THE GCARS SYSTEM FORTRAN IV USERS MANUAL

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BY

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JHRP

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Final Report (Part II)
THE GCARS SYSTEM FORTRAN IV USERS MANUAL

by
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Final Report (Part II)

THE GCARS SYSTEM FORTRAN IV USERS MANUAL

TO: J. F. McLaughlin, Director
Joint Highway Research Project

September 1969

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

File: 1-6-1

Project: C-36-72A

Attached is Part II of the Final Report on the research project "Evaluation of Numerical Surface Techniques Applied to Highway Location Analysis" which was approved on July 1, 1967. This report has been authored by Dr. A. Keith Turner under the direction of Professor Robert D. Miles.

This report describes the overall arrangement of the twenty-eight FORTRAN IV computer routines which make up the GCARS System. The report also outlines in some detail the GCARS standards for program language and documentation, the formats of identification cards, data storage arrays, and data storage tapes. Necessary modifications to certain routines are described so that the GCARS System can be implemented at other computer installations.

This report is one of a series of four reports documenting the GCARS System. It is presented to the Board for review and comment and for the record.

Respectfully submitted,

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Professor Robert D. Miles, P. E., directed the research project and reviewed the manuscript. His assistance is gratefully acknowledged.

THE GCARS SYSTEM
FORTRAN IV USERS MANUAL

BY

A. Keith Turner

INTRODUCTION

The GCARS System is a computer-aided highway location system. Man-machine communications are required between the engineer and the computer during all phases of the procedure if the system is to operate efficiently.

a) The Purpose of the GCARS System

The Generalized Computer - Aided Route Selection (GCARS) System has been developed to assist engineers in defining and ranking a series of regional highway location alternatives (3)*. These alternatives may be defined in terms of one or more highway location factors. The GCARS System programs develop and store within the computer a series of "utility surfaces", one for each factor believed pertinent by the engineer. These surfaces, alone or in combination, are then repetitively analyzed to produce a series of ranked "optimal" locations. Conflicts among factors can be studied by progressively varying the importances of the factors being studied.

Any form of ground transportation system can be studied by judicious selection of pertinent factors to reflect the mode and level of service desired. The GCARS System techniques can be utilized equally well for regional studies in developing regions and for more detailed studies in sub-urban areas, provided the data collected represent the location factors with sufficient detail.

* Numbers in parenthesis refer to references.

b) The Purpose of Users Manual

The GCARS System was tested during development using data from two Indiana test areas (3, 7). These studies indicate that the GCARS System is of significant assistance to the engineer responsible for defining and evaluating alternative highway corridors. The author and the members of the Joint Highway Research Project recognize that further field testing of the GCARS System is necessary before valid conclusions may be reached concerning its merits and application in full-scale location studies. A number of such studies are currently under way. Further studies are greatly encouraged. This manual, and the associated three-part Programmers Manual, (4, 5, 6) have been prepared to assist other interested agencies, researchers, and engineers in modifying the GCARS System programs to suit their needs and their computer installations.

This Users Manual briefly describes the overall GCARS System organization. It outlines in some detail the GCARS Standards for program language and documentation, the formats of the identification cards, data storage arrays, and data storage tapes.

c) The CDC 6500 Computer

The original GCARS System was programmed to run on the Control Data Corporation 6500 computer installed at Purdue University. The programs are currently being modified by the author so as to run on an International Business Machines 360/65 computer installed at the University of Toronto.

A CDC 6500 System contains twelve separate computers. Ten of these are designed to handle peripheral and operating systems and are therefore called Peripheral Processors (PP's). The CDC 6500 also contains two Central Processors (CP's). These independent computers utilize a common Central Memory. In addition each Peripheral Processor has a separate small memory of its own.

Although it is the main component from the users point of view, the CP is completely under the control of every PP at all times. One of the PP's is in permanent supreme control of the system; it contains the monitor program. Another permanently deals with the operator's console. The remaining PP's, the dual CP's, and the Central Memory are at the disposal of a user.

The characteristics of the CDC 6500 of particular concern to a FORTRAN IV programmer are as follows:-

- 1 - The Central Memory contains 60-bit words.
- 2 - The maximum amount of Central Memory storage available is 131,072 words (octal).
- 3 - All arithmetic operations involve 60-bit words.
- 4 - Storage tapes are seven (7) track, and may be written at 200, 556, or 800 bpi densities.
- 5 - FORTRAN IV statements must be punched on cards using binary coded decimal (BCD) codings.

The long (60-bit) word length on the CDC 6500 makes double precision arithmetic operations generally unnecessary. A maximum of ten alphanumeric characters can be stored in a single word, thus (A10) field designations are possible.

The CDC 6500 FORTRAN IV language does include a few non-standard statements. These are reviewed in the GCARS System III Standards section of this manual.

ORGANIZATION OF THE GCARS SYSTEM

Figure 1 shows a flowchart of the operations contained within the GCARS System. Three distinct classes of operations, or "activities" can be defined. The data preparation activity concerns the conversion of mapped data into machine usable numeric data. The search activity converts these data into utility models, checks the models for accuracy and lack of bias, and then generates a series of alternatives by analyzing the models alone or in combinations. The selection activity is concerned with the engineers input of evaluation of the analysis.

The GCARS System is a computer-aided system; both the man and the machine have definite roles to play in the process. Considerable effort has been expended in making the man-to-machine and machine-to-man information exchanges, or "dialogs", as efficient and convenient as possible.

Twenty-eight distinct FORTRAN IV routines have been developed to form the GCARS System. There are eight main programs and twenty associated subroutines. Some of these routines perform specific objectives within the data preparation and search activities. The remaining routines produce contour maps of three dimensional data, either on the printer or on the off-line plotter. Such graphical techniques are extremely useful aids during machine-to-man dialogs.

The routines and their uses are listed in Table 1. The Programmers Manuals describe these programs in detail (4, 5, 6). The Manuals have been sub-divided into three parts, reflecting a natural sub-division of the GCARS routines, as follows:-

FIGURE 1. FLOWCHART FOR THE GCARS SYSTEM

TABLE 1
LIST OF GCARS SYSTEM PROGRAMS

	NAME		PURPOSE
	MAIN PROGRAM	SUBROUTINE	
PART A	VECTOR	TILTS WULFF HISTO	Computes terrain roughness and variability measures. Computes stripes and dips from Vector cosines. Produces Wulff stereonet plots of vectors. Prepares histograms of strikes and/or dips. (STATS also used - described in Part C.)
	LOADS		Loads irregularly-spaced data from cards to tape according to TAPE2 format standards.
	LOADG		Loads gridded data arrays from cards to tape according to TAPE3 format standards.
	TREND	IREAD RITER ANOVA INVER POLY	Computes trend surface equations according to Least Squares criteria. Input routine. Output routine. Computes analysis of variance statistics and prints them. Inverts matrices. Evaluates computed trend equations at specified coordinate locations. (PRTCON4 and STATS also used to produce contour maps of trend surfaces - described in Part C.)
	RESMAP		Prepares data to produce contour maps or residuals (with PRTCON4 and STATS.)
PART B	NETSUM	PRTOUT MPATH PATH	Input and control program for generation of alternatives. Output routine. Calculates minimum paths. Prepares and prints maps of paths. (PRTCON4 and STATS also may be used - see below.)
PART C	MAPPER	GRID STATS PRTCON4 HYPSO	Input and control program for printer contour maps. Interpolates irregularly spaced to gridded data sets. Computes mean, range, average, etc. of data arrays. Produces contour maps of gridded data on printer. Performs hypsometric analysis.
	CONTUR	SCAN TRACE CALC DRAFT PROJ	Input and control program for Calcomp contour maps. Scans data and locates the contours. Traces each contour line in turn. Interpolates within data matrix squares to locate contour lines. Performs optional rotations and translations of axes and prepares plot tape for plotter. Routine to allow additional future options.

Part A - Programs for Data Collection and Evaluation

Part B - Programs for Generation of Alternatives

Part C - Programs for Contour Mapping

The main programs and subroutines form an interconnected system, the GCARS System. The inherent flexibilities of GCARS allow the engineer to select those programs and a sequence of operations suitable for his analysis. Figures 2, 3, and 4 show some of the typical interconnections between the programs described in Parts A, B, and C of the Programmers Manual (4, 5, 6). The reader should note that the contouring routines and the subroutine STATS described in Part C are utilized at several stages within the GCARS System.

THE GCARS SYSTEM STANDARDS

a) Programming Language Standards

The GCARS System has been programmed in the version of FORTRAN IV supplied by Control Data Corporation for their 6000 Series computers. Program CONTUR and its associated subroutines utilize some Calcomp library routines implemented by the Purdue University Computer Sciences Center. The calling arguments for one of these routines has been modified from the standard Calcomp library procedures. Specific machine-dependent features are discussed in the section on Modifications. The following is a summary of the basic CDC-FORTRAN IV standards:-

- 1 - Variables may contain up to seven alphanumeric characters. Those starting with the letters I, J, K, L, M, or N will be interpreted as being integer variables unless declared otherwise.

FIGURE 2. INTER-RELATIONSHIPS AMONG THE GCARS SYSTEM DATA COLLECTION PROGRAMS DESCRIBED IN PROGRAMMERS MANUAL PART A

FIGURE 3. GCARS SYSTEM PROGRAMS FOR GENERATION OF ALTERNATIVES DESCRIBED IN PROGRAMMERS MANUAL PART B

FIGURE 4. GCARS CONTOURING PROGRAMS DESCRIBED IN PROGRAMMERS MANUAL PART C

2 - Arithmetic Expressions. Mixing of integer and real variables (mixed mode) is not permitted.

3 - Logical Expressions. The relational and/or logical operators (.LT. , .LE., .EQ., .GE., .GT., .AND., .OR., .NOT.) must be used.

4 - DATA Statements

i) The DO-implying form is permitted. For example:

DATA (A(I), I = 1,4)/ 5.0, 4.0, 3.0, 2.5/

is possible.

ii) The maximum number of alphanumeric characters per word is ten. For example:

DATA NAME/10H*IRREGULAR/

is permissible.

5 - COMMON Statements. Either blank (unlabelled) or labelled COMMON may be used. Labelled COMMON must be used if constants are to be initialized.

6 - Transfer of Control Statements.

i) Unconditional GO TO statements have the form

GO TO n

where n is a statement number.

ii) Computed GO TO statements have the form

GO TO (n₁, n₂, n₃, n₄,, n_n), I

where n₁, n₂,, n_n are statement numbers and I is an integer variable.

iii) Arithmetic IF statements have the form

IF (arithmetic expression) n₁, n₂, n₃,

where control is transferred to statements n₁, n₂, or n₃ respectively if the expression is less than zero, zero, or greater than zero.

iv) Logical IF statements have the form

IF (LE) ES

where LE is a logical expression and ES is an executable statement which is executed only if LE is true.

v) Special Logical IF statements have the form

IF (EOF, SYSIN) n_1 , n_2

where (EOF, SYSIN) is a logical expression meaning

"is an end of file (written EOF) read on SYSIN?".

SYSIN is a defined input (read) file.

n_1 and n_2 are statement numbers.

If the logical expression in the parentheses is true, control transfers to n_1 , otherwise control transfers to n_2 . Thus control is transferred to n_1 whenever an end of file is read.

7 - DO Statements have the form

DO nn I = J, K, L or

DO nn I = J, K

where nn is statement terminating the DO-Loop.

I is control parameter

J is the initial value of I

K is the final value of I

L is the increment increase of I

if L is omitted, it is assumed to equal one

8 - CALL Statements have the form

CALL FLNAM (x_1 , x_2 ,, x_n)

where FLNAM is the valid name of a library function or user supplied subroutine (of 1-7 alphanumeric characters)

x_1 , x_2 ,, x_n are arguments. They cannot be logical expressions or statement numbers.

9 - PROGRAM Statement the first statement of a main program must have the form

PROGRAM PRGNAM (In, Out, Pn, T₁, T₂,, T_n, A,B)

where PRGNAM is a valid program name of 1-7 alphanumeric characters.

In is the word INPUT, used to signify data will be read from files.

Out is the word OUTPUT, used to signify data will be read to files.

Pn is the word PUNCH, used to signify data will be punched onto cards.

T₁,, T_n are the words TAPE_n where n = 1, 2, etc. These indicate which system data files are needed.

A is the statement TAPE5 = INPUT indicating input will come from the card reader.

B is the statement TAPE6 = OUTPUT, indicating output is to be sent to the printer.

10 - SUBROUTINE Statement. The first statement of a subroutine must have the form:-

SUBROUTINE FLNAM (x₁, x₂,, x_n)

where FLNAM is a valid subroutine name of 1-7 alphanumeric characters as in the CALL statement, and x₁, x₂,, x_n are the arguments, which must correspond in number and type to those of the CALL Statement.

11 - INPUT/OUTPUT Statements. The following forms are valid:

- i) READ (i,n) list
- ii) WRITE (i,n) list
- iii) READ (i) list
- iv) WRITE (i) list
- v) PUNCH n, list

In each case "i" is an integer variable corresponding to the desired input or output medium, logical unit, or data set file reference

number, "n" is a FORMAT statement reference number and "list" is a list of variable names whose values are to be listed, where "list" may be omitted when writing headings.

The reader should note that the first two forms are used when formatted data are being transmitted, while the third and fourth cases are used when binary data (internal machine coded) are being transmitted. The PUNCH statement punches the variables in the list onto cards according to the format "n". This is generally compatible with FORTRAN languages on other computers.

For ease in converting the GCARS programs from one installation to another the "i" parameters are integer variables whose values are given in DATA statements. The following variables names have been used in the GCARS System:-

SYSIN - Input from the card reader (value = 5)

SYSOT - Output to the printer (value = 6)

SDF1 - "TAPE1" is any temporary "scratch" tape

SDF2 - "TAPE2" is any tape containing irregularly spaced observations.

SDF3 - "TAPE3" is any tape containing gridded data matrices

SDF4 - "TAPE4" is a tape containing original values, computed values, and residuals for a series of observations. It may be generated on request by Program TREND (4).

These tapes have specific standard formats which are described in detail under "Tape Standards".

12 - FORMAT Statements. The GCARS System uses the F, I, E, X, H, and A format codes. The maximum number of alphanumeric characters per word in an A code is ten. In all other respects the use of FORMAT statements follows universal FORTRAN IV procedures.

The GCARS System uses a number of other FORTRAN IV statements including type declaration (INTEGER, REAL) statements, CONTINUE, RETURN, STOP and END statements, REWIND i statements (for rewinding data tape i), and DIMENSION statements. None of these depart from universal FORTRAN IV procedures.

b) Program Documentation Standards

In the past much duplication of programming effort has occurred because little or no effort was made to communicate information concerning accomplished programming procedures. Documentation is required to communicate pertinent information concerning programs to interested parties, and to provide the basis for understanding, modifying, and using the programs and the program results.

With this purpose in mind, a standard form of program documentation was developed for the GCARS System. The author wishes to acknowledge the assistance given by the research engineers of the Bureau of Public Roads Total Integrated Engineering System (TIES) in developing these programming standards (1). Table 2 gives a list of section titles as they appear in any one of the three-parts of the Programmers Manual (4, 5, 6). It should be noted that not all of these headings may be required for any one program or subroutine.

To assist persons desiring to modify certain GCARS routines, flow-charts showing the interactions among the routines are included in the Method of Operation Section of each Manual and flowcharts of the important computational routines (see below) are also included in the Method of Computation Section.

TABLE 2

GCARS SYSTEM DOCUMENTATION STANDARDS
TYPICAL SECTION TITLES

Title Page

Table of Contents

List of Figures

Acknowledgments

Introduction

Method of Operation

Present Capacities, Options, Restrictions

Future Modifications

Method of Computation

Program Operating Characteristics

Program Listing and Documentation

References

To further assist the person wishing to implement the GCARS System on a different computer configuration, the overall system operations have been assigned to a number of program segments, each having a specific function. Certain program segments are concerned with the actual mathematical calculations required; these are called computational routines. Other program segments are concerned with the reading in of data and control cards specifying the options desired, with the printing out of answers, or with the transferring of data from one medium to another (cards-to-tape for example). These routines are called data-handling routines. Since data-handling procedures are generally much more computer-dependent than computational procedures, the grouping of such functions into INPUT and/or OUTPUT routines will facilitate modifications to the GCARS System. The reader will find that most computational routines contain no READ, WRITE or FORMAT statements.

The detailed listing of a FORTRAN IV routine includes many COMMENT card headings identifying the purpose of the sections of the program that follow. In addition each routine contains, on COMMENT cards, detailed instructions concerning its purpose, use, needed control cards, and required or optional subroutines.

In those routines where control cards are read and options selected, a detailed explanation of each card, field by field, is given. All such information is included as COMMENT cards when a source program is ordered from the Joint Highway Research Project at Purdue University.

For each program set consisting of one main program and associated subroutines, the Programmers Manual, in general, contains a diagram showing a typical card-deck setup. There is also a set of test data and an

example of the output obtained by analyzing these data immediately following the detailed listings of the necessary routines. The test data is included when a source program is ordered from Purdue University.

The FORTRAN IV programs were prepared for publication by first re-sequencing all statement numbers, removing extraneous numbers, and placing card sequence numbers in columns 73-80 of each card. This was accomplished through the use of a library program (TIDY) available at Purdue University. For this reason the statement numbers in each routine increase progressively in increments of five, all FORMATS (if any) appear at the end, and the card sequence numbers increase in increments of two.

It did not appear feasible to identify the purpose of all variables in the GCARS routines. However, another library routine (FORSTAT) was available at Purdue University which checked the syntax of FORTRAN programs and produced cross-reference listings of all variables and statement numbers found within the routines. These cross-reference listings allow the person modifying the program to find where a variable is defined, where it is used, and its type (REAL, INTEGER, etc.) The FORSTAT cross-reference listings are included in the Programmers Manual following each routine (4, 5, 6).

c) Identification Card Standards

The GCARS System uses identification cards ("Title cards") to identify data sets. Whenever a set of data is punched by the machine, an identification card (or cards) precede the actual data. There are two kinds of data utilized by the GCARS System, irregularly spaced observations and gridded observations. Irregularly spaced observations are located in terms of X and Y co-ordinates giving their geographical locations, and a Z co-ordinate

value which represents the "cost" or "benefit" of the factor being measured at that location. Gridded observations form an array, or matrix, of Z coordinates; their position in the array represents their geographical locations. Both types of data use the same basic form of identification card.

The basic identification card used in the GCARS System has the following five fields:-

- 1 - FACTOR, which identifies the factor being studied. In general the first 40 columns (1-40 alphanumeric characters) are assigned to this field. Exceptions to this rule are discussed below.
- 2 - AREA, which identifies the test area being studied. Columns 41-70 are assigned to this field.
- 3 - NCOL, which specifies the number of columns in the gridded data array. This information is assigned to columns 71-73. It is not used with irregularly spaced data.
- 4 - NROW, which specifies the number of rows in the gridded data array. This information is assigned to columns 74-76. It is not used with irregularly spaced data.
- 5 - ITYPE, which specifies the type of data being studied. Columns 77-78 are assigned to this field.

Figure 5 shows a typical GCARS identification card. Such cards are given different names in the documentation of the GCARS routines. "Title Cards", "Subtitle Cards", and "Header Cards" are terms used for this type of card.

Certain routines read such a card as a single field called TITL or TITLE (for example Program VECTOR). No problem should arise however, since the sequence of FACTOR-AREA is a natural one.

Those routines utilizing irregular data prior to the regression analysis performed by Program TREND allow only 30, rather than 40 alphanumeric characters for the FACTOR identification. This restriction occurs because Program TREND, when producing punched gridded data sets for each surface, will insert the expression DEGREE n in columns 31 - 40, where "n" will be 1, 2, 3, 4, or 5. Allowing for a leading and a trailing blank this expression is ten characters long.

If the PUNCH option is requested from Program NETSUM, a printed matrix of the combined utility surface is produced (5). This is identified by a Series of N cards having the form

NUMBER n OF N FACTORS, WEIGHT = x.xx, "FACTOR"

where N is the number of factors being combined

n takes on the values 1, 2, N

x.xx is the weighting factor

and "FACTOR" is the FACTOR field of that factor.

These are followed by a standard identification card containing the words "COMBINED UTILITY SURFACE." and the NCOL, NROW, and ITYPE fields. This is the only case of multiple identification cards being produced. For further information see Part B of the Programmers Manual (5).

d) Data Array Standards

The present maximum dimensioned size is a 50 x 50 array. Neither dimension can be exceeded without modifying the DIMENSION statements in the various programs. Changes in shape, for instance to 100 x 25, can be accomplished without increasing the overall storage requirements of the programs. An overall increase in array size will cause the redimensioning of many variables in the generation of alternatives routines (Program NETSUM and associated routines). The capacity of the CDC 6500 was almost

reached with the 50 x 50 arrays during this stage in the GCARS analysis. However larger arrays, up to 100 x 100, have been successfully used by most other portions of the GCARS System.

NOTE: 1) The arrays are dimensioned

ARRAY (NROW, NCOL)

where ARRAY = the array name (Z or ZZ)

NROW = number of rows (height of array)

NCOL = number of columns (width of array).

- 2) The arrays are read in row-wise, from the top down and from left to right across the rows, just as one reads a page in a book. Any other sequence of reading in gridded data will jumble the array and produce unpredictable, but definitely wrong, results.

e) Tape Standards

The GCARS System data tapes are of two main types - those containing irregularly spaced observations (TAPE2) and those containing gridded values (TAPE3). A third type (TAPE4) may be produced by Program TREND but is not normally used or requested. All tapes are written in relocatable binary at 556 bpi.

1 - TAPE 2 Tapes

These tapes contain one lead record giving identification information. The parameters are "FACTOR" (30 characters), "AREA" (30 characters), and ITYPE. Following is a series of logical records each containing 1000 sets of observations. Each observation set contains three words, X co-ordinate, Y co-ordinate, and Z value; thus the records are 3000 words long. Since the total number of observations

is unlikely to be an exact multiple of 1000, the last record contains any remainder and is therefore of variable length. An end of file mark is placed at the end of the data. Program LOADS, described in Part A of the Programmers Manual will prepare such a tape (4).

2 - TAPE3 Tapes

These tapes contain gridded data arrays. Each array will appear as a series of binary records. The first record contains identification information arranged in the fields "FACTOR" (40 characters), "AREA" (30 character), "NCOL" (one word integer), "NROW" (one word integer), and "ITYPE" (one word integer). Each row is stored row-wise (left to right) from the top downwards.

A single array, or a group of arrays, may be separated from other arrays and form a single binary file. Such binary files can form the data sets of factor combinations to be studied by Program NETSUM (5).

Program LOADG described in Part A of the Programmers Manual, can load data onto tapes according to TAPE3 standards (4).

3 - Other Tapes

The TAPE4 tape format is described in the documentation for sub-routine IREAD (4, page 59) and will not be discussed. Temporary "Scratch" tapes (TAPE1) are never used to transfer data from one routine to another; therefore, their formats are not required by most programmers.

NECESSARY MODIFICATIONS

Due to certain unique characteristics of the CDC 6500 computer, and of its version of the FORTRAN IV language, some program modifications are necessary before the GCARS System can be implemented on other computer installations.

The following is a brief discussion of those modifications which have come to the author's attention during conversion of several of these routines so that they run on an IBM 360/65. The list is probably not exhaustive. However, it should be of assistance to those persons attempting conversion.

a) Modifications Required on Shorter Word Computers

The CDC 6500 has a 60-bit word in both the Central Memory and in its arithmetic registers. The GCARS System programs take advantage of this feature. As a consequence, certain changes are necessary for program modifications and use on other computers.

1 - "A" Field Designations in FORMAT Statements

Many formats utilize (A10) field designations during Input or Output operations. These will have to be changed to (A4) or (A6) designations depending on the computer used.

2 - Single to Double Precision

Due to the long word length, single precision arithmetic is quite accurate on the CDC 6500.

The only routines where the loss in precision has to be taken into account are the matrix inversion calculations in Program TREND and its associated routines (4). Specifically, the following variables need to be declared double precision:

PAR, XX, A, B, BB, XINV, SSZ, SSQZ, SSR

Also BBB in Subroutine RITER

and AM in subroutine INVER.

The author believes the other routines will not be unduly affected, but advises caution initially and a careful comparison of results of analyses of test data with the published results.

3 - Redimensioning of Variables

The changes indicated in the above two sections will automatically cause changes to be made in the dimensions of variables.

Where changes in field designation are required, the same number of characters should be retained.

For example:

DIMENSION AREA (3)

when AREA is used with

FORMAT (3A10)

will become

DIMENSION AREA (8)

when the new format is

FORMAT (7A4, A2)

Such changes, and the changes caused by conversion of variables from single to double precision will cause changes in some COMMON statements and the dimensions of DUMMY VARIABLES used to skip portions of COMMON arrays. The author can only advise extreme care in these areas.

b) Modifications to DATA Statements

1 - Implied DO-Loops

Many computers, including the IBM 360 series, do not allow implied DO-Loops in DATA statements. This is a comparatively simple modification.

2 - Conversion of Long Hollerith Fields

Many DATA Statements involve long Hollerith assignments since up to (10H) is permitted. For example:

DATA NAME/10H*IRREGULAR

such fields must be reduced to either (4H) or (6H) maximum provided the variable is not redimensioned, since the maximum number of characters per word is only 4 or 6.

c) Specialized CDC "LOGICAL IF" Statements

The GCARS programs normally return to the beginning of the program once an analysis is finished so as to perform another analysis. Ultimately a new set of data and/or control cards is required and a READ statement will therefore be executed. At this point it is possible to test for the end of all data by checking to see if an end-of-file, rather than a data or control card, has been read. This is accomplished in CDC FORTRAN in the following way:-

```
      READ (SYSIN, n) list
      IF (EOF, SYSIN) k, 1,
k STOP
      1 next executable statement
```

The same test can be performed on IBM System 360 computers in the following way:-

```
      READ (SYSIN, n, END = k) list
      next executable statement
      ...
      ...
      ...
      Last executable statement in program
k STOP
```

d) Program VECTOR Correction (Manual A, Page A-33)

The following cards must be inserted in subroutine TILTS:

Card #73

IF (AC. EQ. O.) GO TO 10

Card #77

GO TO 15

77

Card #77A

10 STRIKE = 0.0

77A

Card #78A (To replace existing #78)

15 DIP = ANGG*57.2957

78A

PROGRAM ORDERING PROCEDURES

The research developed what has been named the GCARS System. Briefly this system is designed to use numerical analysis procedures in conjunction with minimum path procedures to analyze alternative regional highway locations. Suitable measures of each highway location factor are processed by the system to produce value surfaces which are converted to utility surfaces. Utility surfaces are then combined in various proportions to produce multiple factor utility surfaces on which utility networks are then constructed. Repeated minimum path analyses of these networks generates a series of alternative locations between any origin and destination, in terms of selected or combined factors. Evaluation of these alternatives determines the sensitivity of the alternatives to the selected factors or combinations.

Five reports are available as follows:

1. "Computer-Assisted Procedures to Generate and Evaluate Regional Highway Alternatives".
2. "The GCARS System Fortran IV User's Manual".
3. "The GCARS System Fortran IV Programmer's Manual Part A - Programs for Data Collection and Evaluation".
4. "The GCARS System Fortran IV Programmer's Manual Part B - Programs for Generation of Alternatives".
5. "The GCARS System Fortran IV Programmer's Manual Part C - Programs for Contour Mapping".

A copy of the above reports is available at a cost of reproduction and handling of \$5 each or \$25 for the set of five reports. A complete punched card deck for all the programs for the GCARS system is also available for the cost of duplication and handling, \$25 per set for punched cards or \$15 per set for tape (the buyer must provide the 7-track tape or else the cost

of a tape will be added to the price). The tape will be loaded as BCD card images at 556 BPI.

All of the above items may be ordered (Make checks payable to PURDUE UNIVERSITY) from:

Director
Joint Highway Research Project
School of Civil Engineering
Purdue University
Lafayette, Indiana 47907

REFERENCES

1. Bureau of Public Roads, 1968, Programming Standards for the Total Integrated Engineering System (TIES), Office of Research and Development, B.P.R., Washington, D. C., 43p.
2. Turner, A. K., 1968, "FORTRAN IV Programs to Develop Contour Maps of Three-Dimensional Data," Joint Highway Research Project, Progress Report, May, No. 6, Purdue University, Lafayette, Indiana.
3. Turner, A. K., 1968, "Computer-Assisted Procedures to Generate and Evaluate Regional Highway Alternatives," Joint Highway Research Project, Final Report (Part I), December, No. 32, Purdue University, Lafayette, Indiana, 218p.
4. Turner, A. K., 1969, "The GCARS System FORTRAN IV Programmers Manual Manual, Part A - Programs for DATA Collection and Evaluation", Joint Highway Research Project, Final Report Part III-A, September, No. 25, Purdue University, Lafayette, Indiana, 104p.
5. Turner, A. K., 1969, "The GCARS System FORTRAN IV Programmers Manual Part B - Programs for Generation of Alternatives," Joint Highway Research Project, Final Report (Part III-B), September, No. 26, Purdue University, Lafayette, Indiana, 58p.
6. Turner, A. K., 1969, "The GCARS System FORTRAN IV Programmers Manual Part C - Programs for Contour Mapping," Joint Highway Research Project, Final Report (Part III-C), September, No. 27, Purdue University, Lafayette, Indiana, 93p.
7. Turner, A. K., and Miles, R. D., 1969, "Computer-Aided Regional Highway Location Studies," Joint Highway Research Project Technical Paper, May, No. 12, Purdue University, Lafayette, Indiana, 39p. (Proceedings/National Conference Committee on Electronics, American Association of State Highway Officials, Seattle, Washington, May 6-7, 1969, pages 36-74).