is obtained by recoding file HAY, designating the good hay growing areas as "H" and the rest as ".". The resulting file HAY1 is then displayed (Figure 9).

Figure 9 -- COMBINE Two Numeric Coverages

```
COMMAND ?COMBINE
NAME OF THE FIRST FILE IN COMBINATION ?AGRIN
FILE TYPE NUMERIC
NAME OF THE SECOND FILE ?SOIL
FILE TYPE NUMERIC
NAME OF THE FINAL FILE ?HAY
OPENING FILE IN POSITION 6
OPTIONS FOR FILE AGRIN
ENTER THE ADDED CONSTANT ?3
ENTER THE WEIGHT ?.5
ENTER THE POWER ?1
ENTER THE NUMBER OF RANGES FOR A RECODE - ELSE ZERO ?Ø
OPTIONS FOR FILE SOIL
ADDED CONSTANT ?Ø
WEIGHT ?.4
POWER ?1
RANGES ?Ø
COMBINE OPTIONS - ENTER 1 FOR ADD, 2 FOR MULTIPLY, 3 FOR MASK ?1
FILE CREATED

COMMAND ?DISPLAY

NAME OF FILE FOR DISPLAY ?HAY
FILE TYPE NUMERIC
ENTER ROW AND COLUMN FOR DISPLAY PAGE ?1,1
HOW MANY RANGES IN NUMERIC DISPLAY ?2
SPECIFY THE UPPER LIMITS OF EACH RANGE ORDERED FROM LOW TO HIGH
LIMIT FOR RANGE 1  ?6.5
LIMIT FOR RANGE 2  ?9

 1   111111111111111111111111111111111111111112121111111112221112
 2   111111111111111111111111111111111111111111211112112111221111
 3   111111111111111111111111111111111122111111111112212222111111
 4   111111111111111111111111111111112222222221111112211211112211
 5   111111111111111111111111111111111122222222212211221111111111
 6   111111111111111111111111111111111122222221212212221111111111
 7   111111111111111111111111111111111122222222222222221111111111
 8   111111111111111111111111111111111111222222222222111111111111
 9   111111111111111111111111111111111111111122222222221111111111
 1Ø  111111111111111111111111111111111111121111111211112111111111
 11  111111111111111111111111111111111112222211211222212211111111
 12  111111111111111111111111111111111112222222221112211121111111
 13  111111111111111111111111111111111111222212211222221122221112
 14  111111111111111111111111111111111111122221111121222222222222
 15  111111111111111111111111111111111111122211221111222212122222
 16  111111111111111111111111111111111111122222211111122221112222
 17  111111111111111111111111111111111111122211122211122222222222
 18  111111111111111111111111111111111111112221122211111222222122
 19  111111111111111111111111111111221111111111122211111111122222
 2Ø  111111111111111111111111111111221111112111112222211111222111
 21  111111111111111111111111111111111111122111111122211111222111
 22  111111111111111111111111111111111111121111111122211111222221
 23  111111111111111111111111111111111111121111121222222111122222
 24  111111111111111111111111111111111111221111112212222222112222
         5    1Ø    15    2Ø    25    3Ø    35    4Ø    45    5Ø    55    6Ø
NEW PAGE - YES OR NO ?NO
```

Figure 9 -- COMBINE Two Numeric Coverages (cont.)

```
COMMAND ?RECODE


NAME OF COVERAGE TO BE RECODED ?HAY
FILE TYPE NUMERIC
WHAT IS THE NEW FILE TYPE TO BE ?ALPHA
NAME OF THE FINAL FILE ?HAY1
OPENING FILE IN POSITION 7
HOW MANY NUMERIC RANGES TO BE RECODED ?2
SPECIFY THE UPPER LIMITS OF EACH RANGE, THEN THE
NEW SYMBOL OR VALUE FOR THE NEW FILE
LIMIT AND SYMBOL OF RANGE Ø  ?6.5,.
LIMIT AND SYMBOL OF RANGE 1  ?9,H
FILE CREATED

COMMAND ?DISPLAY


NAME OF FILE FOR DISPLAY ?HAY1
FILE TYPE ALPHA
ENTER ROW AND COLUMN FOR DISPLAY PAGE ?1,1

 1   ........................................H.H..........HHH...H
 2   ..........................................H....H..H...HH....
 3   .................................HH............HH.HHHH......
 4   ................................HHHHHHHHH......HH..H....HH..
 5   .................................HHHHHHHHH.HH..HH...........
 6   .................................HHHHHHH.H.HH.HHH...........
 7   .................................HHHHHHHHHHHHHHHH...........
 8   ...................................HHHHHHHHHHHH.............
 9   .......................................HHHHHHHHHH...........
 1Ø  ....................................H.......H....H..........
 11  ..................................HHHHH..H..HHHH.HH.........
 12  ..................................HHHHHHHHH...HH...H........
 13  ....................................HHHH.HH..HHHHH..HHHH...H
 14  ....................................HHHH......H.HHHHHHHHHHHH
 15  .....................................HHH..HH....HHHH.H.HHHHH
 16  .....................................HHHHHH......HHHH...HHHH
 17  .....................................HHH...HHH...HHHHHHHHHHH
 18  ......................................HHH..HHH.....HHHHHH.HH
 19  .............................HH............HHH.........HHHHH
 2Ø  .............................HH.......H.....HHHHH.....HHH...
 21  .....................................HH.......HHH.....HHH...
 22  .....................................H........HHH.....HHHHH.
 23  .....................................H.....H.HHHHHH....HHHHH
 24  ....................................HH.....HH.HHHHHHHH..HHHH
         5    1Ø   15   2Ø   25   3Ø   35   4Ø   45   5Ø   55   6Ø

NEW PAGE - YES OR NO ?NO
```

Figure 9 -- COMBINE Two Numeric Coverages (cont.)

```
COMMAND ?CONTIG

NAME OF COVERAGE FOR CONTIGUITY TABULATION ?HAY
FILE TYPE NUMERIC
ENTER MIN AND MAX VALUES TO DEFINE RANGE OF INTEREST
 ?6.5,9
ENTER MINIMUM AREA IN GEOGRAPHIC UNITS ?3.0
VALUE 6.7 AREA 3.25 ROW 1 COLUMN 73
VALUE 6.6 AREA 6 ROW 3 COLUMN 34
VALUE 7.6 AREA 3.75 ROW 2 COLUMN 105
VALUE 7 AREA 7.25 ROW 4 COLUMN 41
VALUE 6.8 AREA 5.75 ROW 2 COLUMN 91
VALUE 6.5 AREA 12.25 ROW 3 COLUMN 10
VALUE 7.5 AREA 17.75 ROW 8 COLUMN 76
VALUE 6.7 AREA 3.75 ROW 15 COLUMN 78
VALUE 7 AREA 5.75 ROW 12 COLUMN 39
VALUE 7.5 AREA 8.25 ROW 15 COLUMN 64
VALUE 6.7 AREA 5.25 ROW 20 COLUMN 89
VALUE 6.7 AREA 3.75 ROW 17 COLUMN 54
VALUE 7.1 AREA 4 ROW 17 COLUMN 118
VALUE 7.5 AREA 23.75 ROW 13 COLUMN 49
VALUE 7.6 AREA 11.5 ROW 14 COLUMN 114
VALUE 7 AREA 13.25 ROW 20 COLUMN 48
VALUE 6.5 AREA 22.75 ROW 16 COLUMN 23
VALUE 7 AREA 4.25 ROW 24 COLUMN 38
VALUE 7.5 AREA 3.75 ROW 26 COLUMN 70
VALUE 6.7 AREA 3.25 ROW 29 COLUMN 52
VALUE 6.8 AREA 4 ROW 29 COLUMN 115
VALUE 7 AREA 5.25 ROW 29 COLUMN 44
VALUE 7.5 AREA 11 ROW 27 COLUMN 58
VALUE 7.5 AREA 21.5 ROW 18 COLUMN 78
VALUE 7.5 AREA 5.75 ROW 32 COLUMN 76
VALUE 6.7 AREA 12.25 ROW 28 COLUMN 79
```

However, the problem was to find the contiguous areas of more than 1920 acres that would have an expected yield of more than 6,500 lbs. per acre. To obtain this tabulation, the function CONTIG is used. The range of interest will be defined as between 6.5 and 9 and the minimum area of interest as 640 acres or 1 square mile.

Problem 7: Determining the amount of class 2 agricultural land flooded in the spring flood of 1970

Since the two coverages in the system do not contain information on the area flooded in 1970, the outline of the flooded area is entered through the POLYGON command into the alphanumeric file FLOOD (see Figure 10). The flooded area is denoted by the symbol 'F' and the remaining study area is denoted as zeroes. The seven points needed to form the polygon are entered in clockwise order by row and column number. The user can now display FLOOD and crosstabulate it with AGRI.

The crosstabulation shows that of the 49 quarter sections flooded, 32 of them were class 2 while 17 were class 3.

Problem 8: Determining the amount of agricultural land affected by the construction of a divided highway

The planner is requested to determine the amount and characteristics of the land which would be taken out of agricultural production by the construction of a divided highway along a given route in the planning area. He is further asked to characterize the area which would be influenced by noise from the highway, given the assumption that the noise would have an effect within

Figure 1Ø -- CROSSTABulate a POLYGON Coverage

```
COMMAND ?POLYGON
POLYGON ROUTINE
WHAT IS THE NEW FILE TYPE TO BE ?ALPHA
NAME OF THE NEW FILE ?FLOOD
OPENING FILE IN POSITION 8
SYMBOL OR VALUE FOR THE POLYGON INTERIOR ?F
NOW ENTER THE NUMBER OF POINTS FOR THE OUTLINE ?7
ENTER THE COORDINATES OF EACH POINT IN CLOCKWISE ORDER
AS COLUMN NUMBER AND THEN ROW NUMBER
POINT 1
 ?5,1
POINT 2
 ?9,1
POINT 3
 ?1Ø,8
POINT 4
 ?12,12
POINT 5
 ?6,13
POINT 6
 ?6,5
POINT 7
 ?5,4
FILE COMPLETE

COMMAND ?CROSSTAB


NAME OF FIRST FILE IN CROSSTAB ?FLOOD
FILE TYPE ALPHA
NAME OF SECOND FILE ?AGRI
FILE TYPE ALPHA
CROSSTABULATION - FLOOD IN ROWSAGRI IN COLUMNS
      2     3     5     4     Ø     6
Ø      71Ø   579   1158  587   26Ø9  356  5999
F      32    17    Ø     Ø     Ø     Ø  49

       742   596   1158  587   26Ø9  356   6Ø48


CHISQUARE STATISTIC 182.668 WITH 5 DF
```

a specified distance (say one half mile) of the proposed route.

The user can resolve this problem by using function LINE to create a coverage HWY which contains the route of the new highway (see Figure 11). Next he runs function STRIPS to build a coverage ROAD in which all cells to be built over will be denoted by a chosen character. The actual width of the highway is assigned at this time. The rerunning of function STRIPS builds a second coverage NOISE for which the assigned width is one half mile. Execution of the function CROSSTAB on coverages ROAD and AGRI determines the agricultural characteristics of the land which will be built over, and on coverages NOISE and AGRI the area influenced by highway noise. Should the planner wish to map the ROAD and NOISE files he may do so by using the DISPLAY function.

Problem 9: Identifying a least-cost route for a pipeline where cost is defined as the cost of agricultural land that would be disturbed during construction

The user may resolve this problem by considering the agricultural capability of his area as a measure of cost. In this case, because the CLI rating scale is low where the capability is high, we must modify the AGRI file, creating a numeric file COST in which the entries represent the cost of disrupting each land type. Once this is done, function ROUTE is executed on file COST. The user specifies the origin and destination of the pipeline and the function defines the "cost" of the cheapest route joining the two points. The user has the option of creating a coverage containing the path defined.

It should be noted that the solution of any routing problem of this nature is an extremely time consuming task. This is especially so when one is working

Figure 11 -- Build LINES and STRIPS for DISPLAY

```
COMMAND ?LINES

LINE FILE CREATION ROUTINE
NAME OF THE NEW FILE ?HWY
OPENING FILE IN POSITION 9
INPUT POINTS AS CONTINUOUS STRINGS, FIRST ROW THEN
COLUMN NUMBER. TO END A STRING ENTER
999,Ø. TO END ALL STRINGS ENTER 888,Ø
STRING 1  POINT 1  ?1,12
STRING 1  POINT 2  ?16,15
STRING 1  POINT 3  ?26,45
STRING 1  POINT 4  ?18,7Ø
STRING 1  POINT 5  ?999,Ø
STRING 2  POINT 1  ?26,45
STRING 2  POINT 2  ?18,5Ø
STRING 2  POINT 3  ?3,44
STRING 2  POINT 4  ?888,Ø
FILE COMPLETE
TYPE YES TO ENTER STRIPS ROUTINE, ELSE NO ?YES
STRIP CREATION ROUTINE
WHAT IS THE NEW FILE TYPE TO BE ?ALPHA
NAME OF THE NEW FILE ?ROAD
OPENING FILE IN POSITION 1Ø
NAME OF THE LINES FILE ?HWY
FILE TYPE LINES
HOW WIDE IS THE STRIP ON EACH SIDE OF THE LINE ?.1
ENTER THE IDENTIFIER FOR THE STRIP ?R
FILE COMPLETE


COMMAND ?STRIPS

STRIP CREATION ROUTINE
WHAT IS THE NEW FILE TYPE TO BE ?ALPHA
NAME OF THE NEW FILE ?NOISE
OPENING FILE IN POSITION 11
NAME OF THE LINES FILE ?HWY
FILE TYPE LINES
HOW WIDE IS THE STRIP ON EACH SIDE OF THE LINE ?.5
ENTER THE IDENTIFIER FOR THE STRIP ?N
FILE COMPLETE
```

Figure 11 -- Build LINES and STRIPS for DISPLAY (CONT.)

```
COMMAND ?CROSSTAB

NAME OF FIRST FILE IN CROSSTAB ?AGRI
FILE TYPE ALPHA
NAME OF SECOND FILE ?ROAD
FILE TYPE ALPHA
CROSSTABULATION - AGRI IN ROWSROAD IN COLUMNS
      Ø     R
2      738   4                            742
3      576   2Ø                           596
5      1146  12                           1158
4      567   2Ø                           587
Ø      26Ø8  1                            26Ø9
6      356   Ø                            356

       5991  57    6Ø48

CHISQUARE STATISTIC 1Ø3.ØØ9 WITH 5 DF

COMMAND ?CROSSTAB
NAME OF FIRST FILE IN CROSSTAB ?AGRI
FILE TYPE ALPHA
NAME OF SECOND FILE ?NOISE
FILE TYPE ALPHA
CROSSTABULATION - AGRI IN ROWSNOISE IN COLUMNS
      Ø     N
2      728   14                           742
3      549   47                           596
5      1117  41                           1158
4      546   41                           587
Ø      26Ø7  2                            26Ø9
6      356   Ø                            356

       59Ø3  145   6Ø48

CHISQUARE STATISTIC 2Ø5.6 WITH 5 DF

COMMAND ?RECODE
NAME OF COVERAGE TO BE RECODED ?ROAD
FILE TYPE ALPHA
WHAT IS THE NEW FILE TYPE TO BE ?ALPHA
NAME OF THE FINAL FILE ?RROAD
OPENING FILE IN POSITION 12
NEW SYMBOL OR VALUE FOR Ø IS  ?.
NEW SYMBOL OR VALUE FOR R IS  ?R
FILE CREATED
```

Figure 11 -- Build LINES and STRIPS for DISPLAY (CONT.)

```
COMMAND ?DISPLAY

NAME OF FILE FOR DISPLAY ?RROAD
FILE TYPE ALPHA
ENTER ROW AND COLUMN FOR DISPLAY PAGE ?1,1

  1    ..........R.................................................
  2    ...........R................................................
  3    ...........R..............................R.................
  4    ...........R...............................R................
  5    ...........R...............................R................
  6    ...........R................................R...............
  7    ............R...............................R...............
  8    ............R...............................R...............
  9    ............R................................R..............
 10    ............R................................R..............
 11    ............R.................................R.............
 12    .............R................................R.............
 13    .............R................................R.............
 14    .............R.................................R............
 15    .............R.................................R............
 16    .............R..................................R...........
 17    ................R...............................R...........
 18    ...................R............................R...........
 19    ......................R.........................R...........
 20    .........................R.....................R............
 21    ............................R..................R...........R
 22    ...............................R..............R.........R...
 23    ..................................R..........R.......R......
 24    .....................................R.......R...R..........
           5   10   15   20   25   30   35   40   45   50   55   60

NEW PAGE - YES OR NO ?
```

Figure 11 -- Build LINES and STRIPS for DISPLAY (CONT.)

```
COMMAND ?RECODE


NAME OF COVERAGE TO BE RECODED ?NOISE
FILE TYPE ALPHA
WHAT IS THE NEW FILE TYPE TO BE ?AP
REPLY NUMERIC, ALPHA, LINES OR POINTS
WHAT IS THE NEW FILE TYPE TO BE ?ALPHA
NAME OF THE FINAL FILE ?RNOISE
OPENING FILE IN POSITION 13
NEW SYMBOL OR VALUE FOR 0 IS  ?.
NEW SYMBOL OR VALUE FOR N IS  ?N
FILE CREATED

COMMAND ?DISPLAY


NAME OF FILE FOR DISPLAY ?RNOISE
FILE TYPE ALPHA
ENTER ROW AND COLUMN FOR DISPLAY PAGE ?1,1

  1   ..........N.................................................
  2   ..........NN................................................
  3   ..........NN..............................N.................
  4   ...........NN.............................NN................
  5   ...........NN..............................NN...............
  6   ...........NN..............................NN...............
  7   ...........NN...............................NN..............
  8   ...........NN...............................NN..............
  9   ............NN..............................NN..............
 10   ............NN...............................NN.............
 11   ............NN...............................NN.............
 12   ............NN................................NN............
 13   ............NN................................NN............
 14   .............NN...............................NN............
 15   .............NN................................NN...........
 16   .............NN................................NN...........
 17   ...............NNNN.............................NN..........
 18   ..................NNNN..........................N...........
 19   .....................NNNN......................NN...........
 20   ........................NNNN...................NN...........
 21   ...........................NNNN...............NN.........NNN
 22   ..............................NNNN...........NN.......NNNN..
 23   .................................NNNN........NN....NNNN.....
 24   ....................................NNNN....NN..NNNN........
          5    10   15   20   25   30   35   40   45   50   55   60

NEW PAGE - YES OR NO ?NO
```

with large matrices. At present ROUTE will not attempt to find paths when the number of grid cells is greater than 3,500. If it is necessary to exceed this limit the program must be modified. Accordingly, the accompanying illustration, Figure 12, is based on 1,800 cells (the western one-third of the study area).

The approach taken in tackling this problem is deserving of comment. The first step was to run POLYGON to create a corridor defining the outer limits of the route the pipeline could be allowed to take. This greatly limited the number of routes the computer had to consider. The corridor was subsequently DISPLAYed for visual checking. Function OVERLAY was then employed to build the COST coverage. Cells within the corridor were assigned a value based on their agricultural capability ($300 for Class 2 and $200, $100 and $75 for Classes 3, 4 and 5 respectively), while those outside the corridor were assigned a high arbitrary value ($99,999) to confine the route search to the corridor cells. The minimum cost path was then identified by ROUTE and a coverage identifying the path was created and DISPLAYed.

The method of determining the COST surface for this example was very simple and direct. In the real world the impact of a route on the land would be much harder to specify. Many different factors would have to be considered. This is not the place to enter into a discussion of which factors should be taken into consideration, or how they should be combined to yield a surface analagous to our COST coverage. Suffice it to say that once such a coverage has been prepared, ROUTE can be used to define minimum paths within it.

Figure 12 -- DISPLAY of a ROUTE Within a POLYGON

```
COMMAND ?POLYGON

POLYGON ROUTINE
WHAT IS THE NEW FILE TYPE TO BE ?ALPHA
NAME OF THE NEW FILE ?BOUNDS
OPENING FILE IN POSITION 8
SYMBOL OR VALUE FOR THE POLYGON INTERIOR ?.
NOW ENTER THE NUMBER OF POINTS FOR THE OUTLINE ?4
ENTER THE COORDINATES OF EACH POINT IN CLOCKWISE ORDER
AS COLUMN NUMBER AND THEN ROW NUMBER
POINT 1
 ?5,1
POINT 2
 ?20,1
POINT 3
 ?50,20
POINT 4
 ?50,36
FILE COMPLETE
```

Figure 12 -- DISPLAY of a ROUTE Within a POLYGON (cont.)

```
COMMAND ?DISPLAY

NAME OF FILE FOR DISPLAY ?BOUNDS
FILE TYPE ALPHA

  1     00000...............000000000000000000000000000000
  2     000000...............00000000000000000000000000000
  3     0000000................000000000000000000000000000
  4     00000000................00000000000000000000000000
  5     0000000000................000000000000000000000000
  6     00000000000................00000000000000000000000
  7     000000000000.................000000000000000000000
  8     00000000000000.................0000000000000000000
  9     000000000000000.................000000000000000000
 10     0000000000000000..................0000000000000000
 11     00000000000000000..................000000000000000
 12     0000000000000000000..................0000000000000
 13     00000000000000000000..................000000000000
 14     000000000000000000000...................0000000000
 15     00000000000000000000000...................00000000
 16     000000000000000000000000...................0000000
 17     0000000000000000000000000....................00000
 18     00000000000000000000000000....................0000
 19     0000000000000000000000000000....................00
 20     00000000000000000000000000000.....................
 21     000000000000000000000000000000....................
 22     00000000000000000000000000000000..................
 23     000000000000000000000000000000000.................
 24     0000000000000000000000000000000000................
 25     00000000000000000000000000000000000...............
 26     0000000000000000000000000000000000000.............
 27     00000000000000000000000000000000000000............
 28     000000000000000000000000000000000000000...........
 29     00000000000000000000000000000000000000000.........
 30     000000000000000000000000000000000000000000........
 31     0000000000000000000000000000000000000000000.......
 32     00000000000000000000000000000000000000000000......
 33     0000000000000000000000000000000000000000000000....
 34     00000000000000000000000000000000000000000000000...
 35     000000000000000000000000000000000000000000000000..
 36     00000000000000000000000000000000000000000000000000
            5   10   15   20   25   30   35   40   45   50
```

Figure 12 -- DISPLAY of a ROUTE Within a POLYGON (cont.)

```
COMMAND ?OVERLAY


NAME OF FIRST OVERLAY FILE ?AGRI
FILE TYPE ALPHA
NAME OF SECOND OVERLAY ?BOUNDS
FILE TYPE ALPHA
WHAT IS THE NEW FILE TYPE TO BE ?NUMERIC
NAME OF THE FINAL FILE ?COST
OPENING FILE IN POSITION 9
SYMBOL OR VALUE FOR 2 WITH Ø ?99999
SYMBOL OR VALUE FOR 3 WITH Ø ?99999
SYMBOL OR VALUE FOR 3 WITH . ?200
SYMBOL OR VALUE FOR 2 WITH . ?300
SYMBOL OR VALUE FOR 5 WITH Ø ?99999
SYMBOL OR VALUE FOR 4 WITH Ø ?99999
SYMBOL OR VALUE FOR Ø WITH Ø ?99999
SYMBOL OR VALUE FOR 4 WITH . ?100
SYMBOL OR VALUE FOR 5 WITH . ?75
FILE CREATED


COMMAND ?ROUTE


ROUTING PROBLEM - SHORTEST PATH ROUTINE
INPUT NUMERIC FILE NAME FOR COST SURFACE ?COST
FILE TYPE NUMERIC
INPUT ORIGIN AS ROW AND COLUMN ?27,50
INPUT DESTINATION ROW AND COLUMN ?1,13
 1Ø94
 1136
 48Ø
 322
ROUTE COMPLETE, COST  771Ø.15
WANT A COVERAGE SHOWING ROUTE ?  YES
  NAME OF THE NEW FILE ?CHEAP
  OPENING FILE IN POSITION 11
  WHAT SYMBOL SHOULD BE GIVEN TO THE ROUTE ?.
  FILE COMPLETE

  ANOTHER ROUTE PROBLEM ?NO
```

Figure 12 -- DISPLAY of a ROUTE Within a POLYGON (cont.)

```
COMMAND ?DISPLAY
NAME OF FILE FOR DISPLAY ?CHEAP
FILE TYPE

 1    000000000000.0000000000000000000000000000000000000
 2    0000000000000.000000000000000000000000000000000000
 3    00000000000000.00000000000000000000000000000000000
 4    000000000000000.0000000000000000000000000000000000
 5    0000000000000000.000000000000000000000000000000000
 6    00000000000000000.00000000000000000000000000000000
 7    000000000000000000..000000000000000000000000000000
 8    00000000000000000000.00000000000000000000000000000
 9    000000000000000000000.......0000000000000000000000
10    0000000000000000000000000000..00000000000000000000
11    000000000000000000000000000000.....000000000000000
12    0000000000000000000000000000000000.000000000000000
13    000000000000000000000000000000000000..000000000000
14    00000000000000000000000000000000000000.00000000000
15    000000000000000000000000000000000000000.0000000000
16    0000000000000000000000000000000000000000.000000000
17    00000000000000000000000000000000000000000.00000000
18    000000000000000000000000000000000000000000.0000000
19    0000000000000000000000000000000000000000000.000000
20    00000000000000000000000000000000000000000000.00000
21    00000000000000000000000000000000000000000000.00000
22    000000000000000000000000000000000000000000000.0000
23    000000000000000000000000000000000000000000000.0000
24    0000000000000000000000000000000000000000000000.000
25    00000000000000000000000000000000000000000000000.00
26    000000000000000000000000000000000000000000000000.0
27    0000000000000000000000000000000000000000000000000.
28    00000000000000000000000000000000000000000000000000
29    00000000000000000000000000000000000000000000000000
30    00000000000000000000000000000000000000000000000000
31    00000000000000000000000000000000000000000000000000
32    00000000000000000000000000000000000000000000000000
33    00000000000000000000000000000000000000000000000000
34    00000000000000000000000000000000000000000000000000
35    00000000000000000000000000000000000000000000000000
36    00000000000000000000000000000000000000000000000000
          5    10   15   20   25   30   35   40   45   50
```

SUMMARY

In the four years since PLUS was first envisaged it has become evident that the objectives of the system have been met. Several agencies have used PLUS successfully, and a number of modifications to the system have been suggested and incorporated.

A computer system like PLUS is never completely finished. There are always additions and enhancements which can be made. This should not alarm the general user as these changes are made by a programmer. All the user must do is suggest enhancements he feels would improve the programs.

The chief problem with PLUS, as with all automated data handling systems, is that of data input. Although PLUS has successfully handled data transferred from other geographic information systems, the input of data from maps is still cumbersome. The problem is presently being attacked by a number of different groups, and it appears reasonable to expect that a relatively fast and economical data input and editing procedure will shortly be available.

Notwithstanding the problem of data entry, those who have been involved with the system are of the opinion that it provides a very attractive alternative to many of the relatively inexact manual processes now utilized by land use planners.