COMPUTERIZED STRATIFIED RANDOM SITE-SELECTION APPROACHES FOR DESIGN OF A GROUND-WATER-QUALITY SAMPLING NETWORK

by Jonathon C. Scott

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DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

UNITED STATES GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
215 Dean A. McGee, Room 621
Oklahoma City, Oklahoma 73102

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ABSTRACT

Computer software was written to randomly select sites for a ground-water-quality sampling network. The software uses digital cartographic techniques and subroutines from a proprietary geographic information system. The report presents the approaches, computer software, and sample applications.

It is often desirable to collect ground-water-quality samples from various areas in a study region that have different values of a spatial characteristic, such as land use or hydrogeologic setting. A stratified network can be used for testing hypotheses about relations between spatial characteristics and water quality, or for calculating statistical descriptions of water-quality data that account for variations that correspond to the spatial characteristic.

In the software described, a study region is subdivided into areal subsets that have a common spatial characteristic to stratify the population into several categories from which sampling sites are selected. Different numbers of sites may be selected from each category of areal subsets.

A population of potential sampling sites may be defined by either specifying a fixed population of existing sites, or by preparing an equally spaced population of potential sites. In either case, each site is identified with a single category, depending on the value of the spatial characteristic of the areal subset in which the site is located. Sites are selected from one category at a time. One of two approaches may be used to select sites. Sites may be selected randomly, or the areal subsets in the category can be grouped into cells and sites selected randomly from each cell.

INTRODUCTION

This report describes approaches for designing a ground-water-quality sampling network. Computer software for implementing these approaches is described and listed in attachments.

This report was produced as part of the pilot National Water-Quality Assessment (NAWQA) Program. The purpose of the pilot NAWQA Program is to test and refine concepts for a full-scale program that would describe the status and trends in the quality of the Nation's streams and aquifers and provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources (Hirsch, Alley, and Wilber, 1988).

The approaches and computer software were designed for and used in the pilot NAWQA Program. However, the approaches can be used for designing ground-water-quality sampling networks for other hydrologic studies.

To avoid confusion, specific terminology is used in this report. These terms are underlined when first defined and used. Definitions of terms and symbols used are included in the glossary located at the end of the report.

Concepts

During the design of a regional ground-water-quality network, it is often desirable to randomly select measurement sites to obtain a statistical representation of the ground-water quality in a particular study area. The study area is frequently divided into smaller contiguous areas, each of which has a particular spatial characteristic such as land use or hydrogeology. These smaller areas are referred to as areal subsets.

The spatial characteristic is used to categorize the different areal subsets. Each possible value of a spatial characteristic is referred to as a category. The categories may help to explain variations in water quality throughout the region. The term category is used instead of the more common term strata to avoid confusion with strata in the geological sense. A stratified study region is composed of areal subsets that are identified by spatial characteristics (fig. 1).

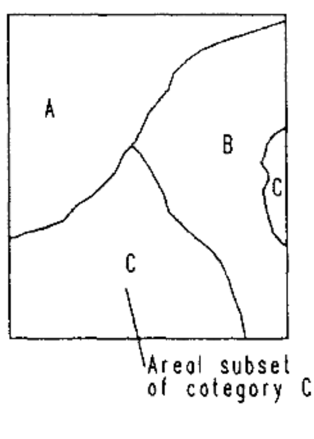
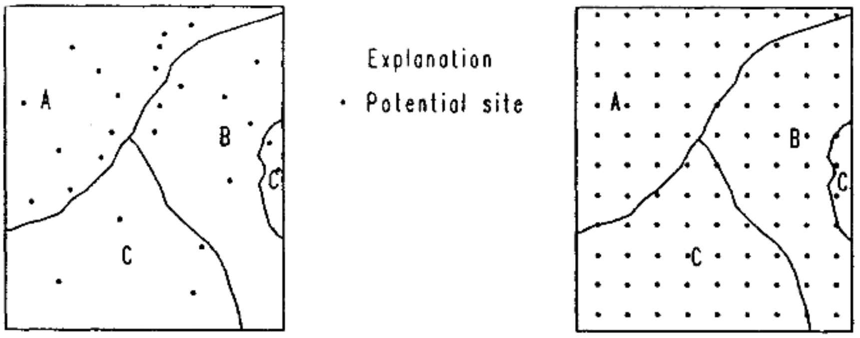


Figure 1.--A stratified study region.



(a) A population of existing wells. (b) An equally spaced population.

Figure 2.--Two populations of potential sites.

Sites are selected from a group of potential sites. The population is the group of all sites in the study region that have the potential to be selected. Potential sites may be existing wells (fig. 2a), or may be points arranged in a equally spaced pattern throughout the study region (fig. 2b).

Sites are often selected from each category to test hypotheses regarding the variation of water quality among the categories, or to compute weighted estimates of the population mean and variance that account for the variation among categories. In either case, random selection of sites is necessary to obtain valid statistical estimates. Random selection of sites by category is called stratified random selection. The term selection is used rather than the more common term sampling to avoid confusion between use of the word sampling in a statistical sense and in reference to water-quality sampling.

Purpose and Scope

This report describes approaches and computer software that can be used during the design of a ground-water-quality sampling network. The software includes several options for stratified random selection of sites. The region of interest can be any combination of one or more irregular polygons.

The software can be used to randomly select sites from a single hydrogeologic or land-use setting or from several different settings. The computer program is designed to select sites from each category, one category at a time.

This report first presents the theoretical discussion of various approaches for designing a ground-water-quality sampling network. The discussion is followed by a description of software that can be used for applying the approaches. The description includes application of the software to a hypothetical study region. Statistical analysis of the approaches presented in this report is described in an appendix.

Approaches

A number of different approaches may be used to select sites from a category. The most basic approach is simple random selection. In this approach, a set of n sites is selected from N potential sites in a manner such that each site has an equal chance of being one of the n selected, and the selection of one site does not influence the selection of other sites (Gilbert, 1987).

Simple random selection is appropriate if the goal is to estimate selected statistics about a study area, and there are no major spatial patterns in water quality. In practice, this assumption is unlikely to be met, although its validity will not be known *a priori*. Furthermore, because potential measurement sites (existing wells) are often clustered in particular areas, simple random selection is unlikely to achieve a set of sampling sites that are areally distributed throughout the region of interest.

A useful modification of simple random selection to ameliorate these problems is to divide the region into cells and to randomly select one or more measurement sites within each cell. Cells are subdivisions of the study area used to areally distribute the locations of selected sites. This approach, referred to as random selection within cells, is likely to produce a more uniform areal distribution of sites than does simple random selection.

Random selection within cells is easy to apply throughout a single rectangular region. However, the region of interest in designing a ground-water-quality sampling network is rarely rectangular and commonly consists of one or more irregular polygons that result from the two-dimensional representation of the region on a map. For example, the region may correspond to areas having a particular land use or to the areal extent of a selected depth range within an aquifer.

Site-selection Biases

Neither of the approaches described in this report, nor any known method, can remove all biases and ensure a set of sites that is representative of the water resource. However, the approaches described in this report are objective procedures that will reduce many biases. Some of the key potential sources of bias that need to be considered when designing a ground-water-quality sampling network include:

(1) Existing water-supply wells commonly are located in areas known to produce usable volumes of potable water. Thus, the use of water-supply wells may introduce a bias that tends to minimize water-quality problems.

(2) Wells in rural settings frequently are drilled near the landowners' houses. Therefore, large areas of the water resource that underlie other land uses and land covers may not be represented adequately by samples from existing water-supply wells in rural settings.

(3) Techniques for constructing water-supply wells commonly are not suitable for the purpose of sampling water from a specific geohydrologic unit. Well screens may be placed in contact with multiple units, making it impossible to determine the source of the water sample. Even when a well is screened within a specific geohydrologic unit, the annulus may be gravel packed through multiple units, allowing water to enter into the well from different units.

(4) Some observation wells emphasize contamination because the original purpose for which they were drilled was to determine the extent and longevity of a known contamination problem.

(5) Existing wells may not be areally distributed throughout the study region. Thus, the results may tend to overemphasize the water quality near clusters of wells.

(6) A conscious or unconscious bias to obtain interesting results can be caused when sites are selected without using a random-selection procedure. This bias can be caused even when sites are not selected from existing wells.

The random selection within cells approach can remove some of the effect of areal biases. However, this approach causes the probability of selection of a site to vary from cell to cell, depending on the population of sites in each cell. Thus, random selection within cells is not statistically random with respect to the population of potential sites, although the approach is random with respect to each cell. Formulas for calculating the selection probabilities for the approaches described in this report and the departure from statistical randomness are presented in the appendix.

Weighted Estimates of the Population Mean and Variance

Mathematical procedures have been developed for calculating weighted estimates of the mean and variance of a population that has been sampled by stratified random-selection methods, such as the ones described in this report (Cochran, 1977, p. 89-92; Gilbert, 1987, p. 46-47). When the variances within categories (strata) are less than the variance of the population as a whole, the estimate of the population mean can be improved by use of these mathematical procedures. Thus, if categories are defined in a manner that accounts for some of the population variance, these procedures can be used to calculate a population mean with a correspondingly lower variance than would be calculated when using an unstratified site-selection method.

The weights used in these procedures are equal to the ratio of the size of the population in a category to the total population in a study region. If the population of potential sites is large and spaced equally, the weights computed in this manner are approximately equal to the ratio of the total area of areal subsets in the category to the total area of the study region. In this instance, either method of computing the values of the weights provides areally weighted estimates.

The computation of weights can be avoided by proportionally allocating the number of sites selected per category to the relative amount of category area in the study region. When proportional allocation is used, statistical estimates for the population are intrinsically areally weighted (Steel and Torrie, 1960, p. 420).

Calculation of weighted estimates of the population mean and variance do not remove all the biases discussed in the previous section, even when sites are selected randomly from existing wells. In this case, weighted estimates of the mean and variance describe the population of these wells, not necessarily the study region. Furthermore, it is questionable whether areally computed weights would produce estimates that characterize the study region because of the biases introduced by the siting of the wells.

APPROACHES FOR DEFINING THE POPULATION OF POTENTIAL SITES

Two different approaches may be used to define the population of potential sites from which sites are selected for water-quality sampling. With the first approach, a fixed population of existing sites is specified. With the second approach, one of two methods may be used to create an arbitrary population of potential sites arranged in an equally-spaced pattern throughout the study region. Either population-definition approach can be used with either of the site-selection approaches discussed in the next section.

The first population-definition approach allows the user to specify the population of potential sites by providing a coverage of points. (A <u>coverage</u> is a computerized representation of the locations and characteristics of spatial data.) Typically, these potential sites are the locations of known water wells. Because the locations of these wells are known, the coverage is referred to as a <u>fixed population of potential sites</u>. In some cases, the locations of all potential measurement sites can be identified readily from maps and (or) computer files. In these cases, the first approach can be used to specify the population of potential sites.

However, in some cases extensive effort would be required to identify all potential measurement sites. In other cases, new wells will be installed as part of the sampling program. Under either of these circumstances, the second approach for defining the population of potential sites is appropriate. The computer software can generate an arbitrary, equally spaced population of potential sites. After sites are selected from an arbitrary population, a sampling crew can then locate the nearest suitable location for sampling.

An equally spaced coverage of potential sites may be created by either of two methods. The two methods differ in the way in which the spacing between sites is determined. With the first method, the user specifies the approximate number of potential sites, and the software calculates the spacing of sites by computing the square root of the ratio of the area of the study region divided by the population size. With the second method, the user specifies the spacing between potential sites.

After the spacing of potential sites has been decided, the software randomly selects a point below and to the left of the lower-left corner of the study region for the first potential site. Then, an equally spaced population of potential sites is prepared that covers the entire study region.

APPROACHES FOR SELECTING SITES

The software provides two different approaches for site selection: simple random selection and random selection within cells. Both approaches randomly select sites from a single category of a stratified population. The site-selection process is performed once for each category to be sampled. The process of selecting sites for a category is referred to as a site-selection <u>pass</u> (fig. 3). Thus, only the sites in a user-specified category are eligible for selection during a site-selection pass. For example, if a study area was stratified by land use, one pass would be used to select sites for each land-use type.

When beginning a site-selection pass, the user specifies the category, the number of <u>primary sites</u> to be selected from the category (η_p), and the number of alternate sites to be selected (η_a) for each primary site. <u>Alternate sites</u> are water-quality sampling locations selected to provide in advance for potential difficulties that may be encountered when visiting sites. For example, it may be impossible to drill at a selected site. When such a difficulty occurs, the hydrologist will have one or more alternative sites to visit if one or more alternate sites are specified during site selection.

A site-selection pass is divided into rounds. A <u>round</u> is the process of selecting one group of sites for a category. Primary sites are selected during the first round. These sites comprise the first choices for selection. Alternate sites are selected during an additional η_a rounds. During each round, η_p sites are selected. The number of rounds (η_r) in a site-selection pass is equal to $(1 + \eta_a)$ (fig. 3). The total number of sites (η_t) selected during a pass is $\eta_t = \eta_p \cdot \eta_r$.

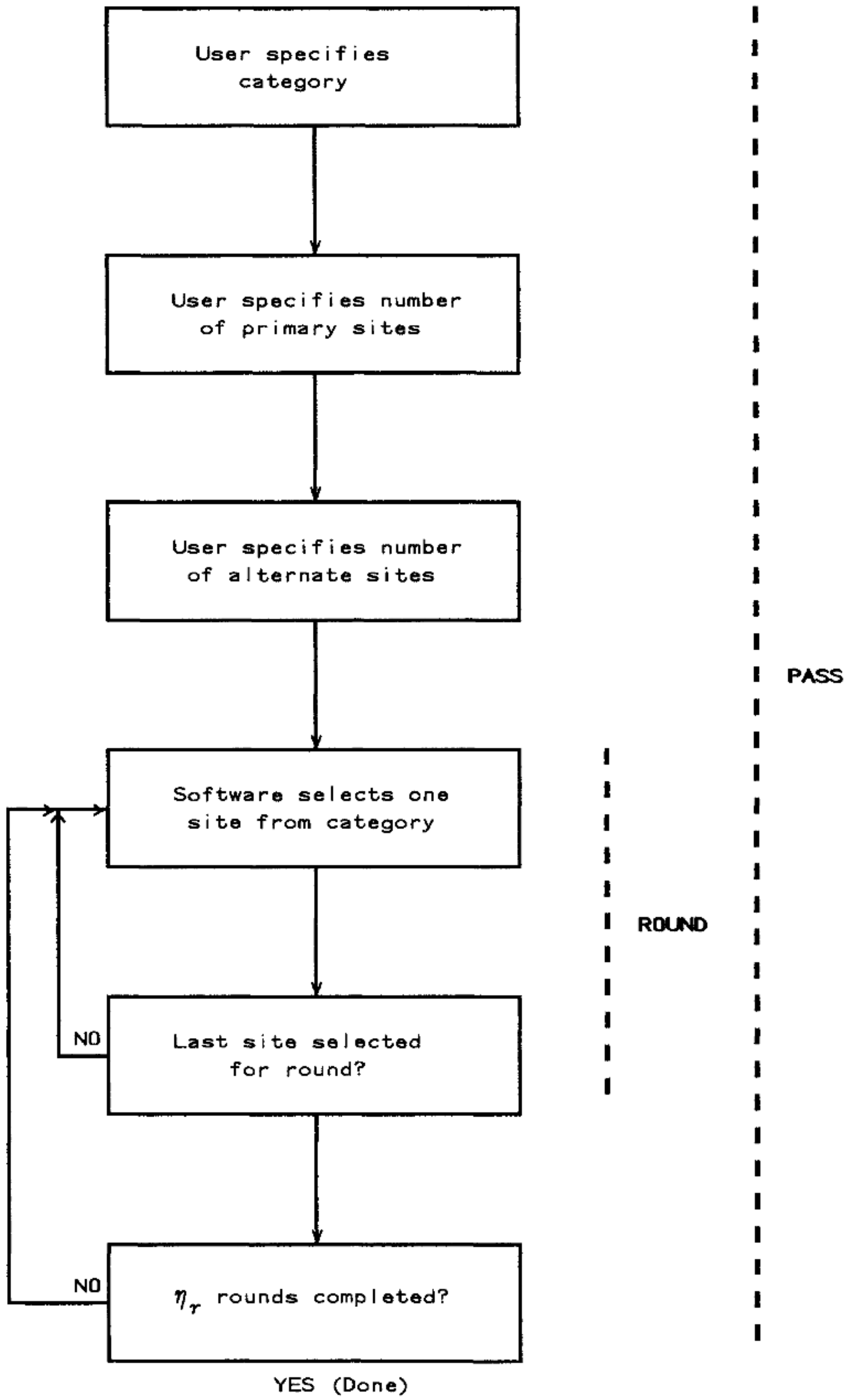


Figure 3.--Flow diagram of the site-selection process.

Table 1.--*Comparison of attributes of the site-selection approaches*

Attribute	Approach		
	Simple random selection	Random selection within cells	
		With equal-area distribution	With iterating grids
Complexity	Simple	Moderate	Complex
Time required to select sites	Minutes	Hours	Hours
Areal distribution	Random	Sites are selected randomly from within cells that contain equal areas of the category in the study region.	Sites are selected randomly from within cells distributed areally.
Cells	One cell includes the entire study region.	Cell definitions are reproducible.	Cell definitions are not reproducible.

The following sections describe each of the two approaches. A summary of the attributes of the site-selection approaches, including two different options for the random selection within cells approach, is presented in table 1.

Simple Random Selection

Simple random selection is performed by first enumerating all potential sites from 1 to *N*, where *N* is the total number of potential sites in the category. Then, an integer number, between 1 and *N*, is chosen randomly, and the site associated with the chosen integer is selected. Next, another integer number and corresponding site is chosen randomly. This process is repeated until the desired number of primary sites, η_p, has been selected. The selections constitute the first round. Site selection continues until η_r rounds have been completed (fig. 3). Once a site has been selected, it is not available for selection again. In statistics texts, this technique often is referred to as "sampling without replacement."

With the stratified random-selection method, only one cell containing all areal subsets for the category is used for site selection. Sites located in the user-specified category are selected randomly. As noted earlier, simple random selection of sites does not ensure that the selected sites will be distributed areally throughout the study region or throughout all areal subsets of the same category.

Random Selection Within Cells

To provide better areal distribution of site selections than may be achieved using the simple random-selection approach, the study region can be divided into cells. Then, sites are selected from within the cells. For a site-selection pass, one site is selected during each round from every cell containing area for the category.

Two methods are provided in the software for creating cells within the study region. The first method, random selection with equal-area distribution, creates cells that contain an equal amount of area for the category. The second method, random selection with iterating grids, creates cells by iteratively overlaying square grid patterns onto the study region until a pattern is found that satisfies the user's site-selection requirements.

Random Selection with Equal-area Distribution

Random selection with equal-area distribution provides areal distribution of the selected sites. If one site from each cell is used for water-quality sampling, each site selected is associated with an equal area for the category.

The study region is divided into small subareas before site selection begins. The subareas are initially small square polygons. These square polygons are used to subdivide the areal subsets to create small irregularly shaped polygons, each of which contains area for a single category (fig. 4). The resultant subareas are later aggregated to create cells from which sites are selected. The subareas are created once for a study region. The subareas are reused when site selection is performed for different categories.

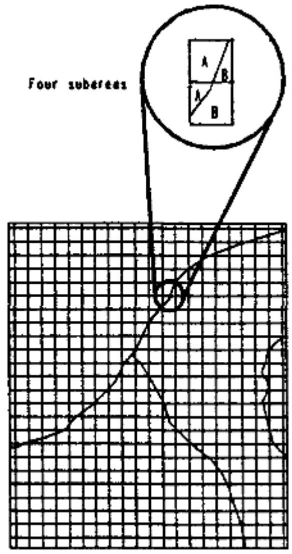


Figure 4.--Subareas for a study region.

The user-specified number of primary sites to be selected for a category (η_p) determines the number of cells that are created. Each cell contains an area approximately equal to the total area of the category in the study region divided by the number of sites to be selected for the category.

Cells are created by first dividing the study region into vertical strips. The number of strips is computed by taking the square root of the user-specified number of sites. The number is rounded to the nearest integer. Each vertical strip contains approximately an equal amount of area for the category. Beginning in the lower-left corner of the study region, subareas in each horizontal row within the strip are aggregated to form a cell containing the desired area. When the correct area for the cell has been obtained, formation of the next cell begins.

The subarea aggregation continues until the top of the vertical strip is reached. If insufficient area has been aggregated to correctly form the current cell, the aggregation continues with the top row of the next vertical strip to the right. The aggregation in this strip continues with each row downward until the correct area for the cell has been reached. Formation of the next cell then begins. A similar process occurs when the bottom of the vertical strip is reached. Cell formation continues until all the subareas are assigned to cells (fig. 5).

Cells formed by this method are reproducible when the method is repeated using the same study region, areal subsets, subareas, and number of sites selected. Altering the size of subareas affects the smoothness of the cell boundaries, but does not noticeably affect the shape of the cells unless the subarea sizes are changed significantly.

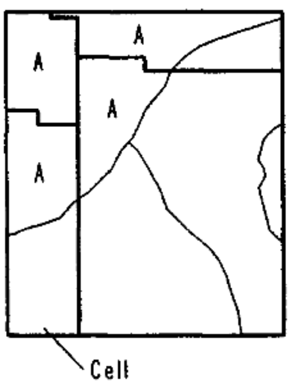


Figure 5.--Four equal-area cells for category "A".

When using the random selection with equal-area distribution method with a fixed population of potential sites that is not areally distributed, a solution may not be feasible. It is possible that some cells will be created that do not contain any potential sites, or that contain fewer than η_r sites. In the latter case, it may be feasible to design the network with the equal-area distribution method by decreasing η_a. Alternatively, either difficulty may be resolved using the random-selection with iterating grids method.

Random Selection with Iterating Grids

This method, a second variation of random selection within cells, is the most complex of the three methods. In this method, the cells are determined by a grid of square cells that is overlaid on the study region. The origin of the grid is located randomly somewhere below and to the left of the lower-left corner of the study region. Grids are overlaid until there are η_p grid cells that contain at least η_r sites in the category of interest or secondary convergence conditions have been satisfied, as explained below. The size of the cells and the origin of the grid are altered between successive iterations. Grids created in this manner are not reproducible, and a solution meeting the convergence criteria is not unique.

This iterative procedure can resolve the difficulties described previously, when a fixed population is not distributed areally. However, some combinations of user requirements, areal-subset distributions, and populations of sites can cause a situation where some potential sites have little or no probability of being selected by the method.

Consider an example study region stratified by land-use with one large agricultural areal subset on the western half of the region, and a few small widely-separated agricultural areal subsets in the eastern half of the region. If few primary sites are being selected (that is, a coarse grid is used) and alternate sites are required, sites in the small agricultural areal subsets have little chance of being selected. This is because the software is unlikely to be able to create a grid with a cell covering the small agricultural areal subsets that contains the required number of sites (η_r).

This type of problem is resolved by relaxing the restriction that every cell must contain η_r sites. The user can specify a number (f_a), between zero and one, that is the <u>fraction of cells</u> that must contain at least as many potential sites as the number of site-selection rounds. This stipulation allows site selection to be made from two groups of cells. Each cell in the first group contains at least η_r sites, and sites are selected randomly from each one. Each cell in the second group contains less than η_r sites. All sites remaining to be selected are chosen from the second group without reference to cell boundaries.

This method can be adjusted to favor or not favor different parts of the study region depending upon the geometry of the areal subsets, the population of potential sites, and the convergence criteria. For the previously described example, decreasing f_a increases the probability that a site from one of the small agricultural areal subsets will be selected. Conversely, increasing f_a and (or) η_a decreases the probability that a site from the small agricultural areal subsets will be selected.

Convergence Criteria

In addition to entering the category, number of primary sites, and number of alternate sites, the user enters additional data to control the iteration process. The iteration-control variables are (1) the fraction of cells that must contain η_r sites (f_a), (2) the maximum number of iterations, and (3) the damping factor (f). The number of primary sites, the number of alternate sites, and the fraction of cells that must contain η_r sites comprise the convergence criteria.

The most stringent convergence criteria exist when the fraction of cells variable is set to one. At the end of each iteration, the software counts the number of cells containing at least η_r sites in the user-specified category. When this count of cells, defined as N_{ct}, exactly equals the number of primary sites to be selected, iteration stops and sites are selected from the cells in the same manner as the previous method.

When the fraction is set to a value less than one, convergence can occur if the previously described condition is met. Alternatively, another set of conditions can meet the convergence criteria. These secondary convergence conditions are expressed mathematically by the following two inequalities.

$$f_a \leq (N_{ct} / \eta_p) < 1 \qquad (1)$$

$$N_a \geq \eta_r \cdot (\eta_p - N_{ct}) \qquad (2)$$

where f_a = the user-specified fraction of cells that must contain at least η_r sites,
N_{ct} = the number of cells that contain η_r sites,
η_p = the user-specified number of sites,
N_a = the number of potential sites not located in cells that contain η_r sites, and
η_r = the user-specified number of alternate sites plus one.

When the secondary convergence conditions are met, site selection is split between cells that contain at least as many potential sites as the number of rounds, and cells that do not. The first secondary convergence condition requires that the ratio of N_{ct} / η_p must be greater than or equal to f_a and less than one. This condition pertains to the group of cells that contain at least η_r sites.

Additionally, the number of potential sites not located in cells containing η_r sites must be sufficient for selection of the remaining sites. The number of sites located in cells not containing η_r sites (N_a) must be at least as large as the product of η_r and the result of η_p minus N_{ct}.

Iteration Procedure

The amount of time required for a site-selection pass can be lengtny. The maximum number of iterations used during a pass is set to eight in the software, but can be increased or decreased by the user. When the maximum number of iterations is reached without finding a satisfactory grid, the user has the option of stopping the software, or attempting to select sites again.

When the grid tested during an iteration fails to meet the convergence criteria, a new grid is prepared. The number of cells in the new grid is based on how well the previous grid satisfied the convergence criteria. A grid is prepared by estimating how many cells are needed to satisfy the convergence criteria. Because the origin of the grid is moved randomly during the preparation of the grid, the method may use approximately the same number of cells repeatedly.

At the beginning of the first iteration, the initial estimate for the number of cells needed is calculated from the following formula.

$$G_i = \eta_p \cdot A / A_c \tag{3}$$

where G_i = estimate for the number of cells needed in the current iteration,
A = total area of the study region, and
A_c = total area of all areal subsets in the category.

When an iteration fails to converge, a new estimate for the next iteration is calculated. The formula shown below is based on the assumption that a linear change in the number of cells will produce a grid that satisfies the convergence criteria.

$$G_{i+1} = G_i \left(\frac{(\eta_p - N_{ct})}{N_{ct}} \cdot f_i + 1 \right) \tag{4}$$

where G_{i+1} = estimate for number of cells needed in the next iteration,
and f_i = damping factor for the iteration.
When f_i = 1,

$$G_{i+1} = G_i \left(\frac{\eta_p}{N_{ct}} \right) .$$

The value of the <u>damping factor for the iteration</u> (f_i) is either one or the user-specified damping factor (f). When the N_{ct} / η_p ratio is less than 0.6 or greater than 1.4 the damping factor for the iteration is equal to 1.0. Otherwise, the damping factor for the iteration is equal to the user-specified damping factor.

The damping factor causes the change in the estimate for the number of cells to be increased (when $f > 1.0$) or decreased (when $f < 1.0$) when a solution is near. The geometry of the areal subsets in some study regions can cause the method to continue to iterate in the vicinity of a potential solution without quickly finding the solution. The damping factor is used to cause larger or smaller changes in the estimate in these cases, thereby accelerating solution of the problem.

DESCRIPTION OF THE SOFTWARE

Hardware and Software Requirements

The site-selection software was developed on a Prime[1] minicomputer using the Primos operating system, revisions 21 and 22. It has not been installed or tested on other computer systems. The site-selection software is dependent on the hardware and software currently used by the U.S. Geological Survey (Rennick, 1986), and must be modified to use the software with a different configuration of hardware and software.

The site-selection software is designed to be used with a computer terminal that can display bold characters using standardized codes (American National Standards Institute, 1979). However, this terminal dependence can be easily removed or changed by modifying the program in attachment A.

The ARC/INFO geographic information system (GIS) (Environmental Systems Research Institute, Inc., 1987a; 1987b), revision 5.0.1, is used within the software to perform many digital cartographic and data-manipulation processes. Use of the software requires licenses for the ARC geographic information system software and the INFO file-management software, revision 9.42 (Henco, Inc, 1983).

The interaction between the user of the software and the programs used by the software is handled by a computer program written in the Arc Macro Language (AML) (Environmental Systems Research Institute, Inc., 1987c). AML can be used with several different computer-operating systems. The AML program performs operations using the ARC/INFO GIS and also runs other computer programs that are part of the site-selection software.

The other computer code (attachments C through N) is written in Fortran 77 (Johnson, 1983) and performs parts of the site-selection process. All of the Fortran computer programs call subroutines in the ARC/INFO subroutine library, revision 5.0.1 (Environmental Systems Research Institute, 1989). Most of these computer programs are written using standard Fortran 77 (American National Standards Institute, 1978). The exceptions to standard Fortran are identified in the Installation of the Software section of this report.

User-supplied Data Requirements

A digital map (coverage) of the study region is needed before the software can be used. The coverage needs to contain polygons for areal subsets that will be used to stratify the selection of sites. Additionally, a character variable in the coverage needs to identify the category of each

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[1] Use of brand, firm, and trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

areal subset. (The maximum number of characters that can be used to identify categories is 16.) In the simplest case, the coverage consists of polygons that are identified as either in or out of the set of polygons from which sites will be selected. More often, each polygon is identified by an alphanumeric code indicating the land use, land cover, or hydrogeologic setting of the area.

The digital cartographic processes used in the software operate with two-dimensional Cartesian representations of the earth's surface. The user selects a mathematical transformation, known as a map projection, to convert three-dimensional coordinates to two-dimensional coordinates. All map projections introduce a combination of errors in the relative locations, shapes, areas, or lengths of map features (Synder, 1987). It is not possible to recommend a particular map projection that is ideal for use of the software for any possible study region. The map projection selected by the user needs to provide a continuous two-dimensional coordinate system and minimize errors of scale. An equal-area map projection needs to be considered if the random selection with equal-area distribution method is used, or if areas from the coverage will be used in statistical computations.

If a fixed population of potential water-quality sampling sites will be used, a coverage containing the locations of these points is needed. If a point coverage of potential sites is supplied, it needs to be in the same units and map projection used for the polygon coverage of areal subsets.

Use of the Software

Overview

The site-selection software is interactive. Interactive software uses two-way communication between the user in the form of entries typed on the terminal keyboard, and the software in the form of messages displayed on the terminal screen.

The site-selection software will work correctly only when the user is running the ARC/INFO software and the "Arc:" prompting message is displayed. To start the site-selection software, the following command is typed.

```
Arc: &R SAMPLE
```

As shown above, font changes are used in this report to distinguish text of the report, messages displayed on the terminal, and information typed by the user. In the example above, "Arc:" is displayed on the terminal and "&R SAMPLE" is typed by the user.

Each time the software is started, messages are displayed that prompt the user to enter the site-selection method, the name of the areal-subset coverage, and the category-variable name. The prompting messages are displayed consecutively; after a response is entered for each, the next one is displayed, as shown on the next page.

```
Site selection may be performed using one of three methods:

   Code    Method

     1     Simple random selection
     2     Random selection with equal-area distribution
     3     Random selection with iterating grids

Enter method code:
Enter name of areal-subset coverage:
Enter name of category variable:
```

The software checks for an existing areal-subset coverage with the user-specified name containing the user-specified category-variable name. If a problem is detected, an error message is displayed, and the prompting message for the areal-subset coverage name is displayed again.

The software displays next a list of options called the main menu, as shown below. When software is run for the first time with a specific areal-subset coverage, the second option, "Select sites from population", is not available. A population must be defined using option one, before sites can be selected using option two.

```
Site-selection software main menu

   Code    Option

     1     Define population
     2     Select sites from population
     3     Exit from site-selection software

Enter option code:
```

When the first main-menu option is selected (Define population), the user is given an opportunity to exclude sites that are located within certain areal subsets. These areal subsets may be identified by specifying a minimum area and (or) a minimum area-perimeter ratio. It may be useful to avoid selection of sites in small or extremely elongated areal subsets. Sometimes the accuracy of assigning a spatial characteristic to such an areal subset is questionable because the actual location of the border of the areal subset is uncertain.

Next, the user selects one of three options for defining the population of potential sites. As described previously, two of these options cause the software to create a coverage of equally spaced points. The other option allows the user to specify the name of a point coverge of potential sites. If the random-selection with equal-area distribution method is used, the user next enters specifications for preparing a coverage of subareas. When the population has been defined, the main menu is displayed again.

When the second main-menu option is selected, the software prints messages prompting the user to enter specifications for selecting sites for a single category. Then, sites are selected, the selections are stored, and the main menu is displayed.

When the third main-menu option is selected, the software stops and the "Arc:" prompting message is displayed again. A simple schematic showing the flow of site-selection software is presented in figure 6.

The results are stored each time the site-selection software is used. All work performed has been stored already when the third main-menu option, "Exit from site-selection software", is selected. This feature permits repeated use of the site-selection software for selecting sites for a study region. Thus, the problem of designing a ground-water-quality sampling network can be separated into stages, and each stage performed when time is available.

For example, a study region is stratified into five categories. The problem could be separated into six stages, each of which can performed at a different time. The first stage necessarily is definition of the population. Each of the other five stages consist of selecting sites for a particular category and can be performed in any order.

Messages

There are four different types of messages displayed by the software: (1) Prompting messages, (2) informative messages, (3) operational messages, and (4) error messages.

Prompting messages are displayed by the software to elicit a response from the user. Some prompting messages are menus that present a numbered list of options. The user selects an option from a menu by entering the corresponding number (referred to as a code). If a value is entered that is not listed on the menu, a message is displayed explaining the error, and the menu is displayed again.

Other prompting messages are simply questions that need to be answered. Questions that require an affirmative (yes) or negative (no) response may be answered in several ways. An affirmative response may be entered by typing YES, YE, Y, OKAY, OKA, OK, or O. A negative response may be entered by typing NO, N, QUIT, QUI, QU, or Q. If none of these responses are entered, the software displays the message "Enter YES, OKAY, NO, or QUIT:". An acceptable affirmative or negative response should be entered.

Some prompting messages require a numeric answer. If a non-numeric answer is entered, an error message is displayed and the prompting message or previously displayed menu is displayed again. Other questions require responses that are integers or positive numbers. If an invalid response is entered, the software displays an appropriate error message, and displays the prompting message again.

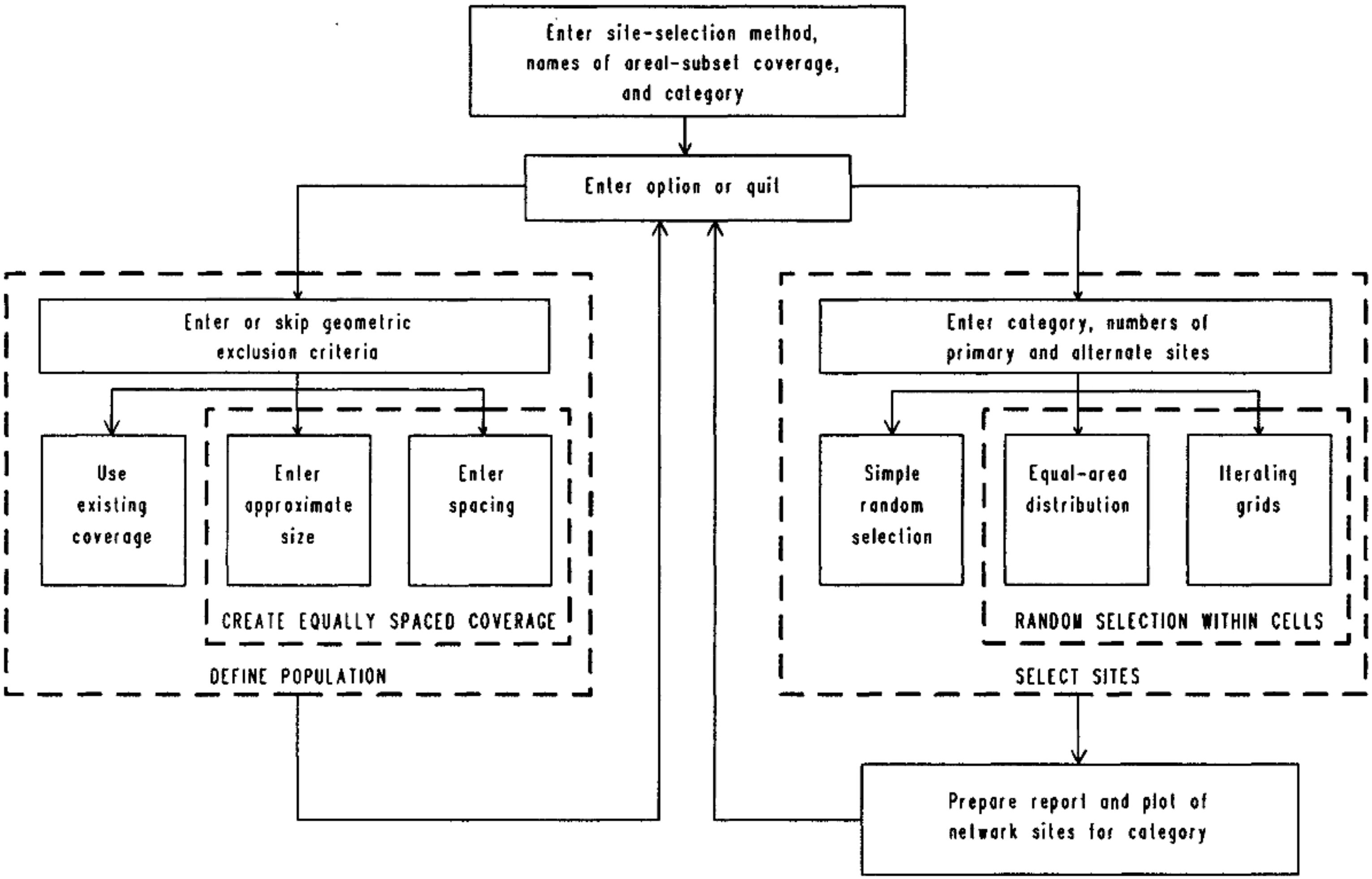


Figure 6.--Simple schematic of the site-selection software.

Informative messages are displayed by the software to describe the data-processing activities during different stages of the site-selection process. Most informative messages are displayed in bold characters to separate them from operational messages.

Operational messages are displayed by the software while performing various operations. Operational messages may not be very informative to a user not conversant with the jargon of the ARC/INFO GIS. Operational messages that are displayed by the software are presented in this report with samples runs of the software.

Error messages are displayed by the software when problems occur during site selection. Some error messages are discussed in this section, and all error messages likely to be displayed are described in a separate section, "Error Messages", near the end of this report.

Hypothetical study region

For the purpose of describing the site-selection software, a stratified areal-subset coverage (fig. 7) was created for a hypothetical study region. Three categories are identified: "URBAN", "MIXED", and "RURAL". The areal-subset coverage is named LUSE and contains a category variable named CATEGORY.

Sample sessions are shown in subsequent sections of this report. In the samples, numbers shown on the left side of each line are not displayed on the terminal when the software is run. These numbers are used for referring to the lines in the text of this report. In the sample sessions, information typed by the user is printed in bold characters, and messages displayed by the software are printed in a sans-serif font. Informative messages, displayed in bold characters on the terminal, are printed in italics. The characters **<CR>** are printed where a carriage return is typed by the user without entering any data.

Products of the Software

After all of the data needed to select sites have been entered and site selection has been performed for a category, the software stores the results in several places. These storage locations and the information they contain are described in the following paragraphs.

Category-index File

When a population is defined, the software creates a category-index file (table 2), and updates the file every time sites are selected. The name given to the category-index file is CATIDX. The file can be accessed using the INFO file-management system (Henco Inc, 1983) as shown on page 22.

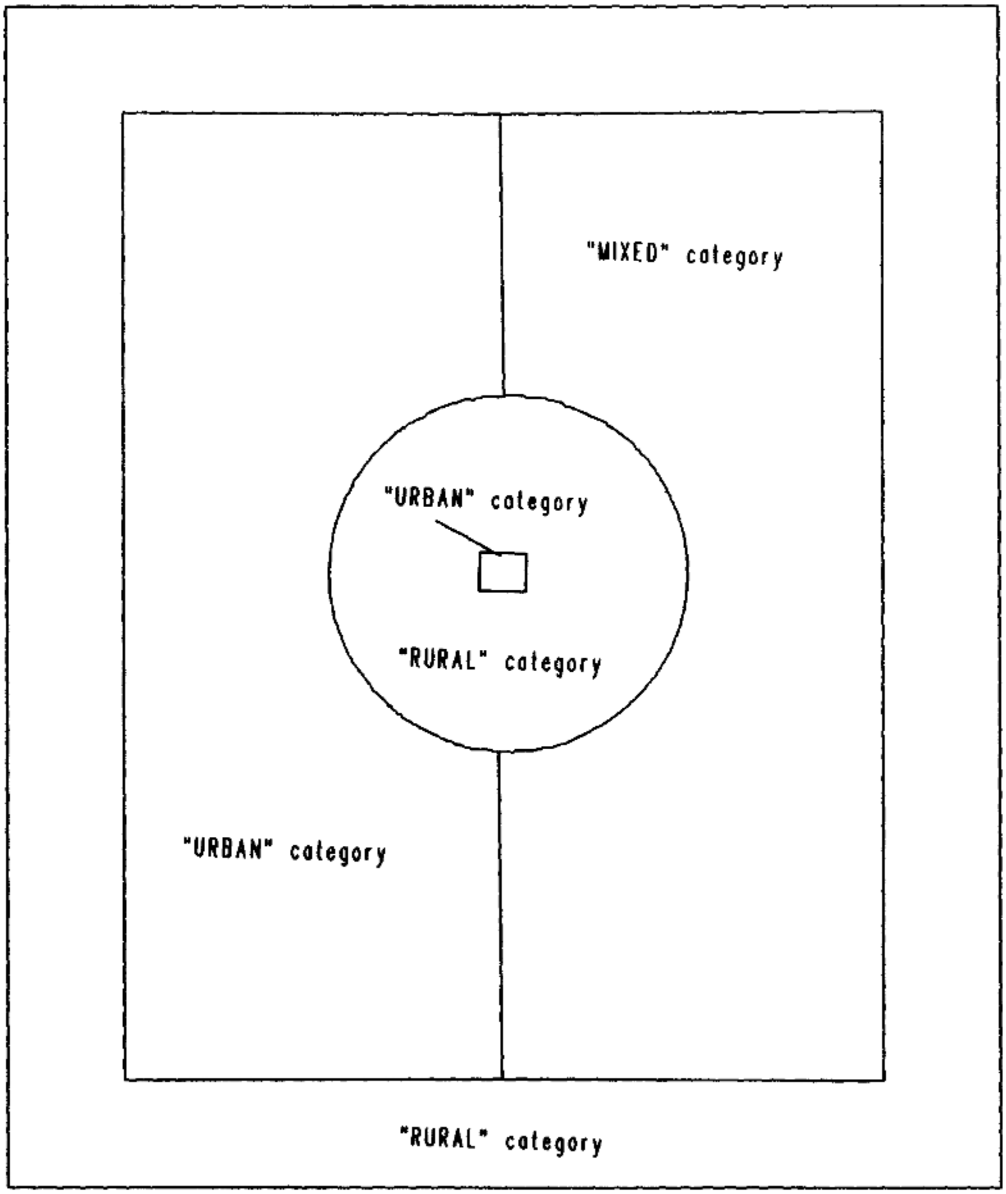


Figure 7.--A hypothetical stratified study region.

Table 2.—*Contents of the category-index file*

[Field-type codes: C = character, F = real number stored in binary format, and B = integer stored in binary format]

Variable name	Position of first byte (bytes)	Field width (bytes)	Output-display width (characters)	Field type (code)	Number of decimal places	Description
CATEGORY	1	16	16	C	–	Name of category
AREA	17	4	12	F	3	Total area of all areal subsets in the category
NUMPOLY	21	4	5	B	–	Number of areal subsets in the category
NUMPTS	25	4	5	B	–	Number of potential sites in the category
FRACTION	29	4	12	F	4	Ratio of category area divided by total area of the coverage
NOSAMP	33	4	5	B	–	Number of sites selected for the category

```
Arc: INFO
 INFO  EXCHANGE  CALL
THU, OCT 12 1989
 INFO  9.42  12/ 1/86  52.74.63*
 COPYRIGHT 1986 HENCO SOFTWARE, INC.
 PROPRIETARY TO HENCO SOFTWARE, INC.
 US GOVT AGENCIES SEE USAGE RESTRICTIONS IN HELP FILES (HELP RESTRICTIONS)
 ENTER USER NAME>ARC

 ENTER COMMAND >SELECT CATIDX
       4 RECORD(S) SELECTED

 ENTER COMMAND >LIST
 $RECNO  CATEGORY               AREA NUMPOLY NUMPTS    FRACTION NOSAMP
      1                         0.000     0       1      0.0000      0
      2  RURAL              81508.880     2     257      0.4579      0
      3  MIXED              47996.840     1     154      0.2697      0
      4  URBAN              48485.970     2     153      0.2724      0

 ENTER COMMAND >Q STOP
Arc:
```

There is one record in the category-index file for every category in the study region, plus one record for unidentified areal subsets (the category variable contains blanks). The number of sites in areal subsets that are excluded geometrically is added to the total number of sites (NUMPTS) in the blank category. However, the areas of subsets that are excluded geometrically are not added to the total area (AREA) of the blank category. Instead, the areas of subsets excluded geometrically are added to the total area for the category of which the areal subsets are members. The computations are performed in this manner to facilitate the computation of weighted estimates of the population mean and variance.

The software uses the category-index file to keep track of the number of primary sites selected from each category and to make an initial estimate for preparing the first grid when selecting sites using the random-selection with iterating grids method.

Site Report

The software writes a file called the site-selection report. The file is named by joining together the characters "SITE.REPORT." and value of the category variable. An example site-selection report from a file named SITE.REPORT.URBAN is shown in figure 8.

Most of the information written on the heading of the report is from the category-index file. The locations of the selected sites are written to the report. The locations are sorted by site number and selection-round number. There is one site number for each primary site.

After each site number, latitude and longitude are listed for the selected sites, along with an round number. The round number designates the order for visiting primary and alternate sites. When selecting a particular site, if the site with round-number 1 can be used for the project, the alternate sites with larger round numbers are not used. Otherwise, the alternate site with the next larger round number is visited until an acceptable site is found.

Plot File

For illustrating the locations of the selected sites, the software prepares a binary file suitable for plotting using the ARC/INFO GIS. Several ARC/INFO commands (Environmental Systems Research Institute, 1987e) can be used to display the contents of the plot file. The binary plot file is named by joining the together the character "#", the name of the areal-subset coverage, a period, and the value of the category variable.

The contents of the plot file depict the locations of the selected sites with circles. Within each circle is the round number of the site. The borders of the areal subsets are included. If the random selection within cells approach is used, the borders of the cells also are included in the plot file. An example drawing of a plot file is shown in figure 9.

RESULTS OF RANDOM SELECTION FOR CATEGORY 'URBAN

Total area of category	=	48486.0
Number of areal subsets	=	2
Number of potential sites	=	153
Number of primary sites selected	=	4
Number of alternate sites selected	=	2

------------- SITE # 1 -------------

ROUND	LATITUDE	LONGITUDE
1	34 00 04	95 59 57
2	34 00 03	95 59 53
3	34 00 03	95 59 58

------------- SITE # 2 -------------

ROUND	LATITUDE	LONGITUDE
1	34 00 03	95 59 57
2	34 00 12	95 59 54
3	34 00 08	95 59 52

------------- SITE # 3 -------------

ROUND	LATITUDE	LONGITUDE
1	34 00 03	95 59 54
2	34 00 02	95 59 53
3	34 00 13	95 59 56

------------- SITE # 4 -------------

ROUND	LATITUDE	LONGITUDE
1	34 00 06	95 59 55
2	34 00 04	95 59 56
3	34 00 02	95 59 55

Figure 8.--An example site-selection report.

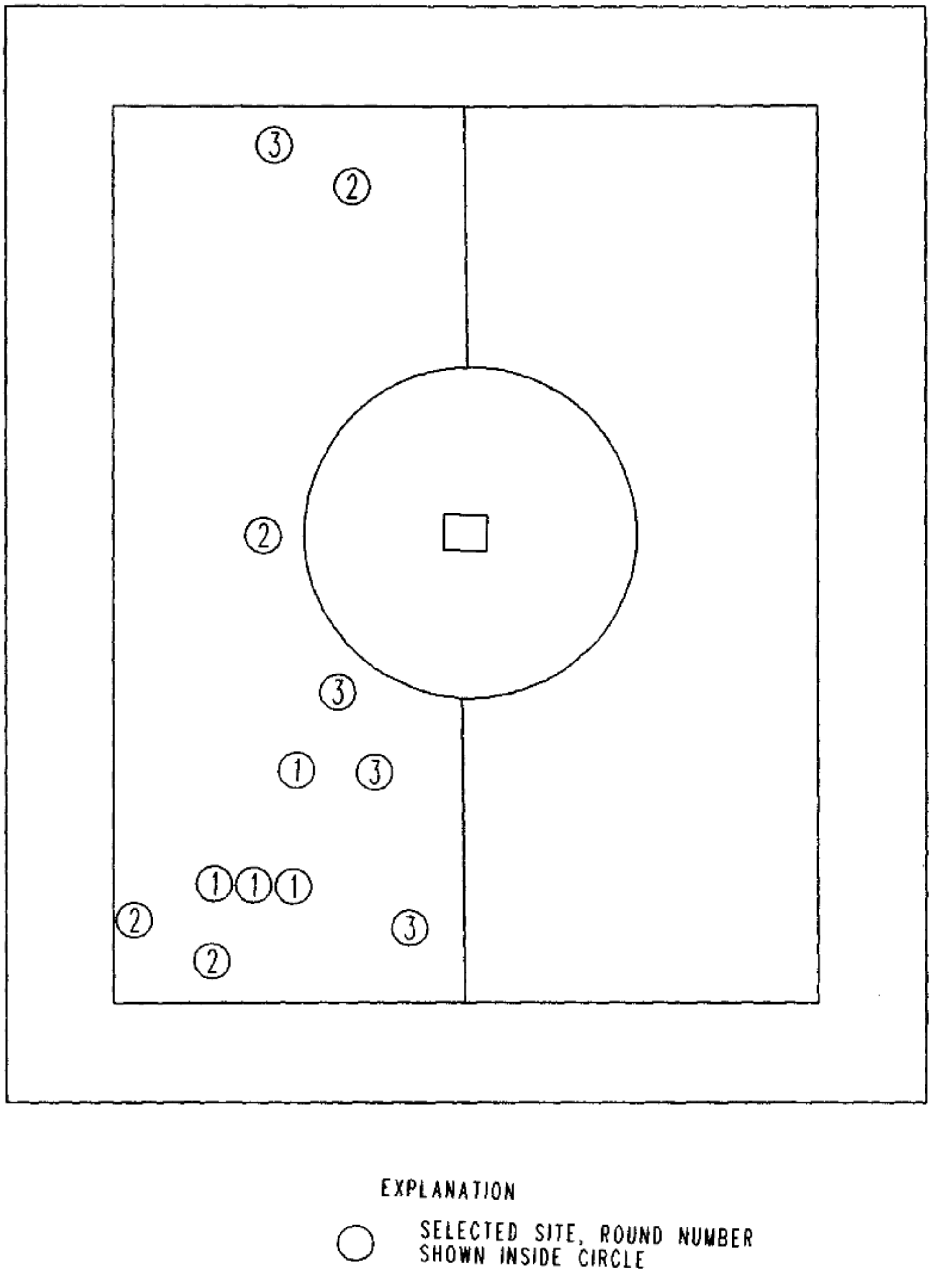


Figure 9.--An example drawing of a plot file created by the site-selection software.

Coverages

The site selections are stored in the coverage containing the population of potential sites. The coverage is named by joining together the name of the areal-subset coverage and the characters ".POP".

Three variables in the population coverage are used to identify the sites. The first of these is an integer variable named CHOSEN. When site selection begins for a category, the value of CHOSEN is set to zero for all potential sites in the category. When a site is selected, the value of CHOSEN is set to the round number during which the site is selected. The second variable is an integer variable named CELLNO. Unless the simple random-selection method is used, the value of the CELLNO variable is equal to the cell in which the site is located. The third variable is a character variable that identifies the areal subset in which the site is located. This variable has the same name as the corresponding variable in the areal-subset coverage.

If the simple random-selection approach is used, one cell is used for the entire study region. Otherwise, a polygon coverage is created containing the cells. The name of the coverage is determined by joining together the name of the areal-subset coverage, the characters ".CELL.", and the value of the category variable. Each polygon in the coverage is identified by a variable named CELL. The value of the CELL variable corresponds to the CELLNO variable in the population coverage and the site number in the site-selection report.

The population and cell coverages are useful for creating plots that illustrate the water-quality sampling network. The reader may refer to the ARC/INFO documentation for information about creating plots using these coverages (Environmental Systems Research Institute, 1987d).

When a population of potential sites is defined, using option one of the main menu, any existing category-index file is deleted and a new one is created. Also, the contents of the variables named CHOSEN and CELLNO in an existing population coverage are lost, because any existing population coverage is deleted before the new one is created. If a coverage of subareas exists, it is deleted and a new one is created.

When sites are selected from a category more than once, the values of the variables CHOSEN and CELLNO in the population coverage are recalculated. Also, the value of the NOSAMP variable in the category-index file is changed, and any existing site-report file or plot file for the category is rewritten. Finally, if a coverage of cells exists for the category, it is deleted and a new one is created.

Definition of the Population

Options

The first task required when selecting sites with the software is to define the population of potential sites by selecting option one from the main menu. Next, the following message is displayed.

```
Do you wish to exclude areal subsets using geometry (CR=NO)?
```

This prompting message provides an option for excluding some areal subsets from the site-selection process. Areal subsets of all categories that contain less than some user-specified area or less than some user-specified ratio of area divided by perimeter can be excluded from the site-selection process. To use this geometric exclusion, an affirmative response is entered. A carriage return or a negative response is entered to omit geometric exclusion.

When an affirmative response is entered, the following two prompting messages are displayed.

```
Enter minimum area (CR=no minimum):
Enter minimum area/perimeter ratio (CR=no minimum):
```

Either or both of these exclusion criteria may be used by entering an appropriate value for each question. As indicated by the prompting messages, entering a carriage return without a value disables the corresponding criterion. Values need to be entered in the same units as the areal-subset coverage.

WARNING: The software implements the geometric-exclusion criteria by setting the value of the category variable to a single blank character for all polygons containing less than minimum area or minimum area/perimeter ratio. Thus, when geometric exclusion is used, a blank should not be used in the areal-subset coverage to identify a category that will be used for site selection.

After geometric exclusion has been performed, or if the user selects not to perform geometric exclusion, the following prompting messages are displayed.

```
You may define a population using any of three methods:

 Code   Method

   1    Specify the approximate number of potential sites
   2    Specify the distance between each potential site
   3    Specify an existing point coverage

Enter a method code:
```

The first two methods create an equally spaced population and the third method uses a fixed population (see the "Approaches for defining the population of potential sites" section of this report).

When the first method is selected, the following prompting message is displayed.

```
Enter approximate number of sites (CR=10,000):
```

A positive integer should be entered. Because the origin of a population of equally spaced sites is placed randomly, the value entered is approximate. Typing a carriage return without entering a value causes the software to define a population with approximately 10,000 potential sites.

When the second method is selected, the following prompting message is displayed.

```
Enter distance between each site:
```

A positive number in length units of the areal-subset coverage should be entered.

When the third method is selected, the following prompting message is displayed.

```
Enter name of point coverage:
```

The name of the coverage containing the fixed population of potential sites should be entered. If the named coverage does not exist, the software displays an error message and displays the prompting message again.

After one of these three methods has been selected and the information required for the method has been entered, the software creates the coverage for the population of potential sites. Next, the main menu is displayed again, unless the random-selection with equal-area distribution method is being used.

When the random-selection with equal-area distribution method is used, additional prompting messages are displayed to elicit information used to create a coverage of subareas. These messages begin with the menu shown below.

```
You may define subareas using either of two methods:

 Code   Method

   1    Specify the approximate number of subareas, or
   2    Specify the width of subareas

Enter a method code:
```

The methods for defining subareas are similar to the first two methods for defining a population. However, in this case square polygons are defined, rather than points. If the first method is selected, the following prompting message is displayed.

```
Enter approximate number of subareas (CR=10,000):
```

A positive integer should be entered. If carriage return is typed without entering a value, approximately 10,000 subarea polygons are created.

The number of subareas determines the resolution of the cell boundaries that are created when sites are selected. A smaller number of subareas causes the percent-difference for areas of different cells to be larger and the boundaries of the cells to be more jagged than would a larger number of subareas.

If the second method is selected, the following prompting message is displayed.

```
Enter width of each subarea:
```

A positive number should be entered in length units of the areal-subset coverage. With this method, the user explicitly controls the resolution of cells.

After one of these two methods is used to define the subareas, the software creates a coverage of the subareas and displays the main menu.

Normally, the population of potential sites is created only once for a study region. **WARNING**: If the user defines the population again, after site selection has been performed, the coverage containing the results of the previous site selections will be deleted. When the population-definition option is selected from the main menu after a population coverage has been created already, the software displays the following prompting message.

```
If you continue, the coverage containing site selections is deleted!
Population coverage already exists, continue (CR=NO)?
```

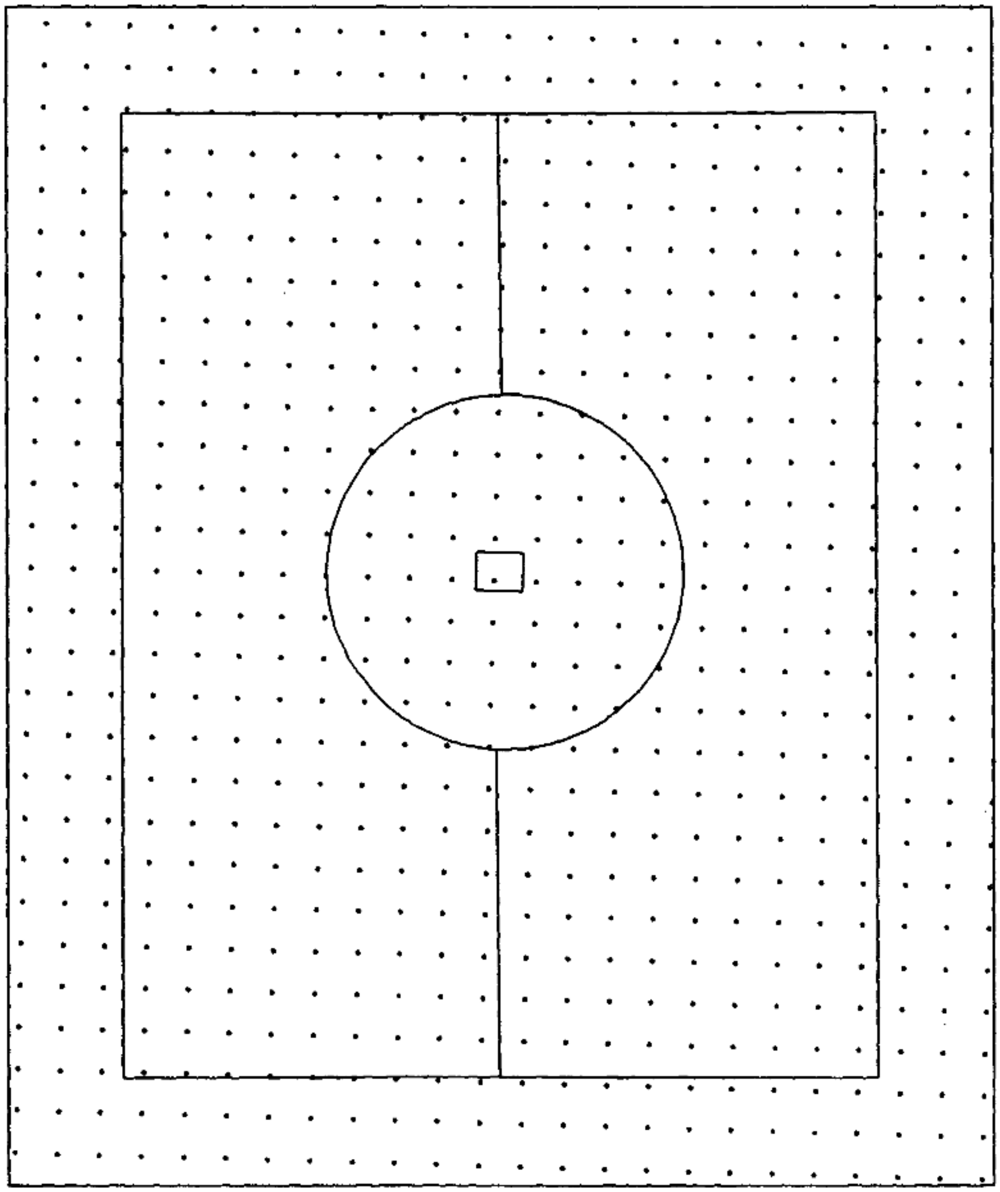
If a carriage return or a negative response is entered, the main menu is displayed again. If an affirmative response is entered, the coverage is deleted and the population is defined again.

The process for defining the population of potential sites is identical for all methods used for selecting sites. However, if the random-selection with equal-area distribution method has been specified and the population-definition option is selected from the main menu, the software creates a coverage of subareas in addition to the coverage of potential sites.

Sample Run

In this sample, an equally-spaced population (fig. 10) is defined and a subarea coverage (fig. 11) is created. Site-selection method two, random selection with equal-area distribution is specified (line 11). Because this method is selected, the software creates a coverage of subareas. In the sample site-selection sessions presented later in this report, "Selection of Sites", all three methods are used to select sites from the population created in the following sample session.

```
(  1)  Arc: &R SAMPLE
(  2)
(  3)  Site selection may be performed using one of three methods:
(  4)
(  5)    Code    Method
(  6)
(  7)      1     Simple random selection
(  8)      2     Random selection with equal-area distribution
(  9)      3     Random selection with iterating grids
( 10)
( 11)  Enter method code: 2
( 12)  Enter name of areal-subset coverage: LUSE
( 13)  Enter name of category variable: CATEGORY
( 14)
( 15)  Checking areal-subset coverage specifications
( 16)  Submitting command RESUME NAWSOFT>SAMP>FINAL>ITEXST.RUN
( 17)  Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
( 18)  INFO user name is ARC
( 19)  INFO file name is LUSE.PAT
( 20)  Variable name is CATEGORY
( 21)
( 22)  Site-selection software main menu
( 23)
( 24)    Code    Option
( 25)
( 26)      1     Define population
( 27)      3     Exit from site-selection software
( 28)
( 29)  Enter option code: 1
( 30)
( 31)  Do you wish to exclude areal subsets using geometry (CR=NO)? Y
( 32)  Copied LUSE to LUSE.SUB
( 33)  Enter minimum area (CR=no minimum): 300
( 34)  Enter minimum area/perimeter ratio (CR=no minimum):<CR>
( 35)  Submitting command INFO
( 36)   INFO  EXCHANGE  CALL
( 37)  FRI, OCT 13 1989
( 38)   INFO  9.42  12/ 1/86  52.74.63*
( 39)   COPYRIGHT 1986 HENCO SOFTWARE, INC.
( 40)   PROPRIETARY TO HENCO SOFTWARE, INC.
```



EXPLANATION
POTENTIAL SITE

Figure 10.--A population of potential sites for the hypothetical study region.

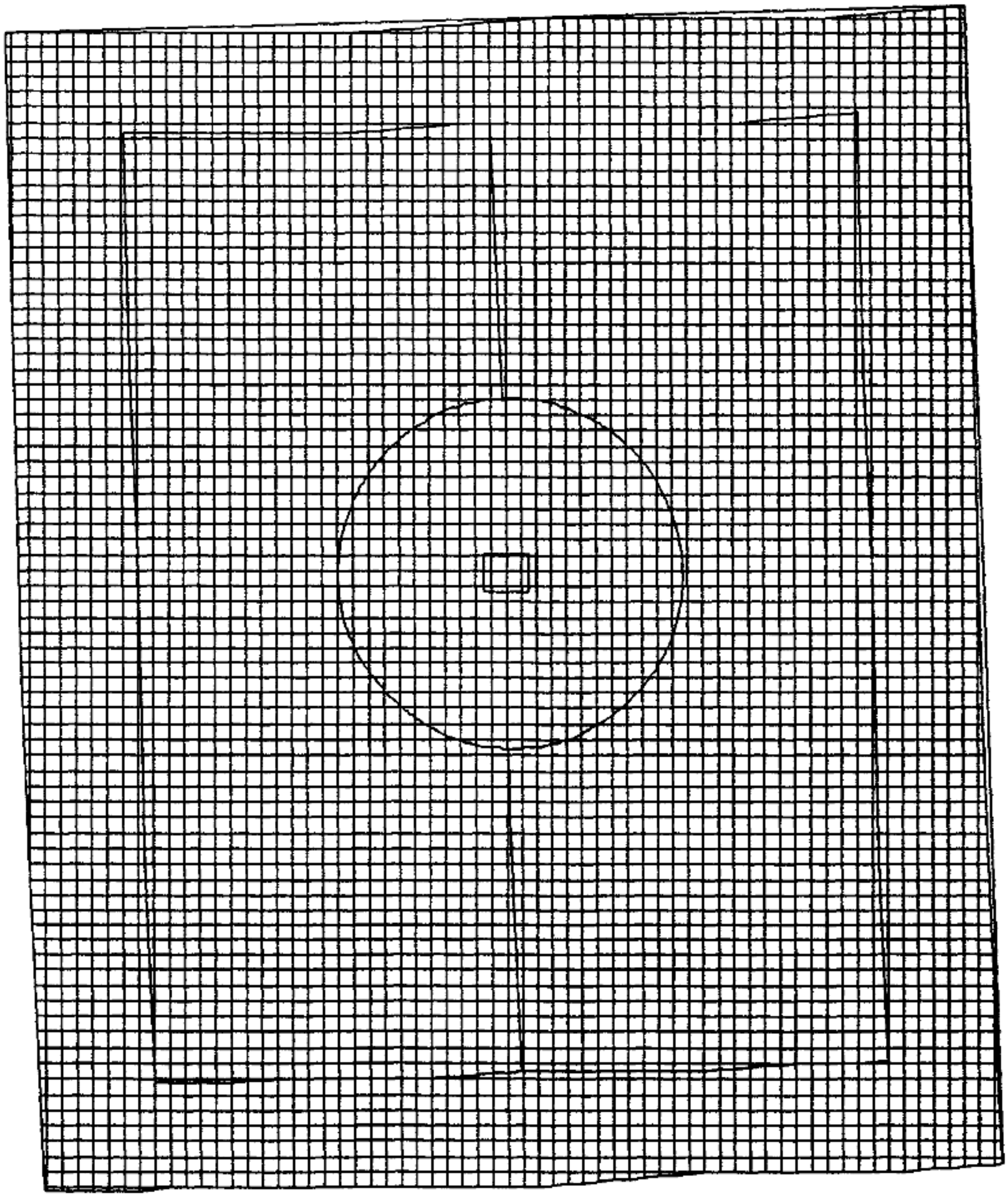


Figure 11.--Subareas of the hypothetical study region used to create cells for random selection of sites with equal-area distribution.

```
 US GOVT AGENCIES SEE USAGE RESTRICTIONS IN HELP FILES (HELP RESTRICTIONS)
 ENTER USER NAME>ARC

 ENTER COMMAND >SELECT LUSE.SUB.PAT
       6 RECORD(S) SELECTED

 ENTER COMMAND >RESELECT AREA LE 300
       2 RECORD(S) SELECTED

 ENTER COMMAND >MOVE ' ' TO CATEGORY

 ENTER COMMAND >QUIT STOP

You may define a population using any of three methods:

 Code   Method

   1    Specify the approximate number of potential sites
   2    Specify the distance between each potential site
   3    Specify an existing point coverage

Enter a method code: 1
Enter approximate number of sites (CR=10,000): 700
Defining population characteristics...
Submitting command RESUME NAWSOFT>SAMP>FINAL>GRIDIM.RUN
Boundary used from the coverage LUSE.SUB
Method code is 1
Approximate number is 700
Building a population with 750 sites...
(C) 1988 - 1990 Environmental Systems Research Institute, Inc.
    All Rights Reserved Worldwide
[GENERATE Version 5.0.1]


Externalling BND and TIC...

 Building points...
Clipping LUSE.GRID with LUSE to create LUSE.POP.
 Overlaying points...
 Creating LUSE.POP.PAT...
 Overlaying annotation...
Killed LUSE.GRID
 Producing identity of LUSE.GRID with LUSE.SUB to create LUSE.POP
 Overlaying points...
 Creating LUSE.POP.PAT...
** Item "AREA" duplicated, Join File version dropped **

** Item "PERIMETER" duplicated, Join File version dropped **

** Item "AREA" duplicated, Join File version dropped **

** Item "PERIMETER" duplicated, Join File version dropped **
```

```
Killed LUSE.GRID
Adding CHOSEN to LUSE.POP.PAT to produce LUSE.POP.PAT.
Adding UNIQUE to LUSE.POP.PAT to produce LUSE.POP.PAT.
Adding CELLNO to LUSE.POP.PAT to produce LUSE.POP.PAT.
 Dropping LUSE.SUB# from LUSE.POP.PAT to create LUSE.POP.PAT
 Dropping LUSE.SUB-ID from LUSE.POP.PAT to create LUSE.POP.PAT
 Dropping LUSE.GRID# from LUSE.POP.PAT to create LUSE.POP.PAT
 Dropping LUSE.GRID-ID from LUSE.POP.PAT to create LUSE.POP.PAT
Submitting command INFO
 INFO  EXCHANGE  CALL
FRI, OCT 13 1989
 INFO  9.42  12/ 1/86  52.74.63*
 COPYRIGHT 1986 HENCO SOFTWARE, INC.
 PROPRIETARY TO HENCO SOFTWARE, INC.
 US GOVT AGENCIES SEE USAGE RESTRICTIONS IN HELP FILES (HELP RESTRICTIONS)
 ENTER USER NAME>ARC

 ENTER COMMAND >SELECT LUSE.POP.PAT
     656 RECORD(S) SELECTED

 ENTER COMMAND >CALC UNIQUE = $RECNO

 ENTER COMMAND >Q STOP

Preparing category-index file, CATIDX, in INFO
Submitting command RESUME NAWSOFT>SAMP>FINAL>DEFIDX.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Coverage of areal subsets is LUSE
Coverage of population is LUSE.POP
Category-variable name is CATEGORY
Number of categories defined =    4
Defining subareas...

You may define subareas using either of two methods:

 Code   Method

   1    Specify the approximate number of subareas, or
   2    Specify the width of subareas

Enter a method code: 1
Enter approximate number of subareas (CR=10,000): 5000
Defining subarea characteristics...
Submitting command RESUME NAWSOFT>SAMP>FINAL>GRIDIM.RUN
Boundary used from the coverage LUSE.SUB
Method code is 1
Approximate number is 5000
Preparing 5148 subareas...
(C) 1988 - 1990 Environmental Systems Research Institute, Inc.
    All Rights Reserved Worldwide
[GENERATE Version 5.0.1]
```

```
(147)  Externalling BND and TIC...
(148)
(149)   Building polygons...
(150)  Clipping LUSE.SUBA with LUSE to create LUSE.GRID.
(151)   Sorting...
(152)   Intersecting...
(153)   Assembling polygons...
(154)   Creating new labels...
(155)   Creating NAWSOFT>SAMP>FINAL>LUSE.GRID.PAT...
(156)   Overlaying annotation...
(157)  Killed LUSE.SUBA
(158)   Unioning LUSE.SUB with LUSE.SUBA to create LUSE.GRID
(159)   Sorting...
(160)   Intersecting...
(161)   Assembling polygons...
(162)   Creating new labels...
(163)   Creating LUSE.GRID.PAT...
(164)  ** Item "AREA" duplicated, Join File version dropped **
(165)
(166)  ** Item "PERIMETER" duplicated, Join File version dropped **
(167)
(168)  ** Item "AREA" duplicated, Join File version dropped **
(169)
(170)  ** Item "PERIMETER" duplicated, Join File version dropped **
(171)
(172)  Adding CELL to LUSE.GRID.PAT to produce LUSE.GRID.PAT.
(173)  Adding VSTRIP to LUSE.GRID.PAT to produce LUSE.GRID.PAT.
(174)   Dropping LUSE.SUB# from LUSE.GRID.PAT to create LUSE.GRID.PAT
(175)   Dropping LUSE.SUB-ID from LUSE.GRID.PAT to create LUSE.GRID.PAT
(176)   Dropping LUSE.SUBA# from LUSE.GRID.PAT to create LUSE.GRID.PAT
(177)   Dropping LUSE.SUBA-ID from LUSE.GRID.PAT to create LUSE.GRID.PAT
(178)  Killed LUSE.SUB
(179)  Killed LUSE.SUBA
(180)
(181)  Site-selection software main menu
(182)
(183)    Code    Option
(184)
(185)      1     Define population
(186)      2     Select sites from population
(187)      3     Exit from site-selection software
(188)
(189)  Enter option code: 3
(190)  Arc:
```

The session begins with entry of the site-selection method code, the name of the areal-subset coverage, and the name of the category variable (lines 1-13). The specifications are checked by the software (lines 14-20). Next, the main-menu is displayed (lines 21-29) and the option code is entered.

The user excludes areal subsets with fewer than 300 coverage area units (lines 31-34). Operational messages are displayed during the geometric-exclusion process (lines 35-53). The small rectangular areal subset in the center of figure 7 is excluded. The population-definition menu is displayed (lines 54-62), and an equally-spaced population with approximately 700 sites is specified (lines 62-63). Operational and informative messages are displayed during creation of the population coverage (lines 64-117). Then, the category-index file is created (lines 118-124).

If the random-selection with equal-area distribution method had not been specified, the software would have displayed the main menu beginning on line 125. However in the sample session, the menu for defining subareas is displayed (lines 125-134). Approximately 5,000 subareas are specified (lines 134-135). Operational and informative messages are displayed during creation of the subarea coverage (lines 136-179). Finally, the main menu is displayed and the session is ended (lines 180-189).

Selection of Sites

Options

Selection of sites begins when the second option of the main menu, "Select sites from population", is chosen. Three prompting messages are displayed consecutively to elicit information about the site selection, as shown below. When the software displays these messages, the word CATEGORY is replaced by the user-specified category-variable name, and word the VALUE is replaced by the user's response to the first prompting message.

```
Enter value of CATEGORY for site selection (or QUIT):
Enter number of primary sites to be selected when CATEGORY = VALUE:
Enter number of alternate sites (CR = 2):
```

When the first prompting message is displayed, the name of the category from which sites will be selected should be entered. If a carriage return is typed without entering a category or the word QUIT is entered, the software stops and the "Arc:" prompting message is displayed.

When the second prompting message is displayed, the number of primary sites to be selected from the previously identified category should be entered. A positive integer is entered normally. If a negative or zero value is entered, the software stops and the "Arc:" prompting message is displayed.

When the third prompting message is displayed, the number of alternate sites to be selected should be entered. Typing a carriage return without entering a value causes two alternate sites to be chosen for each primary site selected.

After the user has responded to all three prompting messages, the user-specified category value is checked to ensure that at least one areal subset is identified with the category value. If not, an error message is displayed and the first of the three prompting messages is displayed again.

Next, a check is made to determine if sites have previously been selected for the user-specified category value. If so, the following prompting message is displayed.

```
Do you want to reselect sites for this category (CR=NO)?
```

WARNING: If an affirmative response is entered, the results of the previous site selection will be removed from the population coverage and sites will be selected for the category again. If a negative response is entered, the three prompting messages that begin site selection are displayed again, beginning with "Enter value of CATEGORY...".

If the simple random-selection or the random-selection with equal-area distribution method is used, the software begins the site selection process. If the random-selection with iterating grids method is used, three more prompting messages are displayed consecutively as shown below.

```
Enter fraction of cells to attain 3 sites for convergence, (CR = .75):
Enter maximum number of iterations, (CR = 8):
Enter damping factor, (CR = .90):
```

When the first prompting message is displayed, the software displays the number of rounds where the number three is shown above. The user enters a value between zero and one to complete the specifications for the secondary convergence criteria. A value of one disables secondary convergence. (See the "Random selection with iterating grids" section of this report.) If a carriage return is typed without entering a value, the fraction-of-cells variable is set to 0.75.

After the second prompting message is displayed, the user enters the maximum number of gridding iterations to be tried. If a carriage return is typed without entering a value, a maximum of eight iterations will be used.

If the maximum number of iterations is reached without finding a grid that meets the convergence criteria, the user is given the opportunity to enter different specifications for site selection. In this case, the prompting messages shown at the beginning of this section of the report ("Selection of sites") are displayed again.

After the third prompting message is displayed, the user enters a damping factor. The user-specified damping factor sometimes is used by the software for preparing a new grid after a failed iteration, as explained in the "Random selection with iterating grids" section of this report. If a carriage return is typed without entering a value, the user-specified damping factor is set to 0.90.

At the end of each failed iteration, the software displays informative messages pertaining to the results of the iteration. These informative messages can be used for specifying a different damping factor if the maximum number of iterations is reached without finding a satisfactory grid.

If the number of cells in the grid that contain at least η_r sites is consistently larger than the desired number of sites, a larger damping factor or a larger number of alternate sites should be used. If the number of cells in the grid that contain η_r sites oscillates above and below the desired number of primary sites, the damping factor should be decreased.

Sample run using simple random selection

In this sample, four sites are selected from the previously defined population using the simple random-selection method. Lines 1-29 differ from the previous sample session only where the site-selection method is specified on line 11.

```
(  1)  Arc: &R SAMPLE
(  2)
(  3)  Site selection may be performed using one of three methods:
(  4)
(  5)    Code    Method
(  6)
(  7)      1     Simple random selection
(  8)      2     Random selection with equal-area distribution
(  9)      3     Random selection with iterating grids
( 10)
( 11)  Enter method code: 1
( 12)  Enter name of areal-subset coverage: LUSE
( 13)  Enter name of category variable: CATEGORY
( 14)
( 15)  Checking areal-subset coverage specifications
( 16)  Submitting command RESUME NAWSOFT>SAMP>FINAL>ITEXST.RUN
( 17)  Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
( 18)  INFO user name is ARC
( 19)  INFO file name is LUSE.PAT
( 20)  Variable name is CATEGORY
( 21)
( 22)  Site-selection software main menu
( 23)
( 24)    Code    Option
( 25)
( 26)      1     Define population
( 27)      2     Select sites from population
( 28)      3     Exit from site-selection software
( 29)
( 30)  Enter option code: 2
( 31)
( 32)  Ready for site selection...
( 33)
( 34)  Enter value of CATEGORY for site selection (CR = QUIT): URBAN
( 35)  Enter number of primary sites to be selected when CATEGORY = URBAN: 4
( 36)  Enter number of alternate sites (CR = 2): <CR>
( 37)  Submitting command RESUME NAWSOFT>SAMP>FINAL>CHKIDX.RUN
( 38)  Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
( 39)  Category is URBAN
( 40)  Submitting command RESUME NAWSOFT>SAMP>FINAL>PICKEM.RUN
( 41)  Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
```

```
( 42)  Coverage of population is LUSE.POP
( 43)  Selection expression is CATEGORY EQ 'URBAN'
( 44)  Number of primary sites is 4
( 45)  Number of alternate sites is 2
( 46)    178 sites in the cell
( 47)  Site selection completed....Updating index file...
( 48)  Submitting command RESUME NAWSOFT>SAMP>FINAL>UPTIDX.RUN
( 49)  Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
( 50)  Category is URBAN
( 51)  Number of primary sites is 4
( 52)  Preparing plot file:  #LUSE.URBAN
( 53)  (C) 1988 - 1990 Environmental Systems Research Institute, Inc.
( 54)      All Rights Reserved Worldwide
( 55)  ARCPLOT Version 5.0.1
( 56)
( 57)  Enter Plot filename #LUSE.URBAN
( 58)  LUSE.POP points : 12 of 656 selected.
( 59)  Leaving ARCPLOT...
( 60)
( 61)  Saving locations of selected sites...
( 62)  Submitting command RESUME NAWSOFT>SAMP>FINAL>CATRPT.RUN
( 63)  Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
( 64)  Coverage of population is LUSE.POP
( 65)  Category-variable name is CATEGORY
( 66)  Category is URBAN
( 67)  Cell-variable name is
( 68)  Projecting to latitude-longitude...
( 69)  Locations projected......formatting report...
( 70)  Submitting command RESUME NAWSOFT>SAMP>FINAL>FCATRP.RUN
( 71)  Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
( 72)  Category is URBAN
( 73)  Number of primary sites is 4
( 74)  Number of alternate sites is 2
( 75)
( 76)  Report is ready in the file:   SITE.REPORT.URBAN
( 77)
( 78)  Site-selection software main menu
( 79)
( 80)    Code    Option
( 81)
( 82)      1     Define population
( 83)      2     Select sites from population
( 84)      3     Exit from site-selection software
( 85)
( 86)  Enter option code: 3
( 87)  Arc:
```

The main menu is displayed and the option to select sites is specified (lines 21-30). The user specifies selection of four sites from category "URBAN" with two alternate sites each (lines 34-36).

Operational and informative messages are displayed on lines 37-76. The first operation (lines 37-39) checks that a valid category value was entered and that a sufficient number of potential sites exist. The second operation randomly selects sites (lines 40-46). The third operation updates the category-index file (lines 47-51). The fourth operation writes the binary plot file (lines 52-59). The fifth operation prepares the site-selection report (lines 60-76). The main menu is displayed again on lines 78-86. The plot file created during this sample session is shown in figure 9.

Sample run using random selection with equal-area distribution

Four sites in category "MIXED" are chosen using the random-selection with equal-area distribution method. The first 29 lines of this sample are the same as the sample presented for defining the population. The option to select sites is chosen (line 30). Again, four sites with two alternate sites each are specified (lines 35-36).

```
(  1)  Arc: &R SAMPLE
(  2)
(  3)  Site selection may be performed using one of three methods:
(  4)
(  5)    Code    Method
(  6)
(  7)      1      Simple random selection
(  8)      2      Random selection with equal-area distribution
(  9)      3      Random selection with iterating grids
( 10)
( 11)  Enter method code: 2
( 12)  Enter name of areal-subset coverage: LUSE
( 13)  Enter name of category variable: CATEGORY
( 14)
( 15)  Checking areal-subset coverage specifications
( 16)  Submitting command RESUME NAWSOFT>SAMP>FINAL>ITEXST.RUN
( 17)  Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
( 18)  INFO user name is ARC
( 19)  INFO file name is LUSE.PAT
( 20)  Variable name is CATEGORY
( 21)
( 22)  Site-selection software main menu
( 23)
( 24)    Code    Option
( 25)
( 26)      1      Define population
( 27)      2      Select sites from population
( 28)      3      Exit from site-selection software
( 29)
( 30)  Enter option code: 2
( 31)
( 32)  Ready for site selection...
( 33)
( 34)  Enter value of CATEGORY for site selection (CR = QUIT): MIXED
( 35)  Enter number of primary sites to be selected when CATEGORY = MIXED: 4
( 36)  Enter number of alternate sites (CR = 2): <CR>
( 37)  Submitting command RESUME NAWSOFT>SAMP>FINAL>CHKIDX.RUN
```

```
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Category is MIXED

Creating 4 equal-area cells
Submitting command RESUME NAWSOFT>SAMP>FINAL>EQARSA.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Coverage of subarea polygons is LUSE.SUBA
Category-variable name is CATEGORY
Category is MIXED
Number of primary sites is 4
Number of alternate sites is 2
Number of vertical strips =              2
       Total area         =          47749.63
       Strip area         =          23874.81
   Equal area for cell    =          11937.41  (25.0%)

            Equal-area grid cells:

          Cell      Area        Percentage
            1    11938.7         (25.0%)
            2    11937.5         (25.0%)
            3    11952.0         (25.0%)
            4    11921.4         (25.0%)
 Producing identity of LUSE.POP with LUSE.SUBA to create LUSE.SAM
 Overlaying points...
 Creating LUSE.SAM.PAT...
** Item "AREA" duplicated, Join File version dropped **

** Item "PERIMETER" duplicated, Join File version dropped **

** Item "AREA" duplicated, Join File version dropped **

** Item "PERIMETER" duplicated, Join File version dropped **

** Item "CATEGORY" duplicated, Join File version dropped **

Preparing coverage of equal-area cells
 Dissolving LUSE.SUBA by CELL to create LUSE.CELL.MIXED
 Creating LUSE.CELL.MIXED.PAT format...
 Creating dissolve table...
 Dissolving...
Number of Polygons (Input,Output) =      5168          5
Number of Arcs     (Input,Output) =     10473          9
 Creating LUSE.CELL.MIXED.PAT...
Selecting sites from cell #1

Submitting command RESUME NAWSOFT>SAMP>FINAL>PICKEM.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Coverage of population is LUSE.SAM
Selection expression is CELL = 1 AND CATEGORY EQ 'MIXED'
Number of primary sites is 1
Number of alternate sites is 2
   38 sites in the cell
```

```
Selecting sites from cell #2

Submitting command RESUME NAWSOFT>SAMP>FINAL>PICKEM.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Coverage of population is LUSE.SAM
Selection expression is CELL = 2 AND CATEGORY EQ 'MIXED'
Number of primary sites is 1
Number of alternate sites is 2
   49 sites in the cell
Selecting sites from cell #3

Submitting command RESUME NAWSOFT>SAMP>FINAL>PICKEM.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Coverage of population is LUSE.SAM
Selection expression is CELL = 3 AND CATEGORY EQ 'MIXED'
Number of primary sites is 1
Number of alternate sites is 2
   44 sites in the cell
Selecting sites from cell #4

Submitting command RESUME NAWSOFT>SAMP>FINAL>PICKEM.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Coverage of population is LUSE.SAM
Selection expression is CELL = 4 AND CATEGORY EQ 'MIXED'
Number of primary sites is 1
Number of alternate sites is 2
   48 sites in the cell
Site selection completed....Updating index file...
Submitting command RESUME NAWSOFT>SAMP>FINAL>UPTIDX.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Category is MIXED
Number of primary sites is 4
Recording results in population coverage
Submitting command INFO
 INFO  EXCHANGE  CALL
MON, OCT 16 1989
 INFO  9.42  12/ 1/86  52.74.63*
 COPYRIGHT 1986 HENCO SOFTWARE, INC.
 PROPRIETARY TO HENCO SOFTWARE, INC.
 US GOVT AGENCIES SEE USAGE RESTRICTIONS IN HELP FILES (HELP RESTRICTIONS)
 ENTER USER NAME>ARC

 ENTER COMMAND >SELECT LUSE.SAM.PAT
     656 RECORD(S) SELECTED

 ENTER COMMAND >RELATE LUSE.POP.PAT UNIQUE

 ENTER COMMAND >RESELECT CATEGORY = 'MIXED'
     179 RECORD(S) SELECTED

 ENTER COMMAND >CALC $1CELLNO = CELL

 ENTER COMMAND >CALC $1CHOSEN =  CHOSEN
```

```
(144)
(145)  ENTER COMMAND >Q STOP
(146) Preparing plot file:  #LUSE.MIXED
(147) (C) 1988 - 1990 Environmental Systems Research Institute, Inc.
(148)     All Rights Reserved Worldwide
(149) ARCPLOT Version 5.0.1
(150)
(151) Enter Plot filename #LUSE.MIXED
(152) LUSE.SAM points : 12 of 656 selected.
(153) Leaving ARCPLOT...
(154)
(155) Saving locations of selected sites...
(156) Submitting command RESUME NAWSOFT>SAMP>FINAL>CATRPT.RUN
(157) Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
(158) Coverage of population is LUSE.SAM
(159) Category-variable name is CATEGORY
(160) Category is MIXED
(161) Cell-variable name is CELL
(162) Projecting to latitude-longitude...
(163) Locations projected......formatting report...
(164) Submitting command RESUME NAWSOFT>SAMP>FINAL>FCATRP.RUN
(165) Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
(166) Category is MIXED
(167) Number of primary sites is 4
(168) Number of alternate sites is 2
(169)
(170) Report is ready in the file:   SITE.REPORT.MIXED
(171)
(172) Site-selection software main menu
(173)
(174)   Code    Option
(175)
(176)     1     Define population
(177)     2     Select sites from population
(178)     3     Exit from site-selection software
(179)
(180) Enter option code: 3
(181) Arc:
```

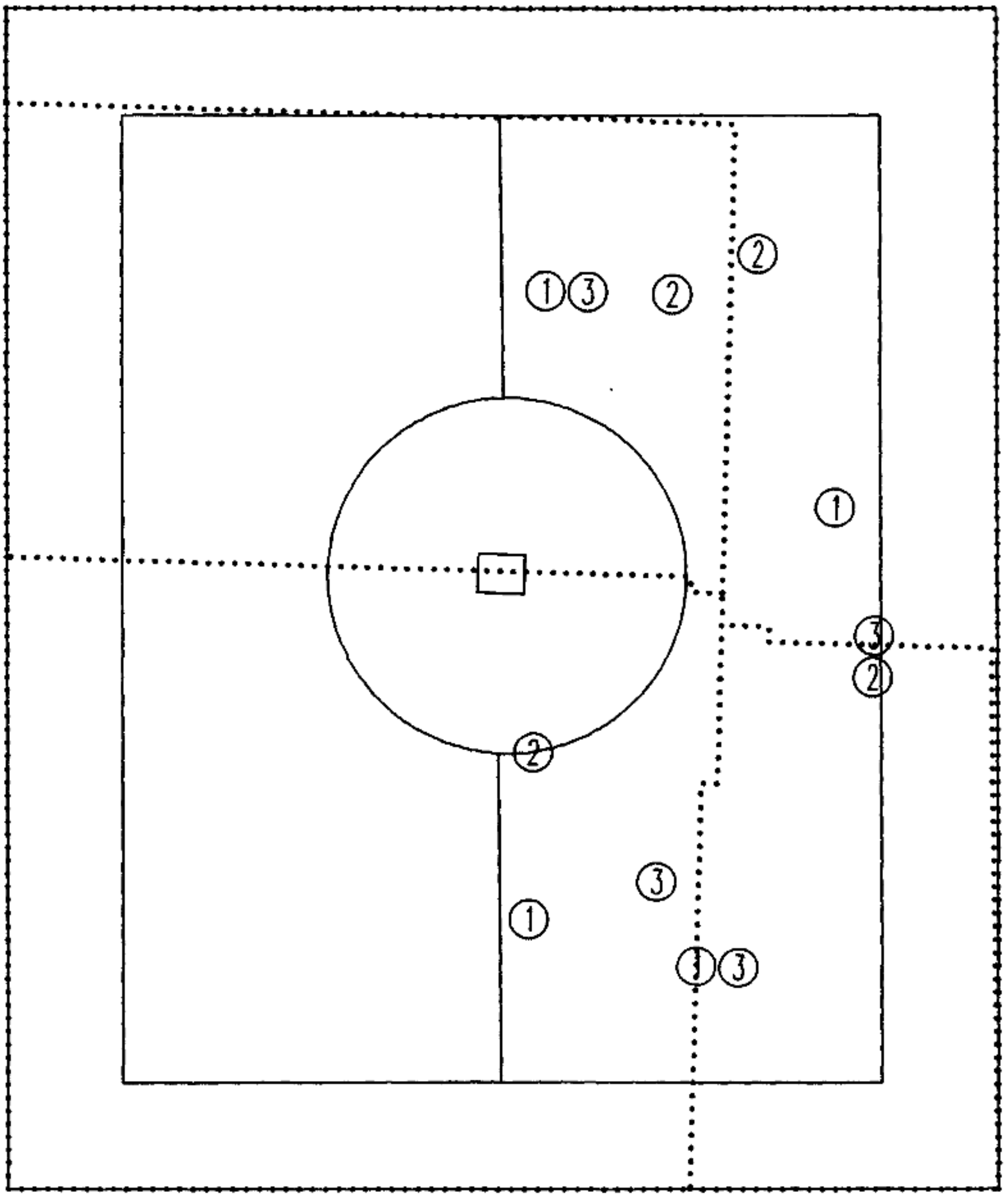
All of the operations during the simple random site-selection sample session are performed in this sample; however, some additional operations are performed. As before, the user's specifications are checked (lines 37-39). The next operation aggregates the subareas into equal-area cells (lines 40-60). The results of computations for the desired areas of strips and cells are displayed (lines 49-52). Next, the actual areas of the cells prepared by aggregating the subareas are shown (lines 53-60). The next group of operational messages (lines 61-72) are displayed while the software determines the cell in which each potential site is located. A coverage of the cells is created (lines 73-81).

Next, one primary and two alternate sites are selected from each cell. This operation is repeated for the user-specified number of primary sites (lines 82-90, 91-99, 100-108, and 109-117). The category-index file is updated (lines 118-122), the results of the site selections are saved in the population coverage (lines 123-145), a plot file is prepared (lines 146-153), and a site-selection report is written (lines 154-170). Finally, the main menu is displayed again (lines 171-180). The cells created and the sites selected for category "MIXED" are shown in figure 12.

Sample run using random selection with iterating grids

This sample shows use of the random-selection with iterating grids method to select four sites from category "RURAL" (lines 1-35). Again, two alternate sites are specified for each primary site selected (lines 35-36). As with the two previous samples, the user's specifications are checked (lines 37-39). Next, the three iteration-control variables are entered (lines 40-42).

```
(  1)  Arc: &R SAMPLE
(  2)
(  3)  Site selection may be performed using one of three methods:
(  4)
(  5)    Code    Method
(  6)
(  7)      1     Simple random selection
(  8)      2     Random selection with equal-area distribution
(  9)      3     Random selection with iterating grids
( 10)
( 11)  Enter method code: 3
( 12)  Enter name of areal-subset coverage: LUSE
( 13)  Enter name of category variable: CATEGORY
( 14)
( 15)  Checking areal-subset coverage specifications
( 16)  Submitting command RESUME NAWSOFT>SAMP>FINAL>ITEXST.RUN
( 17)  Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
( 18)  INFO user name is ARC
( 19)  INFO file name is LUSE.PAT
( 20)  Variable name is CATEGORY
( 21)
( 22)  Site-selection software main menu
( 23)
( 24)    Code    Option
( 25)
( 26)      1     Define population
( 27)      2     Select sites from population
( 28)      3     Exit from site-selection software
( 29)
( 30)  Enter option code: 2
( 31)
( 32)  Ready for site selection...
( 33)
( 34)  Enter value of CATEGORY for site selection (CR = QUIT): RURAL
( 35)  Enter number of primary sites to be selected when CATEGORY = RURAL: 4
( 36)  Enter number of alternate sites (CR = 2): <CR>
```



EXPLANATION

··· CELL BOUNDARY

○ SELECTED SITE, ROUND NUMBER SHOWN INSIDE CIRCLE

Figure 12.--Results of selecting sites from the "MIXED" category using random selection with equal-area distribution.

```
Submitting command RESUME NAWSOFT>SAMP>FINAL>CHKIDX.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Category is RURAL
Enter fraction of cells to attain 3 sites for convergence, (CR = .75): <CR>
Enter maximum number of iterations, (CR = 8): 10
Enter damping factor, (CR = .90): 1.5
Making an initial guess at grid characteristics...
Submitting command RESUME NAWSOFT>SAMP>FINAL>NFLATE.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Category is RURAL
Number of primary sites is 4
Number of alternate sites is 2
Defining cell characteristics...
Submitting command RESUME NAWSOFT>SAMP>FINAL>GRIDIM.RUN
Boundary used from the coverage LUSE
Method code is 1
Approximate number is 8
Constructing a grid with 12 cells...
(C) 1988 - 1990 Environmental Systems Research Institute, Inc.
    All Rights Reserved Worldwide
[GENERATE Version 5.0.1]
Externalling BND and TIC...
 Building polygons...
Killed LUSE.SAM
 Producing identity of LUSE.POP with LUSE.CELL.RURAL to create LUSE.SAM
 Overlaying points...
 Creating LUSE.SAM.PAT...
** Item "AREA" duplicated, Join File version dropped **
** Item "PERIMETER" duplicated, Join File version dropped **
** Item "AREA" duplicated, Join File version dropped **
** Item "PERIMETER" duplicated, Join File version dropped **
Checking for convergence...
Submitting command RESUME NAWSOFT>SAMP>FINAL>SAMINF.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Coverage of iteration results is LUSE.SAM
Cell-variable name is LUSE.CELL.RURAL-ID
Category-variable name is CATEGORY
Category is RURAL
Number ‹f primary sites is 4
Current number of cells is 12
Number of alternate sites is 2
Percentage required for convergence is .75
Damping factor is 1.5
```

```
***********************************************************************
Iteration failed to converge using    12 cells
Average populated cell contained 18.6 sites
  16 cells contained at least   3 sites.
Next iteration will use at least      3 cells
***********************************************************************
Convergence failed on iteration #1
Defining cell characteristics...

.
.
.

***********************************************************************
Iteration failed to converge using     4 cells
Average populated cell contained 33.1 sites
   9 cells contained at least   3 sites.
Next iteration will use at least      2 cells
***********************************************************************
Convergence failed on iteration #2
Defining cell characteristics...

.
.
.

***********************************************************************
Iteration failed to converge using     4 cells
Average populated cell contained 49.7 sites
   6 cells contained at least   3 sites.
Next iteration will use at least      3 cells
***********************************************************************
Convergence failed on iteration #3
Defining cell characteristics...

.
.
.

***********************************************************************
Iteration failed to converge using     4 cells
Average populated cell contained 33.1 sites
   9 cells contained at least   3 sites.
Next iteration will use at least      2 cells
***********************************************************************
Convergence failed on iteration #4
Defining cell characteristics...
Submitting command RESUME NAWSOFT>SAMP>FINAL>GRIDIM.RUN
Boundary used from the coverage LUSE
Method code is 1
Approximate number is 2
```

```
Constructing a grid with 2 cells...
Killed LUSE.CELL.RURAL
(C) 1988 - 1990 Environmental Systems Research Institute, Inc.
    All Rights Reserved Worldwide
[GENERATE Version 5.0.1]
Externalling BND and TIC
 Building polygons...
Killed LUSE.SAM
 Producing identity of LUSE.POP with LUSE.CELL.RURAL to create LUSE.SAM
 Overlaying points...
 Creating LUSE.SAM.PAT...
** Item "AREA" duplicated, Join File version dropped **
** Item "PERIMETER" duplicated, Join File version dropped **
** Item "AREA" duplicated, Join File version dropped **
** Item "PERIMETER" duplicated, Join File version dropped **
Checking for convergence...
Submitting command RESUME NAWSOFT>SAMP>FINAL>SAMINF.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Coverage of iteration results is LUSE.SAM
Cell-variable name is LUSE.CELL.RURAL-ID
Category-variable name is CATEGORY
Category is RURAL
Number of primary sites is 4
Current number of cells is 2
Number of alternate sites is 2
Percentage required for convergence is .75
Damping factor is 1.5
Site selection completed....Updating index file...
Submitting command RESUME NAWSOFT>SAMP>FINAL>UPTIDX.RUN
Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
Category is RURAL
Number of primary sites is 4
Recording results in population coverage
Submitting command INFO
 INFO  EXCHANGE  CALL
MON, OCT 16 1989
 INFO  9.42  12/ 1/86  52.74.63*
 COPYRIGHT 1986 HENCO SOFTWARE, INC.
 PROPRIETARY TO HENCO SOFTWARE, INC.
 US GOVT AGENCIES SEE USAGE RESTRICTIONS IN HELP FILES (HELP RESTRICTIONS)
 ENTER USER NAME>ARC
```

```
(291)    ENTER COMMAND >SELECT LUSE.SAM.PAT
(292)        656 RECORD(S) SELECTED
(293)
(294)    ENTER COMMAND >RELATE LUSE.POP.PAT UNIQUE
(295)
(296)    ENTER COMMAND >RESELECT CATEGORY = 'RURAL'
(297)        298 RECORD(S) SELECTED
(298)
(299)    ENTER COMMAND >CALC $1CELLNO = LUSE.CELL.RURAL-ID
(300)
(301)    ENTER COMMAND >CALC $1CHOSEN =  CHOSEN
(302)
(303)    ENTER COMMAND >Q STOP
(304)   Preparing plot file:  #LUSE.RURAL
(305)   (C) 1988 - 1990 Environmental Systems Research Institute, Inc.
(306)       All Rights Reserved Worldwide
(307)   ARCPLOT Version 5.0.1
(308)
(309)   Enter Plot filename #LUSE.RURAL
(310)   LUSE.SAM points : 12 of 656 selected.
(311)   Leaving ARCPLOT...
(312)
(313)   Saving locations of selected sites...
(314)   Submitting command RESUME NAWSOFT>SAMP>FINAL>CATRPT.RUN
(315)   Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
(316)   Coverage of population is LUSE.SAM
(317)   Category-variable name is CATEGORY
(318)   Category is RURAL
(319)   Cell-variable name is LUSE.CELL.RURAL-ID
(320)   Projecting to latitude-longitude...
(321)   Locations projected......formatting report...
(322)   Submitting command RESUME NAWSOFT>SAMP>FINAL>FCATRP.RUN
(323)   Directory of INFO data base is NAWSOFT>SAMP>FINAL>INFO
(324)   Category is RURAL
(325)   Number of primary sites is 4
(326)   Number of alternate sites is 2
(327)
(328)   Report is ready in the file:   SITE.REPORT.RURAL
(329)
(330)   Site-selection software main menu
(331)
(332)     Code    Option
(333)
(334)       1     Define population
(335)       2     Select sites from population
(336)       3     Exit from site-selection software
(337)
(338)   Enter option code: 3
(339)   Arc:
```

The characteristics of the first grid are calculated (lines 43-53), the grid coverage is prepared (lines 54-74), and the grid is compared to the user-specified convergence criteria (lines 75-87). Convergence is not attained on the first iteration and informative messages are displayed (lines 88-94).

The amount of time required to select sites and number of lines displayed on the terminal can be large because the site-selection process with this method is iterative. A satisfactory grid was found for this sample problem on the fifth iteration. To avoid unnecessary repetition in this report, lines 96-134, 143-181, and 190-228 were omitted. These lines contain operational and informative messages for the second, third, and fourth iterations similar to those printed for the first iteration (lines 50-87).

The operational and informative messages displayed during the fifth iteration (lines 236-275) are similar to messages displayed during the first iteration. The remainder of the sample session is similar to the previous sample. The category-index file is updated (lines 276-280), the site selections are stored in the population coverage (lines 281-303), the plot file is written (lines 304-311), and the site-selection report is prepared (lines 312-328), and the main menu is displayed (lines 330-338).

The cells created and the sites selected during this sample session are shown in figure 13.

Site Selection for the Central Oklahoma Aquifer Study Region

The site-selection software has been tested and applied to several hydrologic studies. Water-quality site selection for the Central Oklahoma aquifer NAWQA project (Christenson and Parkhurst, 1987) was performed using the software. Areal subsets were identified by hydrogeologic unit. An equally spaced population of potential sites was created for the study region and sites were selected using the random-selection with equal-area distribution method. The existing well suitable for sampling nearest the selected location was found in the field and used for water-quality sampling. This technique was workable because the population of existing wells in central Oklahoma is large and evenly distributed throughout the study region.

A three-dimensional network was designed for the Central Oklahoma NAWQA study region by using three areal-subset coverages. The first areal-subset coverage identified alluvium and terrace deposits. The second areal-subset coverage contained shallow and medium depth hydrogeologic units, and the third coverage contained deep hydrogeologic units. Site selection was performed separately with each coverage.

Alluvium and terrace deposits overlie approximately one third of the study area. An equally spaced population of potential sites (fig. 14) was created using the site-selection software. Sixty primary sites for the alluvium and terrace deposits were selected. Two alternate sites were selected for each primary site. Thus, 3 sites were selected from each of 60 equal-area cells (fig. 15).

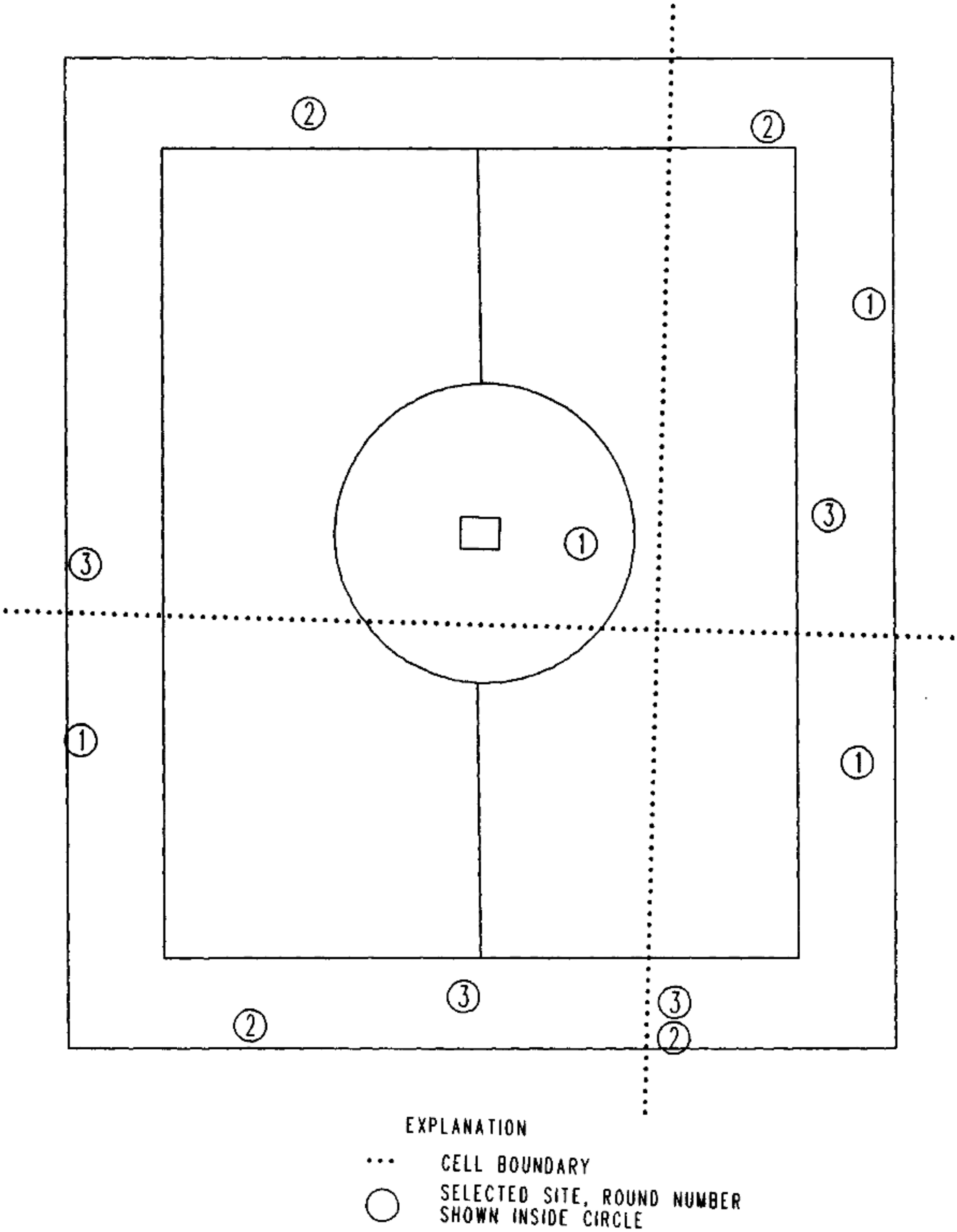


Figure 13.--Results of selecting sites from the "RURAL" category using random selection with iterating grids.

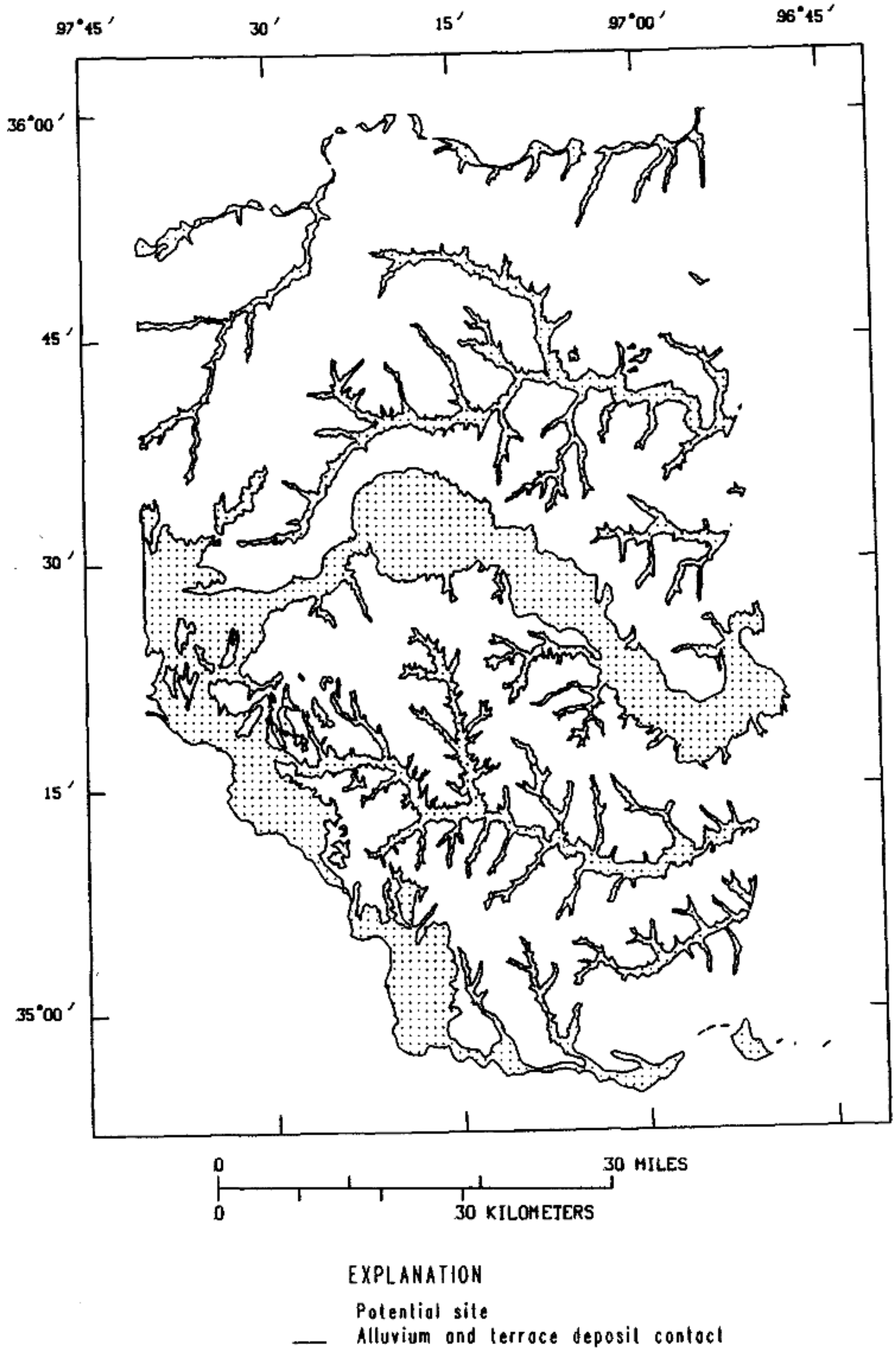


Figure 14.--Equally spaced population of potential sites in the alluvium and terrace deposits of the Central Oklahoma aquifer study unit.

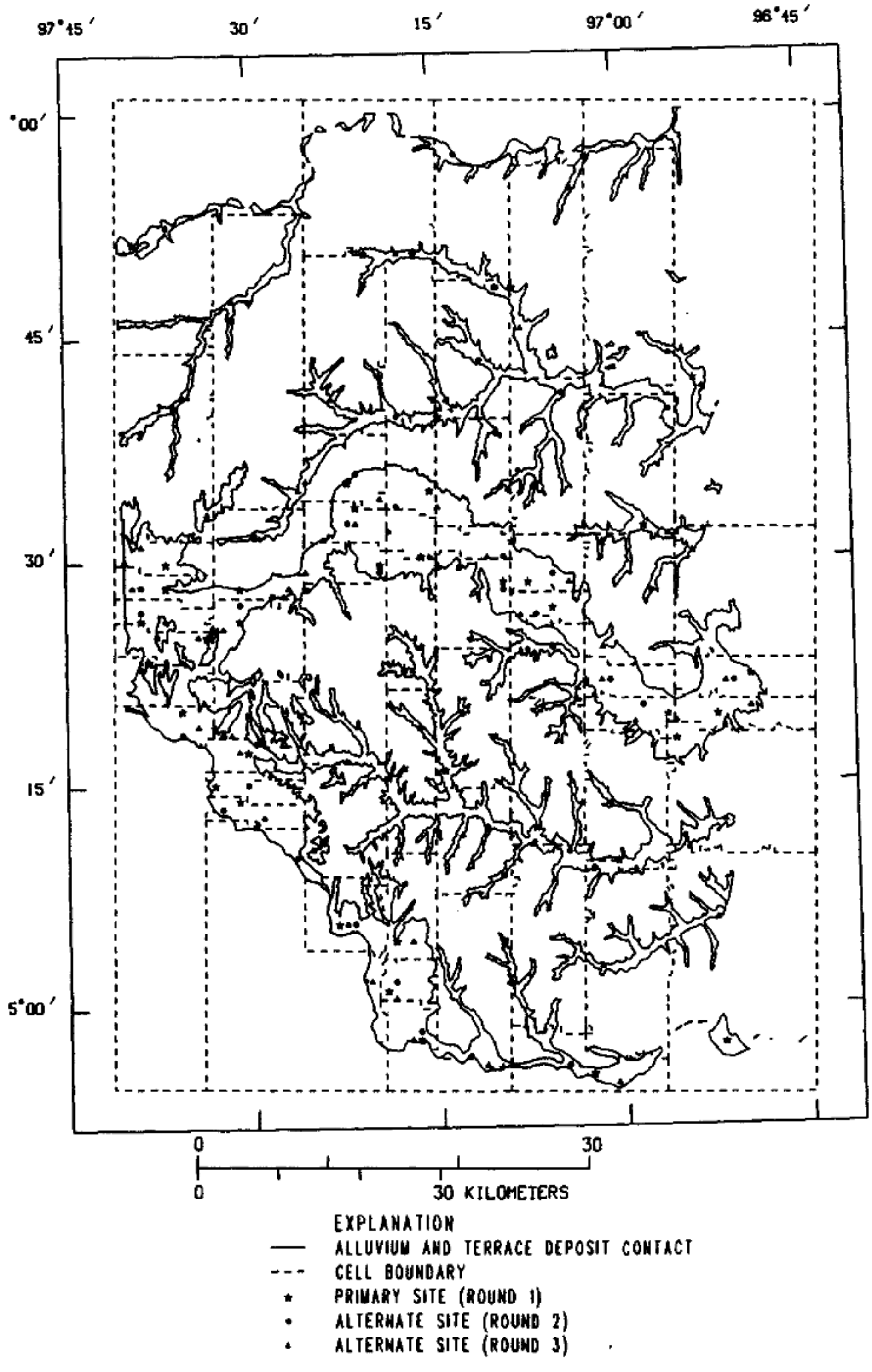


Figure 15.--Site selections in the alluvium and terrace deposits for the Central Oklahoma aquifer study unit.

SOFTWARE DESIGN

Installation of the Software

The SAMPLE.AML program uses 11 Fortran programs to perform various operations during the population-definition and site-selection processes (table 3). Four of the Fortran programs contain the $INSERT compiler directive to insert the statements presented in attachment B. The inserted statements define five integer variables that limit the maximum sizes of arrays used in the software. The values of the five variables may need to be increased in order to use the software for some problems. The values for the first four variables can be determined by examining the characteristics of the site-selection problem. There is no general method for determining in advance the required size for the fifth variable.

If any of the array limits are reached when the software is running, an error message is printed and the program stops. If this occurs, the value of the corresponding array limit should be increased, and the affected Fortran programs should be recompiled and linked. Then the site-selection software can be run again.

All 11 Fortran programs should be compiled and linked before the site-selection software is used on a computer system. A Command Procedure Language (CPL) (Landy, 1982) program for compiling and linking the programs on a Prime computer system is shown below. To use the program, the statements in attachment B need to be stored in a file named SAMPLE.INSERT, the subroutines in attachment C need to be stored in a file named SUBS.F77, and the programs in attachments D-M need to be stored in files named by joining together the name of the program and the characters ".F77".

```
F77 SUBS
&DO PROG &LIST ITEXST CATRPT DEFIDX EQARSA FCATRP GRIDIM NFLATE PICKEM ~
               SAMINF UPTIDX CHKIDX
  F77 %PROG%
  &DATA BIND
    LO %PROG%
    LO SUBS
    LI ARC>LIB>ARCLIB
    LI VAPPLB
    LI VSRTLI
    LI
    FILE
  &END
  DELETE %PROG%.BIN
&END
&RETURN
```

Table 3.--*Descriptions of Fortran programs used in site-selection software*

[An "X" in the "Inserted statements" column indicates the programming statements in attachment B are inserted into the program.]

Program name	Attachment	Inserted statements	Purpose
ITEXST	D		Check if INFO file for areal-subset coverage can be opened, and if the user-specified category-variable name exists.
GRIDIM	E		Calculate variables for preparation of a grid of points (equally-spaced population-definition methods) or polygons (random-selection with equal-area distribution and random-selection with iterating grids methods).
DEFIDX	F	X	Define an INFO category-index file (all population-definition methods).
CHKIDX	G		Check user-specified category in category-index file (all site-selection methods).
PICKEM	H	X	Randomly select sites (simple random-selection and random-selection with equal-area distribution methods).
EQARSA	I	X	Aggregate subareas into equal-area cells (random-selection with equal-area distribution method).
NFLATE	J		Calculate the initial guess for preparing a grid (random-selection with iterating grids method).
SAMINF	K	X	Determine if convergence criteria have been met and randomly select sites or compute another guess (random-selection with iterating grids method).
UPTIDX	L		Store number of sites selected in category-index file (all site-selection methods).
CATRPT	M		Retrieve and sort locations of selected sites (all site-selection methods).
FCATRP	N		Prepare site-selection report (all site-selection methods).

It will be necessary to modify the site-selection software to install it on a non-Prime computer system. The Fortran code contains four dependencies on the Primos computer-operating system, as follows.

(1) A computerized function named RND is used to obtain a random number (attachments E, H, and K). The RND function is a Prime extension of standard Fortran 77.

(2) To obtain a value to initialize RND, a Primos subroutine named TIMDAT (Spencer, 1986) is called to retrieve the number of seconds since midnight from the computer-system clock. The call to TIMDAT is made from a subroutine called IRSEED (attachment C).

(3) The Primos subroutine named SUBSRT (Frost, 1986) is called from within ISRTFL (attachment C) to sort the contents of a file.

(4) The other non-standard language feature in the software is the Prime $INSERT compiler directive (Johnson, 1983, p. 3-15). The $INSERT directive causes the compiler to include the contents of a named file at the location of the directive. This allows repetition of a statement or a group of statements in several programs in the software. The $INSERT directive is used in the site-selection software to repeat PARAMETER statements that define variables for sizing of arrays. Other compiler vendors provide a similar compiler directive for Fortran 77. Often, the corresponding compiler directive is called INCLUDE. The user of a compiler that does not have this capability can insert the appropriate statements into the program at the locations of the applicable $INSERT directive. The programming statements in attachment B are inserted into the programs and subroutines in attachments F, H, I, and K.

Several installation-dependent variables are defined at the beginning of program SAMPLE.AML. The four variables, TOLER, MAXITER, PERCENT, and DAMPER contain values for (1) the maximum number of iterations, (2) number of alternate sites, (3) the fraction of cells needed to contain the user-specified number of alternate sites for secondary convergence, and (4) the damping factor. All four of these variables can be modified by the user while the program is running. The values in the program are the values used when the prompting message is displayed for the variable, and the user enters a carriage return without entering a value. The last three variables pertain only to the random-selection with iterating grids method.

The next two variables, EXECUTE and INFOPATH, store the operating-system command for running an executable Fortran program, and the location of the INFO files for an ARC/INFO workspace.

The next two variables, BOLD_ON and BOLD_OFF, store the terminal-specific codes for enabling and disabling the display of bold characters on a terminal.

The next eleven variables: CHEK_PGM, GRID_PGM, DCAT_PGM, CHEK_PGM, PICK_PGM, EQAR_PGM, INFL_PGM, MTHR_PGM, UCAT_PGM, RPT1_PGM, and RPT2_PGM, store the locations of each of the executable Fortran programs. The contents of these variables should be modified to contain the correct locations for the local computer system.

The final variable, PROJ_DES, stores the location of a file that contains ARC/INFO commands. The file is used for converting the coordinates from the map projection used for the areal-subset coverage to latitude and longitude (Environmental Systems Research Institute, 1987b). The example projection-file listing (attachment N) is used to convert coordinates in zone 14 of the Universal Transverse Mercator map projection to latitude and longitude. When creating a customized projection file, only the lines affecting the input map projection should be changed. Thus, only the following lines should be changed.

```
PROJECTION UTM
ZONE 14
UNITS METERS
```

Additional lines describing the input map projection may be added, if necessary.

If more than one person is using the site-selection software on a computer system, it may be necessary for each person to copy and modify the SAMPLE.AML program. Each user may want to modify the values of the variables: TOLER, PERCENT, MAXITER, DAMPER, BOLD_ON, BOLD_OFF, and PROJ_DES. The Fortran programs do not need to be copied, unless the values of the array sizes (attachment B) have to be changed.

When revisions to the ARC/INFO GIS are made, some of the subroutines used in the site-selection software may be changed. This may create a need to modify some subroutine call statements in the site-selection software. Table 4 describes the ARC/INFO subroutines that are used in each of the eleven Fortran programs.

Data Used by the Software

The site-selection software uses the areal-subset coverage provided by the user and a population coverage, if supplied. The software makes copies of these coverages, so the original data are not modified. Other files and coverages are created while the software is running. Some of these are products of the software, as described previously in this report.

However, many files and coverages are created and deleted by the software during normal operation. Because most users do not need to be concerned with these "temporary" files and coverages, this report does not contain detailed descriptions. However, the users needs to be aware of the names because the software will delete any existing file or coverage with the same name.

Table 4.—*Locations of call statements and descriptions of ARC/INFO subroutines*

[An "X" beneath a program name indicates the subroutine is called within the program.]

Subroutine name	ITEXST	GRIDIM	DEFIDX	CHKIDX	PICKEM	EQARSA	NFLATE	SAMINF	UPTIDX	CATRPT	FCATRP	Description
ACLOSE	X	X		X		X	X	X		X	X	Close logical unit: sequential access
ACREAT	X	X		X		X	X	X		X	X	Create and open logical unit: sequential access
ADELET						X						Delete file: sequential access
AEXIT	X	X	X	X	X	X	X	X	X	X	X	Stop program and return to AML program
AOPEN						X					X	Open logical unit: sequential access
ANAME										X		Construct file name: ARC
BOXGET		X										Get minimum and maximum coordinates for a coverage
ERROR			X	X	X	X	X	X	X	X	X	Print message, stop program, and stop AML program
INFADI			X									Add field to file: INFO
INFCLE			X					X	X		X	Clear expression: INFO
INFCLS	X		X	X	X	X	X	X	X	X	X	Close logical unit: INFO
INFDEC			X	X		X	X	X		X	X	Decode record: INFO
INFDEF			X									Create file and open logical unit: INFO
INFENC			X		X	X		X	X			Encode record: INFO
INFERS			X									Delete file: INFO
INFEXF					X							Determine existence of file: INFO
INFEXI	X		X	X	X	X	X	X	X	X	X	Describe field: INFO
INFGET			X	X	X	X	X	X	X	X	X	Read record: INFO
INFINT	X		X	X	X	X	X	X	X		X	Initialize subroutines: INFO
INFNAM					X					X		Construct file name: INFO
INFOPN	X		X	X	X	X	X	X	X	X	X	Open logical unit: INFO
INFORM	X		X		X		X	X				Display message with carriage return and line feed
INFPUT			X		X	X		X	X			Write record: INFO
INFSEL			X	X	X	X	X	X	X	X	X	Determine if record matches expression: INFO
INFTRN			X	X	X	X	X	X	X	X	X	Encode expression: INFO
LABOPN										X		Open file: label-point coordinates
LABRDR										X		Read direct-access: label-point coordinates
LABCLS										X		Close file: label-point coordinates
LUNINI	X	X	X	X	X	X	X	X	X	X	X	Initialize subroutines: logical units
MESINI	X	X	X	X	X	X	X	X	X	X	X	Initialize subroutines: messages
MINIT	X	X	X	X	X	X	X	X	X	X	X	Initialize subroutines: direct access
PRMSTR	X	X	X	X	X	X	X	X	X	X	X	Display message without carriage return and line feed
VINIT										X		Initialize subroutines: variable-length records

During definition of the population, regardless of the method selected, the SAMPLE.AML program creates a copy of the areal-subset coverage. The name of the copy is formed by joining together the name of the areal-subset coverage and the characters ".SUB".

The Fortran program, GRIDIM, creates a file that contains data used by the SAMPLE.AML program with the ARC GENERATE command (Environmental Systems Research Institute, 1987b). The GRIDIM program is used by the SAMPLE.AML program in three places for three different purposes. The first use of the GRIDIM program occurs during preparation of an equally spaced population. The second use of the GRIDIM program occurs during preparation of a subarea coverage. In both these cases, a temporary file is created and named by joining together the name of the areal-subset coverage and the characters ".SUB.GRD". The third use of the GRIDIM program, when using the random-selection with iterating grids method, creates a file containing the characteristics of the grid for current iteration. The name of this file is formed by joining together the name of the areal-subset coverage and the characters ".GRD".

During many operations performed by the software, a temporary coverage is needed. The name of the temporary coverage is formed by joining together the name of the areal-subset coverage and the characters ".GRID".

One other temporary coverage is needed when using the random-selection within cells approach. This temporary coverage is named by joining together the name of the areal-subset coverage and the characters ".SAM".

During preparation of a site-selection report, three temporary files are created. These files are named SAMPTS, SAMSRT, and SAMSRT.GEO. Two temporary files, named SUBA.ASCII and SUBA.SORT, are created during the aggregation of subareas into cells when the random-selection with equal-area distribution method is used. A temporary file named INFLATED is created when the random-selection with iterating grids method is used.

Error Messages

This section provides an alphabetical listing of many error messages that may be displayed by the software, the name of the program(s) that displays the message, and possible corrective actions that may be taken by the user. Some error messages in this section have been described previously in this report, but are included here for easy reference.

The software is capable of producing other error messages that are not listed in this section. These messages are not included because it is unlikely that they will be displayed during normal use of the software. The capability to display these messages was incorporated into the software during initial coding and testing and was not removed from the published version of the code. If the software is revised or moved to another computer-operating system, these undocumented messages may be useful to the programmer.

Message: __ sites have already been selected from the category: ____
Do you want to reselect sites from this category (CR=NO)?
Source: SAMPLE.AML
Action: If you type an affirmative answer, the previous site selections will be removed, and site selection will be performed again. If you type a negative answer, the prompting message for the name of the category will be displayed again.

Message: A population must be defined before site selection
Source: SAMPLE.AML
Action: Select option one (Define population) or option three (Exit) when the main menu is displayed again.

Message: Areal-subset coverage does not exist
Source: SAMPLE.AML
Action: Enter the name of an existing areal-subset coverage when the prompting message is displayed again.

Message: Category value: ____ not found in category-index file
Source: SAMPLE.AML
Action: Enter a valid category value when prompting message is displayed again.

Message: Coverage not found
Source: SAMPLE.AML
Action: Enter the name of an existing point coverage when the prompting message is displayed again.

Message: Damping factor should not be less than or equal to zero
Source: SAMPLE.AML
Action: Enter a valid damping factor when the prompting message is displayed again.

Message: Fraction of cells must be a value between zero and one
Source: SAMPLE.AML
Action: Enter a number between zero and one when the prompting message is displayed again.

Message: If you continue, the coverage containing site selections is deleted
Population coverage already exists, continue (CR=NO)?
Source: SAMPLE.AML
Action: If an affirmative answer is entered, a new population coverage is created. If a negative answer is entered, the main menu is displayed again.

Message: INFO file does not exist
Source: ITEXST
Action: Enter the name of an existing areal-subset coverage when the prompting message is displayed again.

Message: Insufficient population (___) to select ___ sites.
Source: NFLATE
Action: For the specified category value, the number of potential sites is less than the number of sites to be selected. Prompting messages beginning with the category value are displayed again. Enter a different category value, number of sites, number of alternate sites, or QUIT.

Message: Integer value required
Source: SAMPLE.AML
Action: Enter an integer when the prompting message is displayed again.

Message: Invalid method code: __
Source: SAMPLE.AML
Action: Enter a valid method code when the menu is displayed again.

Message: Invalid option code: __
Source: SAMPLE.AML
Action: Enter a valid option code when menu is displayed again.

Message: No exclusion criteria entered...
Source: SAMPLE.AML
Action: Either disable geometric exclusion, or enter exclusion criteria after the population-definition options menu is displayed again.

Message:	No sites in population
Source:	PICKEM
Action:	The program stops. If a fixed population is being used, there are no potential sites in the category for the population. If an equally-spaced population is being used, the areal subsets for the category are small and the distance between potential sites is relatively large. Either create a new population, or do not select sites from the same category when the software is run again.

Message:	Number of alternate sites must be greater than or equal to zero
Source:	SAMPLE.AML
Action:	Enter a non-negative integer when the prompting message is displayed again.

Message:	Numeric value required
Source:	SAMPLE.AML
Action:	Enter a number when the prompting message is displayed again.

Message:	Numeric value required, redisplaying menu...
Source:	SAMPLE.AML
Action:	Enter desired method code and required numeric data when the menu is displayed again.

Message:	Positive number required
Source:	SAMPLE.AML
Action:	Enter a positive number when the prompting message is displayed again.

Message:	Positive value required, redisplaying menu...
Source:	SAMPLE.AML
Action:	Enter desired method code and required positive number when the menu is displayed again.

Message:	Resizing needed for MAXCAT
Source:	DEFIDX
Action:	The program stops. Alter the value of MAXCAT in the inserted file or in the DEFIDX program, recompile, relink, and run the software again.

Message: Resizing needed for MAXCEL
Source: SAMINF
Action: The program stops. Alter the value of MAXCEL in the inserted file or in the SAMINF program, recompile, relink, and run the software again.

Message: Resizing needed for MAXPNT
Source: SAMINF or PICKEM
Action: The program stops. Alter the value of MAXPNT in the inserted file or in the SAMINF (including the RNDSEL subroutine) and PICKEM programs, recompile, relink, and run the software again.

Message: Resizing needed for MAXPOP
Source: SAMINF
Action: The program stops. Alter the value of MAXPOP in the inserted file or in the SAMINF program, recompile, relink, and run the software again.

Message: Resizing needed for MAXSUB
Source: EQARSA
Action: The program stops. Alter the value of MAXSUB in the inserted file or in the EQARSA program, recompile, relink, and run the software again.

Message: Selection quantity exceeds cell population
Source: PICKEM
Action: The program stops. In at least one cell, the total number of sites to be selected is greater than the number of potential sites. Define a new population, or reduce the number of primary or alternate sites. A previous informative message will have displayed the number of potential sites in the cell where the problem was detected.

Message: Unable to select from an empty subset
Source: PICKEM
Action: The program stops because there are no potential sites to be selected in the cell. If using the simple-random selection method, the user may either not select sites from the category or create a new population. If using the random-selection with equal-area distribution method, the user may either reduce the number of primary sites or create a new population.

Message: Variable name does not exist
Source: ITEXST
Action: Re-enter category-variable name when prompting message is displayed again.

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GLOSSARY

Terms

Alternate sites.--Alternate sites are water-quality sampling locations selected to provide in advance for potential difficulties that may be encountered when visiting sites. For example, it may be impossible to drill at a selected site. When such a difficulty occurs, the hydrologist will have one or more alternative sites to visit if more than one alternate site is specified during site selection. Zero, one, or more alternate sites may be selected for each primary site.

Areal subsets.--An areal subset is a part of the study region that is contiguous and consistent with respect to some spatial characteristic (fig. 1). The characteristic can be based on land use, topography, geology, or some other spatial variable. A study region may be composed of many areal subsets, and commonly several distinct areal subsets may represent those parts of a region having a particular value (or range of values) of the characteristic.

Category.--A category is a value of a spatial characteristic that identifies a group of similar areal subsets (fig. 1). Within a study region, there may be more than one discrete areal subset in the same category. The number of different categories determines the amount of stratification of the study region. Categories often are referred to as "strata" in statistics texts.

Cell.--A cell is a polygon that subdivides the study region (fig. 5). A cell is used in the random selection within cells approach to define a group of sites that may be selected from a part of the study region. Cells sometimes are referred to as "blocks" in statistics texts.

Convergence.--Convergence is a condition that occurs when the solution to a problem is found at the end of a series of iterations.

Convergence criteria.--Convergence criteria are a set of user-specified conditions that are tested at the end of each iteration. The convergence criteria are used to determine if a solution to a problem has been found.

Coverage.--A coverage is a computerized representation of the locations and characteristics of spatial data. Spatial data stored in coverages include points, lines, and polygons.

Damping factor.--The damping factor is a coefficient for controlling the change in cell size between successive iterations when selecting sites using the random-selection with iterating grids method.

Fixed population of potential sites.--A fixed population is a group of existing locations that may be selected. Commonly, the fixed population consists of existing water wells that might be used for water-quality sampling.

Grid.--A grid is a collection of cells used for the areal distribution of sites during the selection process. The grid of cells completely covers the study region.

Iteration.--An iteration is a single attempt to find a solution using a sequence of computations. Normally, several iterations are needed to find a solution.

Pass.--A pass is defined as the site-selection process for a single category (fig. 3). The number of passes necessary to select sites for the study region is equal to the number of categories that will have at least one site selected. The total number of sites selected during a pass is the number of site-selection rounds multiplied by the number of primary sites selected. (See "primary site" and "round".)

Polygon.--A polygon is a two-dimensional shape that defines an area.

Population.--The population is the group of all sites in the study region that have the potential to be selected (fig. 2).

Potential site.--A potential site is a location in the study region that may be selected for the collection of a water-quality sample.

Primary site.--A primary site is the first choice made by the site-selection software for the collection of a water-quality sample. If the primary site is not suitable for sampling, and alternate sites have been selected, the alternate site selected during round-number two should be visited next.

Random.--In general, random means without statistical bias. With respect to this computer program, random selection denotes making a choice among arbitrarily numbered alternatives using a computerized method for generating a random number, scaled to the range of alternatives.

Round.--A round is part of the site-selection process for a category (fig. 3). Site selection is performed by rounds. The number of rounds in a selection pass is one plus the user-specified number of alternate sites. Sites are identified by the round number during which the sites were selected. Primary sites are selected during round-number one. Alternate sites are selected during rounds two, three, and so on.

Stratified.--Stratified means organized into internally consistent groups. A stratified study region is subdivided into areal subsets, each of which is homogenous internally with respect to some characteristic (fig. 1).

Study region.--The study region is the two-dimensional spatial extent of the part of the earth's surface that is being investigated during a project.

Subarea.--A subarea is a polygon that contains a small part of the study region. Each areal subset is subdivided into one or more subareas when site selection is performed using the random-selection with equal-area distribution method. Subareas are aggregated into the cells that are used for the selection of sites. Each subarea contains area for a single category (fig. 4).

Symbols

Symbol	Definition
A	Total area of the study region
A_c	Total area for a category
C	Number of cells containing parts of an area
δ	Number of water-quality samples collected within a cell
f	User-specified damping factor
f_a	User-specified fraction of cells that must contain η_r sites
f_i	Damping factor for an iteration
G_i	Guess for the number of cells needed for the current iteration
η_a	User-specified number of alternate sites to be selected for a category
η_p	User-specified number of primary sites to be selected for a category
η_r	Number of site-selection rounds $(1 + \eta_a)$
η_t	Total number of sites to be selected for a category $(\eta_p \cdot \eta_r)$
N	Number of potential sites in a category
N_a	Number of potential sites in cells that contain less than η_r sites
N_{ct}	Number of cells containing η_r potential sites
N_i	Number of potential sites inside an area
N_c	Number of potential sites inside a cell
N_o	Number of potential sites outside an area and within a cell
P_a	Probability of selecting a site from within a specific area
P_s	Prcbability of selecting a specific site
Π	A mathematical operator indicating all terms in a sequence are multiplied together

APPENDIX. SELECTION PROBABILITIES

This discussion of selection probabilities presents equations for calculation of the probability that a site or an area will be selected by the software described in this report. These equations are included to (1) explain mathematically how the selection methods differ, (2) provide a method for determining the randomness of site selections using the random selection within cells approach, and (3) establish a framework for additional studies of ground-water sampling-network design.

In the discussion that follows, the mathematical expressions are based on the assumption that only one water-quality sample is collected from each set of primary and alternate sites.

Sites in the same cell have equal probabilities of being selected. During selection of the first site, the probability of selecting a specific site (P_s) is equal to the reciprocal of the total number of sites available for selection (N). After a site is selected, it is not available for selection again (referred to in statistics texts as "sampling without replacement"). Therefore, the number of sites available for selection decreases by one each time a site is selected. With multiple selections from the same cell, the probability that a site will be chosen is one minus the product of the probabilities that the site will not be chosen during each selection.

$$P_s = 1 - \prod_{i=1}^{\delta} \frac{N - i}{N - i + 1}$$

$$= \delta \,/\, N \qquad (5)$$

where P_s = the probability of selecting a specific site,
N = the number of sites available for selection,
δ = the number of water-quality samples collected within a cell, η_p for the simple random-selection approach, and 1 for the random selection within cells.

The simple random-selection approach always provides a statistically random selection of sites from the population because only one cell is used. Thus, every site in a category has an equal probability of being selected. The random-selection within cells appproach does not provide a strictly random selection because different numbers of potential sites may be present in each of the cells from which sites are selected. The departure from randomness may be determined using equation 5 by calculating the selection probability for the simple random-selection approach, and comparing it to the selection probability calculated for each cell created during the random-selection within cells approach.

It also may be useful to calculate the probability that a site will be selected from a specific area of the study region (P_a). The area may be the limits of some known contamination problem, or the area may be one of the areal subsets used for categorizing the study region. The following equations can be used to perform this calculation.

When the area is completely contained within one cell, P_a is determined by the number of sites within the area and the number sites within the cell. When selecting one site, the probability of selecting a site from an area (P_a) in the cell is equal to the number of sites located within the area (N_i) divided by the total number of sites available for selection in the cell. When more than one site is selected, the probability of selecting at least one site within an area is equal to one minus the product of the probabilities of not choosing a site from the area during each selection.

$$P_a = 1 - \prod_{i=1}^{\delta} \frac{N_c - N_i - i + 1}{N_c - i + 1}$$

$$= 1 - \frac{(N_c - N_i)!\,(N_c - \delta)!}{(N_c - N_i - \delta)!\,N_c!}$$

where P_a = the probability of selecting a site within a specific area, and
N_i = number of sites located within the area.

Let $N_o = N_c - N_i$, the number of sites in the cell that are outside of the area.

$$P_a = 1 - \frac{N_o!\,(N_c - \delta)!}{(N_o - \delta)!\,N_c!} \tag{6}$$

When an area is contained in more than one cell, the probability that at least one site within the area will be chosen is one minus the product of the probabilities that a site within the area will not be chosen from each cell.

$$P_a = 1 - \prod_{i=1}^{C} \frac{N_{o,i}!\,(N_{c,i} - \delta_i)!}{(N_{o,i} - \delta_i)!\,N_{c,i}!}$$

where C = the number of cells that contain parts of the area.

The simple random-selection method uses one cell for the entire study area; therefore, the above equation does not pertain to the method. The random selection within cells approach selects η_r sites from each cell, but because only one water-quality sample is collected per cell ($\delta = 1$), the above equation simplifies to the following one.

$$P_a = 1 - \prod_{i=1}^{C} \frac{N_{o,i}}{N_{c,i}} \tag{7}$$

Some area-based approximations to these equations are possible, depending on the methods chosen for defining the population of potential sites, and for selecting sites. These approximations are discussed below. If the requirements for the approximations are not met, the above equations should be used to calculate selection probabilities.

Using the simple random-selection approach, each site in the same category has an equal probability of being selected. If the population of potential sites is spaced equally, the probability of selecting at least one site from an area is equal approximately to the ratio of the size of the area to the total area of areal subsets in the same category.

Using the random-selection with equal-area distribution method, each cell contains approximately the same category area. If the population of potential sites is spaced equally, the following two statements are true: (1) Sites in different cells have approximately equal probabilities of being selected, and (2) the probability of selecting at least one site from an area is equal approximately to the ratio of the size of the area to the total area for the category.

Using the random-selection with iterating grids method, sites within the same cell have equal probabilities of being selected. However, no further conclusions regarding selection probabilities can be made until a grid is found that satisfies the convergence criteria. After a grid has been found, equations 5, 6, and 7 should be used to calculate selection probabilities for sites and areas.

ATTACHMENTS

Attachment A.--Arc macro language program SAMPLE.AML listing

```
/* SAMPLE.AML - RANDOMLY SELECT SAMPLING SITES FROM A STRATIFIED STUDY REGION
/*              USING ONE OF THREE METHODS
/*
/* Use of U.S. Geological Survey program SAMPLE.AML is described in U.S.
/*  Geological Water-Resources Investigations Report 90-4101, by Jonathon C.
/*  Scott.  This program is written in the Arc Macro Language (AML).  The
/*  program uses the following proprietary software:  the INFO file-management
/*  system and the ARC/INFO geographic information system.  The program runs
/*  various programs written in Fortran 77.  This program was last modified
/*  and run on a Prime 9955-II minicomputer running revision 22 of the PRIMOS
/*  operating system on July 26, 1990.
/*
/* Although this computer software has been used by the U.S. Geological Survey,
/*  no warranty, expressed or implied, is made by the USGS as to the accuracy
/*  and functioning of the program and related program material nor shall the
/*  fact of distribution constitute any such warranty, and no responsibility
/*  is assumed by the USGS in connection therewith.
/*
/*
/* THE FOLLOWING FILE-SYSTEM NAMES ARE USED:
/*
/*    NAME         TYPE      DISPOSITION  METHOD     CONTENTS
/*                                        1 2 3
/*  cover        coverage   input/kept    X X X    stratification polygons
/*  cover.SUB    coverage   work/deleted  X X X    incover after geom. exclusion
/*  cover.GRD    file       work/deleted  X X X    gridding data
/*  cover.GRID   coverage   work/deleted  X X X    generated sampling points
/*  SUBA.ASCII   file       work/deleted    X      subarea centroid coordinates
/*  SUBA.SORT    file       work/deleted    X      sorted SUBA.ASCII
/*  INFLATED     file       work/deleted      X    "guess" for next iteration
/*  SAMPTS       file       work/deleted  X X X    selected coordinates
/*  SAMSRT       file       work/deleted  X X X    sorted selected coordinates
/*  SAMSRT.GEO   file       work/deleted  X X X    projected selected coordinates
/*  TSTINF       file       work/deleted  X X X    logical record (.TRUE./.FALSE.)
/*  cover.POP    coverage   output/kept   X X X    sampling point population
/*  cover.SUBA   coverage   output/kept     X      area-resolution polygons
/*  cover.CELL   coverage   output/kept     X X    sampling cell polygons
/*  cover.SAM    coverage   work/deleted    X X    selected points
/*  CATIDX       INFO-file  output/kept   X X X    category index/sampling data
/*
/* STORE CURRENT DIRECTORY AND SET DEFAULT VALUES FOR VARIABLES
&S HOME     := [DIR [PATHNAME *]]
&S TOLER    := 2
&S MAXITER  := 8
&S PERCENT  := .75
&S DAMPER   := .90
/*
/* SET OPERATING-SYSTEM-DEPENDENT VARIABLES
&S EXECUTE  := RESUME                     /* COMMAND TO RUN A PROGRAM
&S INFOPATH := %HOME%>INFO                /* PATHNAME OF INFO DATABASE
/*
/* SET TERMINAL-DEPENDENT VARIABLES (ANSI)
&S BOLD_ON  := '[1m'                      /* TURN ON BOLD CHARACTERS
&S BOLD_OFF := '[0m'                      /* TURN OFF BOLD CHARACTERS
/*
/* SET INSTALLATION-DEPENDENT VARIABLES
&S ITCK_PGM := <GIS>NAWSOFT>SAMP>R5>ITEXST.RUN  /* INFO-FILE CHECK
&S GRID_PGM := <GIS>NAWSOFT>SAMP>R5>GRIDIM.RUN  /* CELL SIZE ALGORITHM
&S DCAT_PGM := <GIS>NAWSOFT>SAMP>R5>DEFIDX.RUN  /* INDEX FILE CREATION
&S CHEK_PGM := <GIS>NAWSOFT>SAMP>R5>CHKIDX.RUN  /* CHECK INDEX FILE
&S PICK_PGM := <GIS>NAWSOFT>SAMP>R5>PICKEM.RUN  /* RANDOM SELECTION
&S EQAR_PGM := <GIS>NAWSOFT>SAMP>R5>EQARSA.RUN  /* RANDOM SELECTION (METHOD II)
&S INFL_PGM := <GIS>NAWSOFT>SAMP>R5>NFLATE.RUN  /* INITIAL GUESS (METHOD III)
&S MTHR_PGM := <GIS>NAWSOFT>SAMP>R5>SAMINF.RUN  /* CONVERGENCE CHECK (METHOD III)
&S UCAT_PGM := <GIS>NAWSOFT>SAMP>R5>UPTIDX.RUN  /* INDEX FILE UPDATING
&S RPT1_PGM := <GIS>NAWSOFT>SAMP>R5>CATRPT.RUN  /* SAMPLING LOCATION EXTRACTION
&S RPT2_PGM := <GIS>NAWSOFT>SAMP>R5>FCATRP.RUN  /* REPORT GENERATION
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
&S PROJ_DES := <GIS>NAWSOFT>SAMP>R5>UTM.2.LL    /* PROJECTION FILE (MAP->LAT-LONG UNITS)
/*
/* DETERMINE SITE-SELECTION METHOD
/*
&LABEL SELECT_METHOD
&TYPE
&TYPE Site selection may be performed using one of three methods:
&TYPE
&TYPE '  Code    Method'
&TYPE
&TYPE '    1     Simple random selection'
&TYPE '    2     Random selection with equal-area distribution'
&TYPE '    3     Random selection with iterating grids'
&TYPE
&S METHOD := [RESPONSE 'Enter method code']
&SELECT %METHOD%
&WHEN 1,2,3
   &DO
   &GOTO STRATIFY
   &END
&OTHERWISE
   &DO
   &TYPE 'Invalid method code:  '%METHOD%
   &TYPE ' '
   &GOTO SELECT_METHOD
   &END
&END
/*
/* DESCRIBE STRATIFYING POLYGONS
/*
&LABEL STRATIFY
&S INCOVER  := [RESPONSE 'Enter name of areal-subset coverage']
&S CATITEM  := [RESPONSE 'Enter name of category variable']
/*
/* CHECK THAT COVERAGE, INFO FILE, AND VARIABLE NAME EXIST
/*
&TYPE
&TYPE %BOLD_ON%Checking areal-subset coverage specifications%BOLD_OFF%
&IF ^ [EXISTS %INCOVER% -COVER] &THEN &DO
   &TYPE Areal-subset coverage does not exist
   &GOTO STRATIFY
&END
&DATA %EXECUTE% %ITCK_PGM%
%INFOPATH%
ARC
%INCOVER%.PAT
%CATITEM%
&END
/*
/* READ RESULTS OF TEST FROM THE OUTPUT FILE WRITTEN BY THE FORTRAN PGM.
/*
&S   AMLU  := [OPEN TSTINF OPENERR -READ]
&S    OK   := [READ %AMLU% EOF]
&S CLOSERR := [CLOSE %AMLU%]
&S DELETER := [DELETE TSTINF]
&IF ^ %OK% &THEN &GOTO STRATIFY
/*
/* MAIN MENU FOR CHOOSING PROCESSING OPTIONS...
/*
&LABEL SELECT_OPTION
&S DEFPOP := [EXISTS %INCOVER%.POP -COVER]
&TYPE
&TYPE 'Site-selection software main menu'
&TYPE
&TYPE '  Code    Option'
&TYPE
&TYPE '    1     Define population'
&IF %DEFPOP% &THEN ~
&TYPE '    2     Select sites from population'
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
&TYPE '    3     Exit from site-selection software'
&TYPE
&S OPTION := [RESPONSE 'Enter option code' 3]
/*
&SELECT %OPTION%
   &WHEN 1
     &DO
     &S GO := .TRUE.
     &S PROMPT := 'Population coverage already exists, continue (CR=NO)'
     &IF %DEFPOP% &THEN &DO
      &TYPE 'If you continue, the coverage containing site selections is deleted!'
      &S GO := [QUERY %PROMPT% .FALSE.]
     &END
     &IF %GO% &THEN &GOTO DEFINE_POP
     &GOTO SELECT_OPTION
     &END
   &WHEN 2
     &DO
     &IF [EXISTS %INCOVER%.POP -COVER] &THEN &GOTO SAMPLE
     &TYPE
     &TYPE A population must be defined before site selection
     &GOTO SELECT_OPTION
     &END
   &WHEN 3
     &RETURN
   &OTHERWISE
     &DO
     &TYPE 'Invalid option code:  '%OPTION%
     &TYPE
     &GOTO SELECT_OPTION
     &END
&END
/*
/* -------------------> DEFINE POPULATION <----------------------
/* CREATE A NEW COVERAGE TO BE USED AS THE POPULATION.  THE NEW COVERAGE
/* IS A COLLECTION OF POINTS OVERLAID ONTO THE AREAL SUBSETS.
/*
&LABEL DEFINE_POP
/*
/* OPTION FOR GEOMETRIC EXCLUSION OF AREAL SUBSETS
/*
&TYPE
&S EXC := [QUERY 'Do you wish to exclude areal subsets using geometry (CR=NO)'~
 .FALSE.]
/*
&IF [EXISTS %INCOVER%.SUB -COVER] &THEN KILL %INCOVER%.SUB
COPY %INCOVER% %INCOVER%.SUB
&IF %EXC% &THEN &DO
&LABEL GET_MINAREA
&S MINAREA  := [RESPONSE 'Enter minimum area (CR=no minimum)' 0]
&IF [TYPE %MINAREA%] > 0 &THEN &DO
   &TYPE Numeric value required
   &GOTO GET_MINAREA
&END
&LABEL GET_MINRATIO
&S MINRATIO := [RESPONSE 'Enter minimum area/perimeter ratio (CR=no minimum)' 0]
&IF [TYPE %MINRATIO%] > 0 &THEN &DO
   &TYPE Numeric value required
   &GOTO GET_MINRATIO
&END
&IF %MINAREA% = 0 & %MINRATIO% = 0 &THEN &DO
    &TYPE No exclusion criteria entered...
    &GOTO DEFINE_POP
    &END                                                  /* END IF ERROR BRANCH
&IF %MINRATIO% > 0 &THEN ~
ADDITEM %INCOVER%.SUB.PAT %INCOVER%.SUB.PAT APRATIO 4 12 F 3
/*
/*  REMOVE POLYGON CATEGORY VALUE FROM GEOMETRICALLY EXCLUDED AREAL SUBSETS
/*
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
&WORKSPACE %INFOPATH%
&DATA INFO
ARC
SELECT %INCOVER%.SUB.PAT
&S EXPRESS := RESELECT
&IF %MINAREA% > 0 &THEN &S EXPRESS := %EXPRESS% AREA LE %MINAREA%
&IF %MINRATIO% > 0 &THEN &DO
   CALC APRATIO = AREA / PERIMETER
   &IF %MINAREA% > 0 &THEN &S EXPRESS := %EXPRESS% OR
   &S EXPRESS := %EXPRESS% APRATIO LE %MINRATIO%
&END                                                                   /* END IF MINRATIO
%EXPRESS%
MOVE ' ' TO %CATITEM%
QUIT STOP
&END                                                                   /* END DATA INFO
&WORKSPACE %HOME%
&END                                                                   /* END IF EXC
/*
/* OPTIONS FOR DEFINING POTENTIAL SITES
/*
&LABEL DEFINE_SIZE
    &TYPE
    &TYPE You may define a population using any of three methods:
    &TYPE
    &TYPE ' Code   Method'
    &TYPE
    &TYPE '   1    Specify the approximate number of potential sites'
    &TYPE '   2    Specify the distance between each potential site'
    &TYPE '   3    Specify an existing point coverage'
    &TYPE
    &S OPT  := [RESPONSE 'Enter a method code']
/*
    &SELECT %OPT%
      &WHEN 1
       &S NPTS := [RESPONSE 'Enter approximate number of sites (CR=10,000)'~
        10000]
      &WHEN 2
       &S NPTS := [RESPONSE 'Enter distance between each site']
      &WHEN 3
       &DO
       &LABEL GET_PCOVER
       &S PCOVER := [RESPONSE 'Enter name of point coverage']
       &IF ^ [EXISTS %PCOVER% -COVER] &THEN &DO
          &TYPE Coverage not found
          &GOTO GET_PCOVER
       &END
       &GOTO OVERLAY
       &END
      &OTHERWISE
       &DO
       &TYPE 'Invalid method code:  '%OPT%
       &GOTO DEFINE_SIZE
       &END
   &END
   &IF [TYPE %NPTS%] > 0 &THEN &DO
       &TYPE Numeric value required, redisplaying menu...
       &GOTO DEFINE_SIZE
   &END
   &IF %NPTS% <= 0 &THEN &DO
       &TYPE Positive value required, redisplaying menu...
       &GOTO DEFINE_SIZE
   &END
/*
/* WHEN USING METHOD ONE OR TWO:
/*  CALCULATE CELL SIZE & PASS BACK THE COVERAGE LIMITS.
/*  RESULTS ARE WRITTEN TO THE DISK FILE:  incover.SUB.GRD
/*
&TYPE %BOLD_ON%Defining population characteristics...%BOLD_OFF%
&IF [EXISTS %INCOVER%.SUB.GRD] &THEN &S DELETER := [DELETE %INCOVER%.SUB.GRD]
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
&DATA %EXECUTE% %GRID_PGM%
%INCOVER%.SUB
%OPT%
%NPTS%
&END
/*
/*  READ THE RESULTS FROM THE FORTRAN PGM IN THE OUTPUT FILE.
/*
&S AMLU := [OPEN %INCOVER%.SUB.GRD OPENERR -READ]
&S LINE := [TRIM [READ %AMLU% EOF]]
&DO VAR &LIST XMIN XMAX YMIN YMAX XDIM YDIM NCELL
    &S TEMP  := [BEFORE %LINE% ' ']
    &S %VAR% := %TEMP%
    &S LINE  := [TRIM [AFTER %LINE% %TEMP%]]
&END
&S CLOSERR := [CLOSE %AMLU%]
&S DELETER := [DELETE %INCOVER%.SUB.GRD]
/*
/*  GENERATE A COVERAGE WITH LABEL POINTS.
/*
&TYPE %BOLD_ON%Building a population with %NCELL% sites...%BOLD_OFF%
    &IF [EXISTS %INCOVER%.GRID -COVER] &THEN KILL %INCOVER%.GRID
    GENERATE %INCOVER%.GRID
    COPYTICS %INCOVER%
    GRID LABELS
    %XMIN%, %YMIN%
    %XMIN%, %YMAX%
    %XDIM%, %YDIM%
    0, 0
    %XMAX%, %YMAX%
    QUIT
/*
/*  CREATE POINT TOPOLOGY FOR THE COVERAGE.
/*
    BUILD %INCOVER%.GRID POINT
    &S PCOVER := %INCOVER%.GRID
/*
/* ALL THREE POPULATION-DEFINITION METHODS BRANCH TO HERE.
/*  OVERLAY THE POINTS ONTO THE AREAL SUBSETS.
/*
&LABEL OVERLAY
    &IF [EXISTS %INCOVER%.POP -COVER] &THEN KILL %INCOVER%.POP
    CLIP %PCOVER% %INCOVER% %INCOVER%.POP POINT 0.001
    KILL %PCOVER%
    RENAME %INCOVER%.POP %PCOVER%
    IDENTITY %PCOVER% %INCOVER%.SUB %INCOVER%.POP POINT 0.001
/*
/* CLEAN-UP THE WORK DATA SETS, AND ADD ITEMS FOR SAVING SELECTED POINTS,
/* UNIQUELY IDENTIFYING POINTS, AND CELLS
/*
    &IF [EXISTS %INCOVER%.GRID -COVER] &THEN KILL %INCOVER%.GRID
    ADDITEM  %INCOVER%.POP.PAT %INCOVER%.POP.PAT CHOSEN 4 5 B
    ADDITEM  %INCOVER%.POP.PAT %INCOVER%.POP.PAT UNIQUE 4 5 B
    ADDITEM  %INCOVER%.POP.PAT %INCOVER%.POP.PAT CELLNO 4 5 B
    DROPITEM %INCOVER%.POP.PAT %INCOVER%.POP.PAT %INCOVER%.SUB#
    DROPITEM %INCOVER%.POP.PAT %INCOVER%.POP.PAT %INCOVER%.SUB-ID
    DROPITEM %INCOVER%.POP.PAT %INCOVER%.POP.PAT %PCOVER%#
    DROPITEM %INCOVER%.POP.PAT %INCOVER%.POP.PAT %PCOVER%-ID
    &IF %METHOD% NE 2 &THEN KILL %INCOVER%.SUB
/*
/* STORE A UNIQUE IDENTIFIER FOR EACH POINT IN THE POPULATION
/*
&WORKSPACE %INFOPATH%
&DATA INFO
ARC
SELECT %INCOVER%.POP.PAT
CALC UNIQUE = $RECNO
Q STOP
&END
```

```
&WORKSPACE %HOME%
/*
/* DEFINE AN INFO-FILE NAMED 'CATIDX' TO KEEP AN INDEX OF CATEGORIES
/*
&TYPE
&TYPE %BOLD_ON%Preparing category-index file, CATIDX, in INFO%BOLD_OFF%
&DATA %EXECUTE% %DCAT_PGM%
%INFOPATH%
%INCOVER%
%INCOVER%.POP
%CATITEM%
&END
/*
/* DEFINITION OF A POPULATION FOR SITE-SELECTION METHODS ONE AND THREE IS DONE.
/*  SITE-SELECTION METHOD TWO NEEDS A COVERAGE OF SUBAREAS FOR RESOLVING
/*  EQUAL-AREA CELLS.
/*
&IF %METHOD% ^= 2 &THEN &GOTO SELECT_OPTION
/*
/* DETERMINE HOW SUBAREAS WILL BE DEFINED...
/*
&LABEL DEFINE_SUBA
    &TYPE %BOLD_ON%Defining subareas...%BOLD_OFF%
    &TYPE
    &TYPE You may define subareas using either of two methods:
    &TYPE
    &TYPE ' Code   Method'
    &TYPE
    &TYPE '   1    Specify the approximate number of subareas, or'
    &TYPE '   2    Specify the width of subareas'
    &TYPE
    &S OPT  := [RESPONSE 'Enter a method code']
/*
    &SELECT %OPT%
      &WHEN 1
       &S NPTS := [RESPONSE 'Enter approximate number of subareas (CR=10,000)'~
        10000]
      &WHEN 2
       &S NPTS := [RESPONSE 'Enter width of each subarea']
      &OTHERWISE
       &DO
       &TYPE 'Invalid method code:  '%OPT%
       &GOTO DEFINE_SUBA
       &END
   &END
   &IF [TYPE %NPTS%] > 0 &THEN &DO
        &TYPE Numeric value required, redisplaying menu...
        &GOTO DEFINE_SUBA
   &END
   &IF %NPTS% <= 0 &THEN &DO
        &TYPE Positive value required, redisplaying menu...
        &GOTO DEFINE_SUBA
   &END
/*
/*  CALCULATE SUBAREA SIZE & PASS BACK THE COVERAGE LIMITS.
/*  RESULTS ARE WRITTEN TO THE DISK FILE:  incover.SUB.GRD
/*
&TYPE %BOLD_ON%Defining subarea characteristics...%BOLD_OFF%
&IF [EXISTS %INCOVER%.SUB.GRD] &THEN &S DELETER := [DELETE %INCOVER%.SUB.GRD]
&DATA %EXECUTE% %GRID_PGM%
%INCOVER%.SUB
%OPT%
%NPTS%
&END
/*
/*  READ THE RESULTS FROM THE FORTRAN PGM IN THE OUTPUT FILE.
/*
&S AMLU := [OPEN %INCOVER%.SUB.GRD OPENERR -READ]
&S LINE := [TRIM [READ %AMLU% EOF]]
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
&DO VAR &LIST XMIN XMAX YMIN YMAX XDIM YDIM NCELL
    &S TEMP := [BEFORE %LINE% ' ']
    &S %VAR% := %TEMP%
    &S LINE := [TRIM [AFTER %LINE% %TEMP%]]
&END
&S CLOSERR := [CLOSE %AMLU%]
&S DELETER := [DELETE %INCOVER%.SUB.GRD]
/*
/*  GENERATE A COVERAGE OF SUBAREAS WITH LABEL POINTS.
/*
&TYPE %BOLD_ON%Preparing %NCELL% subareas...%BOLD_OFF%
/*
    &IF [EXISTS %INCOVER%.SUBA -COVER] &THEN KILL %INCOVER%.SUBA
    GENERATE %INCOVER%.SUBA
    COPYTICS %INCOVER%
    GRID LABELS
    %XMIN%, %YMIN%
    %XMIN%, %YMAX%
    %XDIM%, %YDIM%
    0, 0
    %XMAX%, %YMAX%
    QUIT
/*
/*  CREATE POLYGON TOPOLOGY FOR THE SUBAREAS, REMOVE SUBAREAS OUTSIDE STUDY
/*   REGION, OVERLAY SUBAREAS ON AREAL SUBSETS, ADD VARIABLES FOR CELL AND
/*   STRIP NUMBER, REMOVE UNNEEDED VARIABLES.  DELETE UNNEEDED COVERAGES.
/*
    BUILD %INCOVER%.SUBA POLY
    &S SACOVER := %INCOVER%.SUBA
    &IF [EXISTS %INCOVER%.GRID -COVER] &THEN KILL %INCOVER%.GRID
    CLIP %INCOVER%.SUBA %INCOVER% %INCOVER%.GRID POLY 0.001
    KILL %INCOVER%.SUBA
    RENAME %INCOVER%.GRID %INCOVER%.SUBA
    UNION %INCOVER%.SUB %INCOVER%.SUBA %INCOVER%.GRID 0.001
    ADDITEM  %INCOVER%.GRID.PAT %INCOVER%.GRID.PAT CELL   4 5 B
    ADDITEM  %INCOVER%.GRID.PAT %INCOVER%.GRID.PAT VSTRIP 4 5 B
    DROPITEM %INCOVER%.GRID.PAT %INCOVER%.GRID.PAT %INCOVER%.SUB#
    DROPITEM %INCOVER%.GRID.PAT %INCOVER%.GRID.PAT %INCOVER%.SUB-ID
    DROPITEM %INCOVER%.GRID.PAT %INCOVER%.GRID.PAT %INCOVER%.SUBA#
    DROPITEM %INCOVER%.GRID.PAT %INCOVER%.GRID.PAT %INCOVER%.SUBA-ID
    KILL %INCOVER%.SUB
    KILL %INCOVER%.SUBA
    RENAME %INCOVER%.GRID %INCOVER%.SUBA
&GOTO SELECT_OPTION
/*
/* -------------------> SAMPLE POPULATION <---------------------
/*
/* POPULATION HAS BEEN DEFINED, READY TO RANDOMLY SELECT FROM ONE CATEGORY.
/*
&LABEL SAMPLE
&TYPE
&TYPE %BOLD_ON%Ready for site selection...%BOLD_OFF%
&TYPE
/*
/* GET SELECTION CONSTRAINTS COMMON TO ALL METHODS
/*
&S PROMPT := 'Enter value of '%CATITEM%' for site selection (CR = QUIT)'
&S CATVAL := [RESPONSE %PROMPT% QUIT]
&IF %CATVAL% = QUIT &THEN &RETURN
/*
&LABEL GET_NOSAMP
&S PROMPT := 'Enter number of primary sites to be selected when '%CATITEM%' = '%CATVAL%
&S NOSAMP := [RESPONSE %PROMPT% 0]
&IF [TYPE %NOSAMP%] ^= -1 &THEN &DO
   &TYPE Integer value required
   &GOTO GET_NOSAMP
&END
&IF %NOSAMP% <= 0 &THEN &RETURN
/*
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
&LABEL ALTERNATE
&S PROMPT := 'Enter number of alternate sites (CR = '%TOLER%')'
&S TOLER  := [RESPONSE %PROMPT% %TOLER%]
&IF [TYPE %TOLER%] ^= -1 &THEN &DO
   &TYPE Integer value required
   &GOTO ALTERNATE
&END
&IF %TOLER% < 0 &THEN &DO
  &TYPE
  &TYPE Number of alternate sites must be greater than or equal to zero
  &GOTO ALTERNATE
&END
/*
/* CHECK CATEGORY-INDEX FILE, DETERMINE IF CATEGORY EXISTS OR ALREADY SELECTED
&DATA %EXECUTE% %CHEK_PGM%
%INFOPATH%
%CATVAL%
&END
&S AMLU    := [OPEN T$NOSAMP OPENERR -READ]
&S NDONE   := [TRIM [READ %AMLU% EOF]]
&S CLOSERR := [CLOSE %AMLU%]
&S DELETER := [DELETE T$NOSAMP]
&IF %NDONE% = -1 &THEN &DO
    &TYPE Category value:  %CATVAL% not found in category-index file
    &GOTO SAMPLE
&END
&IF %NDONE% > 0 &THEN &DO
    &TYPE %NDONE% sites have already been selected from the category:  %CATVAL%
    &S PROMPT := 'Do you want to reselect sites for this category (CR=NO)'
    &S GO := [QUERY %PROMPT% .FALSE.]
    &IF ^ %GO% &THEN &GOTO SAMPLE
&END
/*
/* BRANCH TO APPROPRIATE CODE PERTAINING TO SITE-SELECTION METHOD
&SELECT %METHOD%
   &WHEN 1
     &DO
     &GOTO METHOD_ONE
     &END
   &WHEN 2
     &DO
     &GOTO METHOD_TWO
     &END
   &WHEN 3
     &DO
     &GOTO METHOD_THREE
     &END
&END
/*
/* ------------------------------------------------------------------------
/* METHOD ONE IS SIMPLE RANDOM SELECTION OF THE STRATIFIED POPULATION.
/* ------------------------------------------------------------------------
&LABEL METHOD_ONE
&DATA %EXECUTE% %PICK_PGM%
%INFOPATH%
%INCOVER%.POP
%CATITEM% EQ [QUOTE %CATVAL%]
%NOSAMP%
%TOLER%
&END
/*
&S CELITM :=
&GOTO REPORT
/*
/* ------------------------------------------------------------------------
/* METHOD TWO IS RANDOM SELECTION OF EQUAL-AREA CELLS OF THE STRATIFIED
/*           POPULATION.
/* ------------------------------------------------------------------------
```

```
&LABEL METHOD_TWO
/*
/*  CREATE AN ASCII FILE OF LABEL POINTS FOR THE SUBAREA POLYGONS
/*
&IF [EXISTS SUBA.ASCII -FILE] &THEN &S DELETER := [DELETE SUBA.ASCII]
UNGENERATE POINT %INCOVER%.SUBA SUBA.ASCII
/*
/* PREPARE EQUAL-AREA CELLS
/*
&TYPE
&TYPE %BOLD_ON%Creating %NOSAMP% equal-area cells%BOLD_OFF%
&DATA %EXECUTE% %EQAR_PGM%
%INFOPATH%
%INCOVER%.SUBA
%CATITEM%
%CATVAL%
%NOSAMP%
%TOLER%
&END
/*
&S DELETER := [DELETE SUBA.ASCII]
/*
/* OVERLAY THE POINT POPULATION ONTO THE EQUAL-AREA CELLS
/*
&IF [EXISTS %INCOVER%.SAM -COVER] &THEN KILL %INCOVER%.SAM
IDENTITY %INCOVER%.POP %INCOVER%.SUBA %INCOVER%.SAM POINT 0.001
/*
/* CREATE POLYGONS OF THE CELLS FOR ILLUSTRATIVE PURPOSES
/*
&TYPE %BOLD_ON%Preparing coverage of equal-area cells%BOLD_OFF%
&S CCOVER := %INCOVER%.CELL.%CATVAL%
&IF [EXISTS %CCOVER% -COVER] &THEN KILL %CCOVER%
DISSOLVE %INCOVER%.SUBA %CCOVER% CELL POLY
/*
/* RANDOMLY SELECT SITES FROM EACH OF THE EQUAL-AREA CELLS
/*
&DO I := 1 &TO %NOSAMP%
&TYPE %BOLD_ON%Selecting sites from cell #%I%%BOLD_OFF%
&TYPE
&DATA %EXECUTE% %PICK_PGM%
%INFOPATH%
%INCOVER%.SAM
CELL = %I% AND %CATITEM% EQ [QUOTE %CATVAL%]
1
%TOLER%
&END                                                       /* END OF DATA TO PICKEM
&END                                                       /* END OF SELECTION LOOP
/*
&S CELITM := CELL
&GOTO REPORT
/*
/* -----------------------------------------------------------------------
/* METHOD THREE IS RANDOM SELECTION FROM CELLS DEFINED BY AN ITERATIVE
/* AREAL DISTRIBUTION ALGORITHM.
/* -----------------------------------------------------------------------
&LABEL METHOD_THREE
&S PROMPT := 'Enter fraction of cells to attain '~
[CALC %TOLER% + 1]' sites for convergence, (CR = '%PERCENT%')'
&S PERCENT := [RESPONSE %PROMPT% %PERCENT%]
&IF [TYPE %PERCENT%] > 0 &THEN &DO
    &TYPE Numeric value required
    &GOTO METHOD_THREE
&END
&IF %PERCENT% < 0 | %PERCENT% > 1 &THEN &DO
    &TYPE
    &TYPE Fraction of cells must be a value between zero and one
    &GOTO METHOD_THREE
&END
/*
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
&LABEL GET_MAX
&S PROMPT := 'Enter maximum number of iterations, (CR = '%MAXITER%')'
&S MAXITER := [RESPONSE %PROMPT% %MAXITER%]
&IF [TYPE %MAXITER%] ^= -1 &THEN &DO
   &TYPE Integer value required
   &GOTO GET_MAX
&END
&IF %MAXITER% <= 0 &THEN &DO
   &TYPE Positive number required
   &GOTO GET_MAX
&END
/*
&LABEL GET_DAMP
&S PROMPT := 'Enter damping factor, (CR = '%DAMPER%')'
&S DAMPER := [RESPONSE %PROMPT% %DAMPER%]
&IF [TYPE %DAMPER%] > 0 &THEN &DO
    &TYPE Numeric value required
    &GOTO GET_DAMP
&END
&IF %DAMPER% <= 0 &THEN &DO
    &TYPE
    &TYPE Damping factor should not be less than or equal to zero
    &GOTO GET_DAMP
&END
/*
/* FOR AN INITIAL GUESS AT THE ITERATION PARAMETERS:
/* SET THE CELL POPULATION TO ACCOUNT FOR THE FRACTION OF THE AREA WHICH
/* CONSISTS OF THE DESIRED POLYGON CATEGORY VERSUS THE TOTAL STUDY AREA.
/*
&TYPE %BOLD_ON%Making an initial guess at grid characteristics...%BOLD_OFF%
&S ITER := 0
/*
&DATA %EXECUTE% %INFL_PGM%
%INFOPATH%
%CATVAL%
%NOSAMP%
%TOLER%
&END
/*
&S AMLU    := [OPEN INFLATED OPENERR -READ]
&S INFLATE := [UNQUOTE [TRIM [READ %AMLU% EOF]]]
&S CLOSERR := [CLOSE %AMLU%]
&S DELETER := [DELETE INFLATED]
/*
&IF %INFLATE% = 0 &THEN &GOTO SAMPLE
/*
/* PREPARE A POLYGON GRID USING THE CURRENT ITERATION PARAMETERS.
/*
&LABEL ITERATE
/*
&TYPE %BOLD_ON%Defining cell characteristics...%BOLD_OFF%
&S ITER := [CALC %ITER% + 1]
&DATA %EXECUTE% %GRID_PGM%
%INCOVER%
1
%INFLATE%
&END
/*
/* READ THE RESULTS FROM THE FORTRAN PGM IN THE OUTPUT FILE
/*
&S AMLU := [OPEN %INCOVER%.GRD OPENERR -READ]
&S LINE := [TRIM [READ %AMLU% EOF]]
&DO VAR &LIST XMIN XMAX YMIN YMAX XDIM YDIM INFLATE
    &S TEMP := [BEFORE %LINE% ' ']
    &S %VAR% := %TEMP%
    &S LINE := [TRIM [AFTER %LINE% %TEMP%]]
&END
&S CLOSERR := [CLOSE %AMLU%]
&S DELETER := [DELETE %INCOVER%.GRD]
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
/*
/* PREPARE A GRIDDED COVERAGE WITH LABEL POINTS.
/*
&TYPE
&TYPE %BOLD_ON%Constructing a grid with %INFLATE% cells...%BOLD_OFF%

&S CCOVER := %INCOVER%.CELL.%CATVAL%
&IF [EXISTS %CCOVER% -COVER] &THEN KILL %CCOVER%
GENERATE %CCOVER%
COPYTICS %INCOVER%
GRID LABELS
%XMIN%, %YMIN%
%XMIN%, %YMAX%
%XDIM%, %YDIM%
0, 0
%XMAX%, %YMAX%
QUIT
/*
/* CREATE POLYGON TOPOLOGY FOR THE CELL COVERAGE.
/*
BUILD %CCOVER% POLY
&S CELITM := [UNQUOTE [SUBSTR %CCOVER%-ID 1 16]]
/*
/* OVERLAY THE CELLS ONTO THE POINT POPULATION.
/*
&IF [EXISTS %INCOVER%.SAM -COVER] &THEN KILL %INCOVER%.SAM
IDENTITY %INCOVER%.POP %CCOVER% %INCOVER%.SAM POINT 0.001
/*
/* CHECK FOR CONVERGENCE, IF CONVERGED, THEN SELECT SITES...
/*
&TYPE %BOLD_ON%Checking for convergence...%BOLD_OFF%
&DATA %EXECUTE% %MTHR_PGM%
%INFOPATH%
%INCOVER%.SAM
%CELITM%
%CATITEM%
%CATVAL%
%NOSAMP%
%INFLATE%
%TOLER%
%PERCENT%
%DAMPER%
&END
/*
&S AMLU    := [OPEN INFLATED OPENERR -READ]
&S INFLATE := [UNQUOTE [TRIM [READ %AMLU% EOF]]]
&S CLOSERR := [CLOSE %AMLU%]
&S DELETER := [DELETE INFLATED]
/*
/* IF CONVERGENCE WAS NOT ATTAINED, ITERATE
/*
&IF %INFLATE% ^= -99998 &THEN &DO
    &TYPE %BOLD_ON%Convergence failed on iteration #%ITER%%BOLD_OFF%
    &IF %ITER% < %MAXITER% &THEN &GOTO ITERATE
    &TYPE %BOLD_ON%'Maximum number of iterations exceeded'%BOLD_OFF%
    &GOTO SAMPLE
&END
/*
/* ---------------------------------------------------------------------
&LABEL REPORT
/*
/* UPDATE THE INFO CATEGORY INDEX FILE:  CATIDX.
/*
&TYPE %BOLD_ON%Site selection completed....Updating index file...%BOLD_OFF%
&DATA %EXECUTE% %UCAT_PGM%
%INFOPATH%
%CATVAL%
%NOSAMP%
&END
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
/*
/* SAVE RESULTS OF SITE SELECTION IN THE POPULATION COVERAGE FOR METHODS TWO AND
/*  THREE.  METHOD ONE RECORDED ITS RESULTS DIRECTLY IN THE POPULATION COVERAGE.
/*
&IF %METHOD% ^= 1 &THEN &DO
&TYPE %BOLD_ON%Recording results in population coverage%BOLD_OFF%
/*
&WORKSPACE %INFOPATH%
&DATA INFO
ARC
SELECT %INCOVER%.SAM.PAT
RELATE %INCOVER%.POP.PAT UNIQUE
RESELECT %CATITEM% = [QUOTE %CATVAL%]
CALC $1CELLNO = %CELITM%
CALC $1CHOSEN =  CHOSEN
Q STOP
&END
&WORKSPACE %HOME%
KILL %INCOVER%.SAM
&END
/*
/* RECORD SITE SELECTION NETWORK IN A PLOT FILE.
/*
&TYPE %BOLD_ON%Preparing plot file:  #%INCOVER%.%CATVAL%%BOLD_OFF%
    ARCPLOT
    DISP 1039
    #%INCOVER%.%CATVAL%
    &TYPE #%INCOVER%.%CATVAL%
    PAGESIZE 7.5 10.0
    MAPEXTENT %INCOVER%
    MAPPOSITION CEN CEN
    POLYS %INCOVER%
    LINECOLOR 3
    &IF %METHOD% ^= 1 &THEN POLYGONS %CCOVER%
    MARKERSET WATER.MRK
    MARKERSYM 109
    TEXTFONT 3
    RESELECT %INCOVER%.POP POINTS %CATITEM% = [QUOTE %CATVAL%] AND CHOSEN > 0
    POINTS   %INCOVER%.POP
    POINTTEXT %INCOVER%.POP CHOSEN CC
    QUIT
&IF [EXISTS %INCOVER%.GRID -COVER] &THEN KILL %INCOVER%.GRID
/*
/* PREPARE SORTED LIST OF CHOSEN SITES.
/*
&TYPE
&TYPE %BOLD_ON%Saving locations of selected sites...%BOLD_OFF%
&IF [EXISTS SAMSRT] &THEN &S DELETER := [DELETE SAMSRT]
&IF [EXISTS SAMPTS] &THEN &S DELETER := [DELETE SAMPTS]
&DATA %EXECUTE% %RPT1_PGM%
%INFOPATH%
%INCOVER%.POP
%CATITEM%
%CATVAL%
%CELITM%
&END
/*
&TYPE %BOLD_ON%Projecting to latitude-longitude...%BOLD_OFF%
&IF [EXISTS SAMSRT.GEO] &THEN &S DELETER := [DELETE SAMSRT.GEO]
PROJECT FILE SAMSRT SAMSRT.GEO %PROJ_DES%
/*
/* FORMAT REPORT SHOWING THE RESULTS OF THE SITE SELECTION
/*
```

Attachment A.--Arc macro language program SAMPLE.AML listing--Continued

```
&TYPE %BOLD_ON%Locations projected......formatting report...%BOLD_OFF%
&DATA %EXECUTE% %RPT2_PGM%
%INFOPATH%
%CATVAL%
%NOSAMP%
%TOLER%
&END
&S DELETER := [DELETE SAMPTS]
&S DELETER := [DELETE SAMSRT]
&S DELETER := [DELETE SAMSRT.GEO]
&TYPE
&TYPE %BOLD_ON%Report is ready in the file:   SITE.REPORT.%CATVAL%%BOLD_OFF%
/*
&GOTO SELECT_OPTION
```

Attachment B.--Statements inserted into several Fortran programs

```
C SAMPLE.INSERT - PROBLEM-DEPENDANT ARRAY LIMITS
C
C     MAXIMUM NUMBER OF POTENTIAL SITES IN A CATEGORY
      PARAMETER (MAXPOP = 10000)
C
C     MAXIMUM NUMBER OF SUBAREAS IN A CATEGORY
      PARAMETER (MAXSUB = 20000)
C
C     MAXIMUM NUMBER OF CATEGORIES IN THE STUDY REGION
      PARAMETER (MAXCAT = 100)
C
C     MAXIMUM NUMBER OF CELLS
      PARAMETER (MAXCEL = 1000)
C
C     MAXIMUM NUMBER OF POTENTIAL SITES IN A CELL
      PARAMETER (MAXPNT = 10000)
```

Attachment C.--Subroutines used in several Fortran programs

```
      SUBROUTINE IRSEED (SSMID)
C
C INTERLUDE TO PRIMOS ROUTINE TO RETRIEVE NUMBER OF SECONDS SINCE MIDNIGHT
C (FOR USE AS A SEED FOR RANDOM NUMBER GENERATION):  TIMDAT
C
      INTEGER*2 TDARAY(28)
      CALL TIMDAT (TDARAY,INTS(28))
      SSMID = TDARAY (5)
      RETURN
      END

      SUBROUTINE ISRTFL (FILEIN,FILOUT,NKEY,KEYSTR,KEYEND,NPASS,NITEM)
C
C INTERLUDE TO PRIMOS FILE-SORTING ROUTINE:  SUBSRT
C
      INTEGER*2 LENIN                /* LENGTH OF INPUT  FILE (IN BYTES)
      INTEGER*2 LENOUT               /* LENGTH OF OUTPUT FILE (IN BYTES)
      INTEGER*2 NUMKEY               /* NUMBER OF SORT KEYS
      INTEGER*2 NSTART (9)           /* VECTOR OF SORT KEY START BYTES
      INTEGER*2 NEND   (9)           /* VECTOR OF SORT KEY END BYTES (output)
      INTEGER*2 NPASS2               /* NUMBER OF PASSES FOR SORT    (output)
      INTEGER*4 NPASS                /* FOUR BYTE COPY OF NPASS2
      INTEGER*4 NITEM                /* NUMBER OF ITEMS SORTED
      INTEGER*4 NKEY                 /* FOUR BYTE COPY OF NUMKEY
      INTEGER*4 KEYSTR (NKEY)        /* FOUR BYTE COPY OF NSTART
      INTEGER*4 KEYEND (NKEY)        /* FOUR BYTE COPY OF NEND
      CHARACTER*128 FILEIN           /* INPUT FILENAME (UNSORTED)
      CHARACTER*128 FILOUT           /* OUTPUT FILENAME (SORTED)
```

Attachment C.--Subroutines used in several Fortran programs--Continued

```
C
      LENIN  = INTS (LENGTH (FILEIN,128))
      LENOUT = INTS (LENGTH (FILOUT,128))
      NUMKEY = NKEY
      DO 30 I=1,MIN (NKEY,9)
         NSTART(I) = KEYSTR(I)
         NEND  (I) = KEYEND(I)
30    CONTINUE
C
      CALL SUBSRT (FILEIN,LENIN,FILOUT,LENOUT,NUMKEY,NSTART,NEND,
     &             NPASS2,NITEM)
      NPASS = NPASS2
      RETURN
      END

      INTEGER FUNCTION LENGTH (STRING,LEN)
C
C  FUNCTION TO DETERMINE THE LENGTH OF A STRING
C
      CHARACTER*(*) STRING
      DO 10 I=LEN,1,-1
10      IF (STRING(I:I) .NE. ' ') GOTO 20
      I = 0
20    LENGTH = I
      RETURN
      END
```

Attachment D.--Fortran program ITEXST listing

```
      PROGRAM ITEXST
C
C TEST IF AN ITEM EXISTS IN AN INFO FILE
C     IF YES:  WRITE .TRUE.  TO OUTPUT FILE
C     IF  NO:  WRITE .FALSE. TO OUTPUT FILE
C JONATHON SCOTT, LAST MODIFIED OCTOBER 24, 1989
C
      CHARACTER DIRECT*128, FILE*32, NAMITM*16, USER*4
      INTEGER   ITEMAR(4)
      PARAMETER (ITWO=2)
C
C1 -- INITIALIZE ARC LIBRARY ROUTINES
      CALL MESINI
      CALL LUNINI
      CALL MINIT
      CALL INFINT
C
C2 -- GET DATA FROM CALLING PROGRAM
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)')    DIRECT
      CALL PRMSTR ('INFO user name is ',18)
      READ (*,'(A)')    USER
      CALL PRMSTR ('INFO file name is ',18)
      READ (*,'(A)')    FILE
      CALL PRMSTR ('Variable name is ',17)
      READ (*,'(A)')    NAMITM
C
C3 -- OPEN THE INFO FILE, TEST FOR ITEM NAME, CLOSE INFO FILE
      CALL ACREAT (LUN,'TSTINF',IER)
      CALL INFOPN (FILE,DIRECT,USER,ITWO,INUM,NUMREC,ILEN,IER)
      IF (IER .NE. 0) THEN
         CALL INFORM ('INFO file does not exist',0)
         WRITE (LUN,'(A)') '.FALSE.'
         GOTO 900
      ENDIF
      CALL INFEXI (INUM,NAMITM,ITEMAR,IEXIST)
      CALL INFCLS (INUM)
```

Attachment D.--Fortran program ITEXST listing--Continued

```
C
C4 -- WRITE RESULTS TO OUTPUT FILE
      IF (IEXIST .EQ. 0) THEN
         CALL INFORM ('Variable name does not exist',0)
         WRITE (LUN,'(A)') '.FALSE.'
      ELSE
         WRITE (LUN,'(A)') '.TRUE.'
      ENDIF
C
C5 -- FINISHED, CLOSE FILES
900   ENDFILE     (LUN)
      CALL ACLOSE (LUN)
      CALL AEXIT
      END
```

Attachment E.--Fortran program GRIDIM listing

```
      PROGRAM GRIDIM
C
C GRIDIM COMPUTES GRID DATA FOR USE WITH THE ARC/INFO GENERATE COMMAND
C JONATHON SCOTT, LAST MODIFIED JULY 25, 1990
C
      CHARACTER COVER*128, FILEN*32
      DOUBLE PRECISION BOX(4)
      EXTERNAL MINIT, LUNINI, BOXGET
C
C1 -- INITIALIZE THE ARC/INFO SUBROUTINE LIBRARIES
      CALL MESINI
      CALL MINIT
      CALL LUNINI
C
C2 -- GET DATA FROM THE CALLING PROGRAM
      CALL PRMSTR ('Boundary used from the coverage ',32)
      READ (*,'(A)')   COVER
      CALL PRMSTR ('Method code is ',15)
      READ (*,'(I20)') IFLAG
      IF (IFLAG .EQ. 1) THEN
         CALL PRMSTR ('Approximate number is ',25)
      ELSE
         CALL PRMSTR ('Distance is ',15)
      ENDIF
      READ (*,'(I20)') NPTS
C
C3 -- GET THE BOUNDARIES OF THE STUDY REGION
      CALL BOXGET (COVER,BOX,IERR)
      XMIN = BOX(1)
      YMIN = BOX(2)
      XMAX = BOX(3)
      YMAX = BOX(4)
C
C4 -- CALULATE:  LENGTH OF AXES & TOTAL AREA WITHIN THE COVERAGE BOUNDARIES
      XLEN = XMAX - XMIN
      YLEN = YMAX - YMIN
      AREA = XLEN * YLEN
C
C5 -- DEPENDING UPON THE METHOD CHOSEN, SET THE DISTANCE BETWEEN POINTS
      IF (IFLAG .EQ. 1) THEN
C
C5A --    WHEN IFLAG = 1: NPTS = APPROXIMATE NUMBER OF POINTS TO BE GENERATED
         CELL = AREA / NPTS
         SIDE = SQRT (CELL)
         XDIM = SIDE
         YDIM = SIDE
      ELSE
```

Attachment E.--Fortran program GRIDIM listing--Continued

```
C
C5B --     WHEN IFLAG = 2: NPTS = THE DISTANCE BETWEEN POINTS
           XDIM = NPTS
           YDIM = NPTS
      ENDIF
C
C6 -- SEED RANDOM NUMBER GENERATOR
      CALL IRSEED (SSMID)
      RAND = RND  (SSMID)
C
C7 -- GET A RANDOM NUMBER AND USE IT TO SET THE ORIGIN OF THE COORDINATES
      RAND = RND (Ø.)
      XMIN = XMIN - RAND * XDIM
      RAND = RND (Ø.)
      YMIN = YMIN - RAND * YDIM
C
C8 -- CALCULATE THE NUMBER OF POINTS TO BE GENERATED IN EACH DIMENSION
      XNUM = (XMAX - XMIN) / XDIM + Ø.5
      YNUM = (YMAX - YMIN) / YDIM + Ø.5
C
C9 -- LENGTHEN MAXIMA TO GET AROUND BUG IN GENERATE
      XMAX = XMAX + XDIM
      YMAX = YMAX + YDIM
C
C1Ø - CALCULATE THE TOTAL NUMBER OF POINTS
      NCELL = INT(XNUM) * INT(YNUM)
C
C11 - PLACE THE COMPUTED DATA INTO THE RETURN-ARGUMENT TEMPORARY FILE
      FILEN = COVER (1:LENGTH(COVER,128)) // '.GRD'
      CALL ACREAT (LUN,FILEN,IER)
      WRITE (LUN,'(6F15.3,I1Ø)') XMIN,XMAX,YMIN,YMAX,XDIM,YDIM,NCELL
      ENDFILE (LUN)
      CALL ACLOSE (LUN)
      CALL AEXIT
      END
```

Attachment F.--Fortran program DEFIDX listing

```
      PROGRAM DEFIDX
C
C DEFIDX IS RUN ONCE TO CREATE A POLYGON CATEGORY INDEX (CATIDX) INFO FILE
C THE CATIDX FILE IS USED TO KEEP INFORMATION ABOUT AREAL SUBSET CATEGORIES
C THERE IS ONE RECORD IN THE FILE FOR EACH CATEGORY
C JONATHON SCOTT, LAST MODIFIED OCTOBER 23, 1989
C
$INSERT SAMPLE.INSERT
      CHARACTER  DIRECT*128, POLCOV*32, PIDCOV*32, FILE*32, CATIDX*32
      CHARACTER  CATITM*16,  ALTERN*16, NAMITM*16, AFTER*16
      CHARACTER  USER*4,     STRING*16
      CHARACTER  INFEXP*8Ø,  MSG*8Ø
      CHARACTER  QUOTE*1
      CHARACTER*16 CATS(MAXCAT)
C
      INTEGER    ITEMAR(4),    INREC(1Ø24)
      INTEGER    EVLEXP(2,8Ø), EXPTYP
      DOUBLE PRECISION REALLY, AREA,   TOTARE
C
      PARAMETER (USER='ARC',CATIDX='CATIDX',ALTERN='',AFTER='')
      PARAMETER (ISIX=6,IFIVE=5,IFOUR=4,ITHREE=3,ITWO=2,IONE=1,IZERO=Ø)
      PARAMETER (NEGONE=-1)
```

```
C
C1 -- INITIALIZE ARC LIBRARY ROUTINES
      CALL MESINI
      CALL LUNINI
      CALL MINIT
      CALL INFINT
      QUOTE = ''''
C
C2 -- GET DATA FROM THE CALLING PROGRAM
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)') DIRECT
      CALL PRMSTR ('Coverage of areal subsets is ',29)
      READ (*,'(A)') POLCOV
      CALL PRMSTR ('Coverage of population is ',26)
      READ (*,'(A)') PIDCOV
      CALL PRMSTR ('Category-variable name is ',26)
      READ (*,'(A)') CATITM
C
C3 -- IF THE INDEX INFO FILE DOES EXIST DELETE IT, THEN CREATE & DEFINE IT...
      CALL INFERS (CATIDX,DIRECT,USER,IONE,IER)
      CALL INFDEF (CATIDX,DIRECT,USER,IZERO,IDXNUM,IER)
      IF (IER .NE. 0) CALL ERROR ('ERROR DURING INFDEF',0)
C
C3A -- DEFINE:  CATEGORY,16,C
      NAMITM = 'CATEGORY'
      IWIDTH = 16
      CALL INFADI (IDXNUM,IZERO,NAMITM,ALTERN,AFTER,ITWO,IWIDTH,
     1             IWIDTH,NEGONE,IFOUR,IZERO,NEGONE,NEGONE,NEGONE,
     2             NEGONE,IZERO,IER)
      IF (IER .NE. 0) THEN
          CALL INFCLS (IDXNUM)
          CALL ERROR ('Error adding item',0)
      ENDIF
C
C3B -- DEFINE:  AREA,4,12,F,3
      NAMITM = 'AREA'
      IWIDTH = 12
      CALL INFADI (IDXNUM,IZERO,NAMITM,ALTERN,AFTER,ISIX,IFOUR,
     1             IWIDTH,ITHREE,IFOUR,IZERO,NEGONE,NEGONE,NEGONE,
     2             NEGONE,IZERO,IER)
C
C3C -- DEFINE:  NUMPOLY,4,5,B
      NAMITM = 'NUMPOLY'
      CALL INFADI (IDXNUM,IZERO,NAMITM,ALTERN,AFTER,IFIVE,IFOUR,
     1             IFIVE,NEGONE,IFOUR,IZERO,NEGONE,NEGONE,NEGONE,
     2             NEGONE,IZERO,IER)
C
C3D -- DEFINE:  NUMPTS,4,5,B
      NAMITM = 'NUMPTS'
      CALL INFADI (IDXNUM,IZERO,NAMITM,ALTERN,AFTER,IFIVE,IFOUR,
     1             IFIVE,NEGONE,IFOUR,IZERO,NEGONE,NEGONE,NEGONE,
     2             NEGONE,IZERO,IER)
C
C3E -- DEFINE:  FRACTION,4,12,F,4
      NAMITM = 'FRACTION'
      CALL INFADI (IDXNUM,IZERO,NAMITM,ALTERN,AFTER,ISIX,IFOUR,
     1                    IWIDTH,IFOUR,IFOUR,IZERO,NEGONE,NEGONE,NEGONE,
     2                    NEGONE,IZERO,IER)
C
C3F -- DEFINE:  NOSAMP,4,5,B
      NAMITM = 'NOSAMP'
      CALL INFADI (IDXNUM,IZERO,NAMITM,ALTERN,AFTER,IFIVE,IFOUR,
     1             IFIVE,NEGONE,IFOUR,IZERO,NEGONE,NEGONE,NEGONE,
     2             NEGONE,IZERO,IER)
      IDXLEN = 36
```

Attachment F.--Fortran program DEFIDX listing--Continued

```
C
C4 -- OPEN THE STUDY REGION AREAL SUBSET (PAT) INFO-FILE
      FILE = POLCOV (1:LENGTH(POLCOV,32)) // '.PAT'
      CALL INFOPN (FILE,DIRECT,USER,ITWO,NFPOLY,NUMPOL,IPOLLN,IER)
      IF (IER .NE. Ø) THEN
          CALL INFCLS (IDXNUM)
          CALL ERROR ('Unable to open polygon attribute table',Ø)
      ENDIF
C
C5 -- OPEN THE SITE POPULATION (PAT) INFO-FILE
      FILE = PIDCOV (1:LENGTH(PIDCOV,32)) // '.PAT'
      CALL INFOPN (FILE,DIRECT,USER,IONE,NFPID,NUMPNT,IPNTLN,IER)
      IF (IER .NE. Ø) THEN
          CALL INFCLS (IDXNUM)
          CALL INFCLS (NFPOLY)
          CALL ERROR ('Unable to open point attribute table',Ø)
      ENDIF
C
C6 -- CHECK TO MAKE SURE THAT THE POLYGON CATEGORY-ITEM NAME EXISTS
      CALL INFEXI (NFPOLY,CATITM,ITEMAR,IEXIST)
      IF (IEXIST .EQ. Ø) THEN
          CALL INFCLS (IDXNUM)
          CALL INFCLS (NFPID)
          CALL INFCLS (NFPOLY)
          CALL ERROR ('Category-variable name does not exist',Ø)
      ENDIF
      LENCAT = ITEMAR(2)
C
C8 -- LOOP THROUGH POLYGONS & KEEP TRACK OF ALL THE DIFFERENT CATEGORIES
C     (SKIP THE 1ST POLYGON, BECAUSE IT IS THE EXTERIOR 'POLYGON')
      NUMCAT = 1
      DO 2Ø IPOLY=1,NUMPOL
          CALL INFGET (NFPOLY,IPOLY,INREC,IER)
          CALL INFDEC (INREC,IPOLLN,ITEMAR,REALLY,STRING,IER)
          IEXIST = Ø
          IF (NUMCAT .GT. 1) THEN
              DO 1Ø I=1,NUMCAT-1
                  IF (CATS(I) .EQ. STRING) IEXIST = 1
1Ø                CONTINUE
          ENDIF
          IF (IEXIST .EQ. Ø) THEN
              CATS (NUMCAT) = STRING
              NUMCAT = NUMCAT + 1
              IF (NUMCAT .GT. MAXCAT) THEN
                 CALL INFCLS (NFPOLY)
                 CALL INFCLS (NFPID)
                 CALL INFCLS (IDXNUM)
                 CALL ERROR ('Resizing needed for MAXCAT',Ø)
              ENDIF
          ENDIF
2Ø    CONTINUE
      NUMCAT = NUMCAT - 1
      TOTARE = Ø.Ø
C
C9 -- LOOP THROUGH THE POLYGON CATEGORIES & DESCRIBE EACH ONE
      DO 5Ø ICAT = 1, NUMCAT
          INFEXP = CATITM // ' EQ ' // QUOTE //
     1             CATS(ICAT)(1:LENCAT) // QUOTE
          CALL INFTRN (NFPOLY,INFEXP,EVLEXP,EXPTYP,IER)
          AREA  = Ø.Ø
          NPOLY = Ø
```

```
C
C9A --     LOOP THROUGH ALL THE POLYGONS & FIND OUT TOTAL AREA AND
C           NUMBER OF POLYGONS IN EACH CATEGORY (IGNORING EXTERIOR POLYGON)
          NAMITM = 'AREA'
          CALL INFEXI (NFPOLY,NAMITM,ITEMAR,IEXIST)
          DO 30 IPOLY = 1,NUMPOL
              CALL INFSEL (NFPOLY,IPOLY,EVLEXP,IEXIST)
              IF (IEXIST .EQ. 1) THEN
                  CALL INFGET (NFPOLY,IPOLY,INREC,IER)
                  CALL INFDEC (INREC,IPOLLN,ITEMAR,REALLY,STRING,IER)
                  IF (REALLY .GT. 0.) THEN
                     AREA  = AREA + REALLY
                     NPOLY = NPOLY + 1
                  ENDIF
              ENDIF
30        CONTINUE
          TOTARE = TOTARE + AREA
C
C9B --     LOOP THE SITES & FIND OUT THE NUMBER OF SITES IN EACH CATEGORY
          NPTS = 0
          CALL INFCLE (EVLEXP)
          CALL INFTRN (NFPID,INFEXP,EVLEXP,EXPTYP,IER)
          DO 40 IPNT = 1,NUMPNT
              CALL INFSEL (NFPID,IPNT,EVLEXP,IEXIST)
              IF (IEXIST .NE. 0) NPTS = NPTS + 1
40        CONTINUE
          CALL INFCLE (EVLEXP)
C
C9C --     WRITE TO THE CATIDX FILE THE INFORMATION ABOUT THE CATEGORY
          NAMITM = 'CATEGORY'
          STRING = CATS(ICAT)
          CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
          CALL INFENC (ITEMAR,REALLY,STRING,IDXLEN,INREC,IER)
          NAMITM = 'AREA'
          CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
          CALL INFENC (ITEMAR,AREA,   STRING,IDXLEN,INREC,IER)
          NAMITM = 'NUMPOLY'
          REALLY = NPOLY
          CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
          CALL INFENC (ITEMAR,REALLY,STRING,IDXLEN,INREC,IER)
          NAMITM = 'NUMPTS'
          REALLY = NPTS
          CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
          CALL INFENC (ITEMAR,REALLY,STRING,IDXLEN,INREC,IER)
          NAMITM = 'NOSAMP'
          REALLY = 0.
          CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
          CALL INFENC (ITEMAR,REALLY,STRING,IDXLEN,INREC,IER)
C
          CALL INFPUT (IDXNUM,ICAT,INREC,IER)
50    CONTINUE
C
C10 - COMPUTE & STORE THE AREA-WEIGHTED FRACTIONS
      DO 60 ICAT=1,NUMCAT
          NAMITM = 'AREA'
          CALL INFGET (IDXNUM,ICAT,INREC,IER)
          CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
          CALL INFDEC (INREC,IDXLEN,ITEMAR,REALLY,STRING,IER)
          REALLY = REALLY / TOTARE
          NAMITM = 'FRACTION'
          CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
          CALL INFENC (ITEMAR,REALLY,STRING,IDXLEN,INREC,IER)
          CALL INFPUT (IDXNUM,ICAT,INREC,IER)
60    CONTINUE
```

Attachment F.--Fortran program DEFIDX listing--Continued

```
C
C11 - FINISHED
      WRITE (MSG,'(A,I4)') 'Number of categories defined = ',NUMCAT
      CALL INFORM (MSG,0)
      CALL INFCLS (NFPID)
      CALL INFCLS (NFPOLY)
      CALL INFCLS (IDXNUM)
      CALL AEXIT
      END
```

Attachment G.--Fortran program CHKIDX listing

```
      PROGRAM CHKIDX
C
C CHKIDX IS RUN EACH TIME A VALUE IS ENTERED FOR THE CATEGORY VARIABLE.
C THE PROGRAM READS THE CATEGORY INDEX FILE (CATIDX) IN INFO
C THE NUMBER OF SITES SELECTED FOR THE CATEGORY (NOSAMP) IS RETURNED.
C NEGATIVE ONE IS RETURNED IF THE CATEGORY IS NOT FOUND IN THE INDEX.
C JONATHON SCOTT, LAST MODIFIED OCTOBER 11, 1989
C
      CHARACTER DIRECT*128, CATIDX*32, FNAME*32
      CHARACTER CATITM*16,  NAMITM*16, CATNAM*16,  STRING*16
      CHARACTER USER*4
      CHARACTER INFEXP*80
      CHARACTER QUOTE*1
C
      INTEGER   ITEMAR(4),    INREC(1024)
      INTEGER   EVLEXP(2,80), EXPTYP
      DOUBLE PRECISION REALLY
C
      PARAMETER (USER='ARC',CATIDX='CATIDX',ITWO=2,QUOTE='''')
      PARAMETER (CATITM='CATEGORY',FNAME='T$NOSAMP')
C
C1 -- INITIALIZE ARC LIBRARY ROUTINES
      CALL MESINI
      CALL LUNINI
      CALL MINIT
      CALL INFINT
C
C2 -- GET DATA FROM CALLING PROGRAM
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)')    DIRECT
      CALL PRMSTR ('Category is ',12)
      READ (*,'(A)')    CATNAM
C
C3 -- OPEN THE CATEGORY INDEX INFO FILE (CATIDX)
      CALL INFOPN (CATIDX,DIRECT,USER,ITWO,IDXNUM,NUMCAT,IDXLEN,IER)
      IF (IER .NE. 0)
     1    CALL ERROR('Unable to open category-index file',0)
C
C4 -- FIND THE RECORD FOR THE CATEGORY
      INFEXP = CATITM // ' EQ ' // QUOTE // CATNAM(1:LENGTH(CATNAM,16))
     1                          // QUOTE
      CALL INFTRN (IDXNUM,INFEXP,EVLEXP,EXPTYP,IER)
      DO 50 ICAT = 1,NUMCAT
          CALL INFSEL (IDXNUM,ICAT,EVLEXP,IEXIST)
          IF (IEXIST .NE. 0) GOTO 100
50        CONTINUE
      NOSAMP = -1
      GOTO 200
```

Attachment G.--Fortran program CHKIDX listing--Continued

```
C
C5 -- READ FROM THE CATIDX FILE THE NUMBER OF SITES SELECTED FOR THE CATEGORY
100   CALL INFGET (IDXNUM,ICAT,INREC,IER)
      NAMITM = 'NOSAMP'
      CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
      CALL INFDEC (INREC,IDXLEN,ITEMAR,REALLY,STRING,IER)
      NOSAMP = REALLY
C
C6 -- FINISHED.
200   CALL ACREAT (LUN,FNAME,IER)
      WRITE (LUN,'(I6)') NOSAMP
      ENDFILE (LUN)
      CALL ACLOSE (LUN)
      CALL INFCLS (IDXNUM)
      CALL AEXIT
      END
```

Attachment H.--Fortran program PICKEM listing

```
      SUBROUTINE PICKEM
C
C RANDOMLY SELECTS SITES FROM A GROUP DEFINED BY A SELECTION EXPRESSION
C JONATHON SCOTT, LAST MODIFIED MARCH 27, 1990
C
      CHARACTER FILE*32,  DIRECT*128, USER*8, ITEM*16, INSTR*1
      CHARACTER COVER*32, INFEXP*320, MSG*80
      INTEGER FNUM, NUMREC, RECLEN, IER, EXISTS, IZERO
      INTEGER RECNUM, REC(1024), ITEMAR(4)
      INTEGER ETYPE, EVLEXP(2,80)
      DOUBLE PRECISION REALLY
C
$INSERT SAMPLE.INSERT
      INTEGER  CHOSEN(MAXPNT), RECORD(MAXPNT)
      COMMON   CHOSEN,         RECORD
      EXTERNAL MINIT,  LUNINI, INFINT, INFNAM, INFOPN, INFEXI
      EXTERNAL INFENC, INFGET, INFPUT
C
      PARAMETER (USER='ARC',ITEM='CHOSEN',INSTR='')
      PARAMETER (ITYPE=1,IACESS=2)
C
C1 -- INITIALIZE THE ARC/INFO LIBRARIES
      CALL MESINI
      CALL MINIT
      CALL LUNINI
      CALL INFINT
C
C2 -- GET COVERAGE NAME, PATH NAME, ITEM NAME, & ITEM VALUE
C       GENERATE ARC/INFO FILENAME FOR POINT ATTRIBUTE TABLE
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)') DIRECT
      CALL PRMSTR ('Coverage of population is ',26)
      READ (*,'(A)') COVER
      CALL PRMSTR ('Selection expression is ',24)
      READ (*,'(A)') INFEXP
      CALL INFNAM (COVER,ITYPE,FILE)
C
C3 -- CHECK TO MAKE SURE THE POINT ATTRIBUTE TABLE CAN BE FOUND, THEN OPEN IT
      CALL INFEXF (FILE,DIRECT,USER,EXISTS)
      IF (EXISTS .LE. 0)
     *   CALL ERROR ('Attribute table not found for population',0)
      CALL INFOPN (FILE,DIRECT,USER,IACESS,FNUM,NUMREC,RECLEN,IER)
      IF (IER .NE. 0)
     *   CALL ERROR ('Unable to open population coverge PAT',0)
```

```
C
C4 -- MAKE SURE THERE ARE SOME POINTS IN THIS COVERAGE
      IF (NUMREC .EQ. Ø) THEN
         CALL INFCLS (FNUM)
         CALL ERROR ('No sites in population',Ø)
      ENDIF
C
C5 -- FIND OUT HOW MANY SITES AND ALTERNATE SITES ARE TO BE SELECTED
      CALL PRMSTR ('Number of primary sites is ',27)
      READ (*,*) NOSAMP
      CALL PRMSTR ('Number of alternate sites is ',29)
      READ (*,*) NDUP
      NDUP = NDUP + 1
      NUMSEL = Ø
C
C6 -- TRANSLATE THE SELECTION EXPRESSION INTO ARC/INFO ENCRYPTION
      CALL INFTRN (FNUM,INFEXP,EVLEXP,ETYPE,IER)
      IF (IER .NE. Ø) THEN
          CALL INFCLS (FNUM)
          CALL ERROR ('Invalid selection expression',Ø)
      ENDIF
C
C7 -- CHECK EVERY RECORD IN THE POINT COVERAGE FOR THE SELECTION CRITERIA
      DO 1ØØ I=1,NUMREC
         CALL INFSEL (FNUM,I,EVLEXP,EXISTS)
         IF (EXISTS .EQ. 1) THEN
C
C7A --          MAKE SURE THAT THE PROGRAM HAS SUFFICIENT SPACE ALLOCATED
                NUMSEL = NUMSEL + 1
                IF (NUMSEL .GT. MAXPNT) THEN
                   CALL INFCLS (FNUM)
                   CALL ERROR ('Resizing needed for MAXPNT',Ø)
                ENDIF
C
C7B --          SAVE THE RECORD NUMBER OF RECORDS MEETING THE CRITERIA
                RECORD (NUMSEL) = I
                CHOSEN (NUMSEL) = Ø
         ENDIF
  1ØØ CONTINUE
      WRITE (MSG,'(I5,A)') NUMSEL, ' sites in the cell'
      CALL INFORM (MSG,Ø)
C
C8 -- CHECK THAT A LEGITIMATE SUBSETTING EXPRESSION WAS ENTERED
      IF (NUMSEL .EQ. Ø) THEN
          CALL INFCLS (FNUM)
          CALL ERROR ('Unable to select from an empty subset',Ø)
      ENDIF
C
C9 -- CHECK THAT SUFFICIENT SITES EXIST TO PERFORM THE DESIRED SELECTION
      NTOTAL = NOSAMP * NDUP
      IF (NTOTAL .GT. NUMSEL) THEN
          CALL INFCLS (FNUM)
          CALL ERROR ('Selection quantity exceeds cell population',Ø)
      ENDIF
C
C1Ø - SEED RANDOM NUMBER FUNCTION
      CALL IRSEED (SSMID)
      RAND  = RND (SSMID)
C
C11 - SELECT FOR THE SUBSET FOR THE SPECIFIED NUMBER OF SITES AND ALTERNATES
      DO 4ØØ IROUND = 1, NDUP
         NFOUND = Ø
C
C11A -   GET A RANDOM NUMBER FUNCTION & SCALE RESULTANT
3ØØ      RAND = RND (Ø.)
         RAND = RAND * FLOAT(NUMSEL) + 1.Ø
         IF (RAND .GT. FLOAT(NUMSEL)) RAND = NUMSEL
         IRAND = RAND
```

Attachment H.--Fortran program PICKEM listing--Continued

```
C
C11B -   CHECK TO MAKE SURE WE HAVEN'T ALREADY CHOSEN THAT ONE
         IF (CHOSEN (IRAND) .GT. Ø) GOTO 3ØØ
C
C11C -   GOT ONE, SAVE IT...
         NFOUND = NFOUND + 1
         CHOSEN (IRAND) = IROUND
         IF (NFOUND .LT. NOSAMP) GOTO 3ØØ
4ØØ   CONTINUE
C
C12 - GET THE ITEM DESCRIPTION ARRAY FOR THE SELECTION-ROUND NUMBER
      CALL INFEXI (FNUM,ITEM,ITEMAR,EXISTS)
C
C13 - WRITE TO THE POINT ATTRIBUTE TABLE THE ROUND IN WHICH EACH SITE
C        IN THE SELECTED SUBSET WAS SELECTED FOR SELECTION (Ø = NOT SELECTED)
      DO 5ØØ I=1,NUMSEL
C
C13A --  RETRIEVE THE RECORD FOR THE SITE
         CALL INFGET (FNUM,RECORD(I),REC,IER)
         IF (IER .NE. Ø) THEN
            CALL INFCLS (FNUM)
            CALL ERROR ('Error retrieving site record',Ø)
         ENDIF
C
C13B --  ENCODE THE SELECTION-ROUND NUMBER INTO THE RECORD
         REALLY = CHOSEN (I)
         CALL INFENC (ITEMAR,REALLY,INSTR,RECLEN,REC,IER)
         IF (IER .NE. Ø) THEN
            CALL INFCLS (FNUM)
            CALL ERROR ('Error encoding site record',Ø)
         ENDIF
C
C13C --  WRITE THE RECORD BACK INTO THE POINT ATTRIBUTE TABLE
         CALL INFPUT (FNUM,RECORD(I),REC,IER)
         IF (IER .NE. Ø) THEN
            CALL INFCLS (FNUM)
            CALL ERROR ('Error writing site record',Ø)
         ENDIF
5ØØ   CONTINUE
C
C14 - CLOSE THE POINT ATTRIBUTE TABLE AND EXIT
      CALL INFCLS (FNUM)
      CALL AEXIT
      END
```

Attachment I.--Fortran program EQARSA listing

```
      PROGRAM EQARSA
C
C EQARSA IS RUN TO RANDOMLY SELECT SITES FROM A STUDY REGION USING CELLS
C OF EQUAL AREA.  THE USER CONTROLS THE CATEGORY, THE NUMBER OF
C CELLS, AND THE NUMBER OF SITES TAKEN FROM EACH CELL.
C JONATHON SCOTT, LAST MODIFIED SEPTEMBER 13, 1989
C
      CHARACTER  DIRECT*128, COVER*32
      CHARACTER  FILE*32,     FILEIN*128, FILOUT*128
      CHARACTER  NAMITM*16,   CATITM*16,   CATVAL*16
      CHARACTER  USER*4,      STRING*16
      CHARACTER  INFEXP*8Ø
      CHARACTER  QUOTE*1
      LOGICAL    FORWRD,      DBG
      INTEGER    ITEMAR(4),   ITEMID(4),   ITEMVS(4),   ITEMLL(4)
      INTEGER    INREC(1Ø24),KEYSTR(2),   KEYEND(2)
      INTEGER    EVLEXP(2,8Ø), EXPTYP
      DOUBLE PRECISION REALLY, AREA,    TOTARE
$INSERT SAMPLE.INSERT
```

Attachment I.--Fortran program EQARSA listing--Continued

```
      INTEGER     ID (MAXSUB), KSTRIP (MAXSUB)
      COMMON      ID,          KSTRIP

C
C1 -- DEFINE VARIABLES, INITIALIZE ARC LIBRARY ROUTINES
      PARAMETER (USER='ARC')
      PARAMETER (ITWO=2,IONE=1)
      DBG = .FALSE.
      QUOTE = ''''
      CALL MESINI
      CALL LUNINI
      CALL MINIT
      CALL INFINT
C
C2 -- GET PATHNAME, COVER NAMES, & ITEM-NAME OF POLYGON CATEGORY VARIABLE
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)') DIRECT
      CALL PRMSTR ('Coverage of subarea polygons is ',32)
      READ (*,'(A)') COVER
      CALL PRMSTR ('Category-variable name is ',26)
      READ (*,'(A)') CATITM
      CALL PRMSTR ('Category is ',12)
      READ (*,'(A)') CATVAL
      CALL PRMSTR ('Number of primary sites is ',27)
      READ (*,*)      NOSAMP
      CALL PRMSTR ('Number of alternate sites is ',29)
      READ (*,*)      NDUPS
      NDUPS = NDUPS + 1
C
C3 -- OPEN THE POLYGON ATTRIBUTE TABLE INFO FILE
      FILE = COVER (1:LENGTH(COVER,32)) // '.PAT'
      CALL INFOPN (FILE,DIRECT,USER,ITWO,NFPOLY,NUMPOL,IPOLLN,IER)
      IF (IER .NE. Ø) CALL ERROR ('Unable to open PAT',Ø)
C
C4 -- CHECK TO MAKE SURE THAT THE POLYGON CATEGORY ITEM-NAME EXISTS
      CALL INFEXI (NFPOLY,CATITM,ITEMAR,IEXIST)
      IF (IEXIST .EQ. Ø) THEN
          CALL INFCLS (NFPOLY)
          CALL ERROR ('Category-variable name does not exist',Ø)
      ENDIF
      LENCAT = ITEMAR(2)
C
C5 -- COMPOSE SELECTION EXPRESSION FOR THE CATEGORY
      INFEXP = CATITM // ' EQ ' // QUOTE //
     *    CATVAL (1:LENGTH(CATVAL,16)) // QUOTE
      CALL INFTRN (NFPOLY,INFEXP,EVLEXP,EXPTYP,IER)
C
C6 -- EXAMINE ALL POLYGONS AND CALCULATE THE TOTAL AREA & NUMBER OF POLYGONS
C     (SKIP THE EXTERIOR 'POLYGON')
      TOTARE = Ø.Ø
      NPOLY  = Ø
      NAMITM = 'AREA'
      CALL INFEXI (NFPOLY,NAMITM,ITEMAR,IEXIST)
      DO 3Ø IPOLY = 1,NUMPOL
         CALL INFSEL (NFPOLY,IPOLY,EVLEXP,INCAT)
         IF (INCAT .LE. Ø.) GOTO 3Ø
         CALL INFGET (NFPOLY,IPOLY,INREC,IER)
         CALL INFDEC (INREC,IPOLLN,ITEMAR,REALLY,STRING,IER)
         TOTARE  = TOTARE + ABS (REALLY)
         NPOLY = NPOLY + 1
3Ø    CONTINUE
      IF (DBG) WRITE (*,'(A)') 'CATEGORY AREA CALCULATED'
C
C7 -- CALCULATE:  NVSTRP = NUMBER OF VERTICAL STRIPS
C                 ARSTRP = AREA OF EACH VERTICAL STRIP
C                 ARCELL = AREA OF EACH CELL
```

```
      ARSTRP = TOTARE / SQRT (FLOAT (NOSAMP))
      NVSTRP = INT ( TOTARE / ARSTRP + 0.5 )
      ARCELL = TOTARE / FLOAT (NOSAMP)
      PCT    = ARCELL / TOTARE * 100.
      WRITE (*,'(A,I17,2(/,A,F20.2),/,A,F20.2,2H (,F4.1,2H%))')
     *       'Number of vertical strips = ', NVSTRP,
     *       '        Total area         = ', TOTARE,
     *       '        Strip area         = ', ARSTRP,
     *       '    Equal area for cell    = ', ARCELL, PCT
      ISTRIP = 1
      STRIPA = 0.
C
C8 -- SORT FILE OF COORDINATES BY HORIZONTAL POSITION ON THE MAP
      FILEIN = 'SUBA.ASCII'
      FILOUT = 'SUBA.SORT'
      KEYSTR(1) = 11
      KEYEND(1) = 25
      CALL ISRTFL (FILEIN,FILOUT,1,KEYSTR,KEYEND,NPASS,NITEM)
      IF (DBG) WRITE (*,'(A)') 'LABELS SORTED BY HORIZONTAL POSITION'
C
C9 -- OPEN & SORTED LABEL POINT FILE, AND GET ITEM DESCRIPTIONS FOR:
C          COVER-ID, AREA, AND STRIP NUMBER
      CALL AOPEN (LUN,FILOUT,IER)
      CALL ACREAT (LOUT,FILEIN,IER)
      NAMITM = COVER (1:LENGTH (COVER,32)) // '-ID'
      CALL INFEXI (NFPOLY,NAMITM,ITEMID,IEXIST)
      NAMITM = 'AREA'
      CALL INFEXI (NFPOLY,NAMITM,ITEMAR,IEXIST)
      NAMITM = 'VSTRIP'
      CALL INFEXI (NFPOLY,NAMITM,ITEMVS,IEXIST)
      READ (LUN,'(A)') FILE
C
C10 - READ THE LABEL POINTS IN SORTED ORDER AND ACCUMLATE INTO VERTICAL STRIPS
21    CONTINUE
         READ (LUN,'(I10,15X,F15.6)',END=28) LABID, YCOORD
         LABSTR = LABID
         LABEND = NUMPOL
C
C10A --   GET THE RECORD NUMBER OF POLYGON
         CALL FNDLAB
     *    (LABID,LABSTR,LABEND,NFPOLY,NUMPOL,IPOLLN,ITEMID,ILAB,INREC)
C
C10B --   DETERMINE IF POLYGON IS IN THE DESIRED CATEGORY,
C         IF NOT:  INCLUDE IN VERTICAL STRIP, BUT DON'T INCLUDE IN STRIP AREA.
         CALL INFSEL (NFPOLY,ILAB,EVLEXP,INCAT)
         IF (INCAT .EQ. 0) GOTO 223
C
C10C --   GET AREA OF THE POLYGON
         CALL INFDEC (INREC,IPOLLN,ITEMAR,REALLY,STRING,IER)
C
C10D --   IGNORE EXTERIOR POLYGON
         IF (REALLY .LE. 0.0) GOTO 27
C
C10E --   ADD POLYGON TO CURRENT VERTICAL STRIP, OR START A NEW STRIP
         WITH  = ABS (STRIPA + REALLY - ARSTRP)
         WITHO = ABS (STRIPA - ARSTRP)
         IF (WITH .LE. WITHO) THEN
            STRIPA = STRIPA + REALLY
         ELSE
            STRIPA = REALLY
            IF (ISTRIP .LT. NVSTRP) ISTRIP = ISTRIP + 1
         ENDIF
C
C10F --   PLACE THE VERTICAL STRIP NUMBER INTO THE POLYGON ATTRIBUTE RECORD,
C         ALSO WRITE TO ASCII FILE: RECORD NUMBER, STRIP NUMBER, AND Y-COORDINATE
```

```
223        CONTINUE
           REALLY = FLOAT (ISTRIP)
           CALL INFENC (ITEMVS,REALLY,STRING,IPOLLN,INREC,IER)
           CALL INFPUT (NFPOLY,ILAB,INREC,IER)
           WRITE (LOUT,'(2(I1Ø,1X),F15.6)') ILAB, ISTRIP, YCOORD
27         CONTINUE
        GOTO 21
C
C11 - ALL SUBAREA LABEL POINTS HAVE BEEN ASSIGNED TO A VERTICAL STRIP;
C       CLOSE SORTED LABEL POINT FILE, AND DELETE IT; CLOSE ASCII FILE.
28      CONTINUE
        CALL ACLOSE (LUN)
        CALL ADELET (FILOUT,IER)
        CALL ACLOSE (LOUT)
        IF (DBG) WRITE (*,'(A)') 'VERTICAL STRIPS COMPLETED'
C
C12 - SORT ASCII FILE OF COORDINATES BY STRIP NUMBER AND Y-COORDINATE
        KEYSTR(1) = 12
        KEYEND(1) = 21
        KEYSTR(2) = 23
        KEYEND(2) = 37
        CALL ISRTFL (FILEIN,FILOUT,2,KEYSTR,KEYEND,NPASS,NITEM)
        IF (DBG) WRITE (*,'(A)')
       *   'SORT BY VERTICAL STRIP & VERTICAL POSITION COMPLETED'
C
C13 - READ THE SORTED STRIP NUMBER AND RECORD NUMBER INTO MEMORY;
C         CLOSE AND DELETE ASCII FILES
        IF (NITEM .GT. MAXSUB) THEN
            CALL INFCLS (NFPOLY)
            CALL ERROR ('Resizing needed for MAXSUB',Ø)
        ENDIF
        CALL AOPEN (LUN,FILOUT,IER)
        DO 1Ø1 I=1,NITEM
1Ø1        READ (LUN,'(I1Ø,1X,I1Ø)') ID(I), KSTRIP(I)
        CALL ADELET (FILEIN,IER)
        CALL ACLOSE (LUN)
        CALL ADELET (FILOUT,IER)
C
C14 - INITIALIZE LOOP VARIABLES FOR THE ASSIGNMENT OF CELL NUMBERS
        NAMITM = 'CELL'
        CALL INFEXI (NFPOLY,NAMITM,ITEMLL,IEXIST)
        CELLA  = Ø.Ø
        NOUT   = Ø
        ICELL  = 1
        IPNT   = 1
        LSTRIP = 1
        NDONE  = Ø
        FORWRD = .TRUE.
        IF (DBG) WRITE (*,'(A)') 'Starting assignment of cells...'
        WRITE (*,44Ø)
44Ø     FORMAT (/,1ØX,'  Equal-area grid cells:',
       *        //,1ØX,'Cell      Area        Percentage')
C
C15 - GET A POLYGON RECORD CORRESPONDING TO THE RECORD NUMBER OF THE NEXT -ID
42      CONTINUE
           CALL INFGET (NFPOLY,ID(IPNT),INREC,IER)
C
C15A --  CHECK IF THE SUBAREA BELONGS TO THE CATEGORY
C          IF NOT, THEN ENCODE THE CELL NUMBER W/O INCLUDING IN THE AREA
C          FOR THE CELL
           CALL INFSEL (NFPOLY,ID(IPNT),EVLEXP,INCAT)
           IF (INCAT .EQ. Ø) GOTO 443
C
C15B --  GET AREA AND CHECK IF IT BELONGS IN THIS CELL
           CALL INFDEC (INREC,IPOLLN,ITEMAR,REALLY,STRING,IER)
           ARPOLY = REALLY
           IF (ARPOLY .LE. Ø.Ø) WRITE (*,'(A)') 'FATAL LOGIC ERROR'
```

```
         WITH  = ABS (CELLA + ARPOLY - ARCELL)
         WITHO = ABS (CELLA - ARCELL)
         IF (WITH .LE. WITHO) THEN
            CELLA = CELLA + ARPOLY
         ELSE
            PCT  = 100. * CELLA / TOTARE
            NOUT = NOUT + 1
            WRITE (*,'(10X,I3,G15.6E3,3X,A,F4.1,A)')
     *               ICELL, CELLA, '(',PCT,'%)'
            CELLA = ARPOLY
            IF (ICELL .NE. NOSAMP) ICELL = ICELL + 1
         ENDIF
C
C15C --   SAVE THE STRIP NUMBER OF THE CURRENT POLYGON
443      CONTINUE
         LSTRIP = KSTRIP (IPNT)
C
C15D --   STORE THE CELL NUMBER WITH THE POLYGON ATTRIBUTES
         REALLY = FLOAT (ICELL)
         CALL INFENC (ITEMLL,REALLY,STRING,IPOLLN,INREC,IER)
         CALL INFPUT (NFPOLY,ID(IPNT),INREC,IER)
C
C15E --   IF FINISHED THE ENTIRE STUDY AREA, THEN EXIT THE LOOP
         NDONE = NDONE + 1
         IF (NDONE .EQ. NITEM) GOTO 50
C
C15F --   FIND THE NEXT POLYGON NUMBER TO BE CHECKED
43       CONTINUE
         IF (FORWRD) THEN
            IPNT = IPNT + 1
C
C15F1 --     WHEN MOVING UP & HIT THE TOP OF STRIP, GO TO TOP OF NEXT STRIP &
C             MOVE DOWNWARD THROUGH THE LIST OF POLYGONS
            IF (KSTRIP (IPNT) .GT. LSTRIP) THEN
44             IPNT   = IPNT + 1
               IF (KSTRIP (IPNT) .EQ. KSTRIP (IPNT-1) ) GOTO 44
               IPNT   = IPNT - 1
               FORWRD = .FALSE.
               IF (DBG) WRITE (*,'(A)') 'MOVING DOWN'
            ENDIF
         ELSE
            IPNT = IPNT - 1
C
C15F2 --     WHEN MOVING DOWN & HIT THE BOTTOM OF STRIP, GO TO BOTTOM OF NEXT
C             STRIP & MOVE UPWARD THROUGH THE LIST OF POLYGONS
            IF (KSTRIP (IPNT) .LT. LSTRIP .OR. IPNT .EQ. 1) THEN
46             IPNT   = IPNT + 1
               IF (KSTRIP (IPNT) .EQ. KSTRIP (IPNT+1) ) GOTO 46
               IPNT   = IPNT + 1
               FORWRD = .TRUE.
               IF (DBG) WRITE (*,'(A)') 'MOVING UP'
            ENDIF
         ENDIF
         GOTO 42
C
C16 - ALL POLYGONS HAVE BEEN ASSIGNED TO A CELL
50    CONTINUE
      IF (NOUT .NE. NOSAMP) THEN
         PCT = 100. * CELLA / TOTARE
         WRITE (*,'(10X,I3,G15.6E3,3X,A,F4.1,A)')
     *            ICELL, CELLA, '(',PCT,'%)'
      ENDIF
      CALL INFCLS (NFPOLY)
      CALL AEXIT
      END
```

Attachment I.--Fortran program EQARSA listing--Continued

```
C
      SUBROUTINE FNDLAB (LABID,LABSTR,LABEND,NFPOLY,NUMPOL,IPOLLN,
     *                   ITEMID,ILAB,INREC)
      INTEGER ITEMID(4), INREC(1024)
      CHARACTER STRING*16
      DOUBLE PRECISION REALLY
      DO 22 ILAB = LABSTR,LABEND
         CALL INFGET (NFPOLY,ILAB,INREC,IER)
         CALL INFDEC (INREC,IPOLLN,ITEMID,REALLY,STRING,IER)
         IF (INT(REALLY) .EQ. LABID) GOTO 25
22    CONTINUE
      CALL INFCLS (NFPOLY)
      CALL ERROR ('FNDLAB LOGIC FAILING ',0)
      IF (LABSTR .NE. 1) THEN
          DO 23 ILAB = 1, LABSTR-1
             CALL INFGET (NFPOLY,ILAB,INREC,IER)
             CALL INFDEC (INREC,IPOLLN,ITEMID,REALLY,STRING,IER)
             IF (INT(REALLY) .EQ. LABID) GOTO 25
23        CONTINUE
      ENDIF
      CALL INFCLS (NFPOLY)
      CALL ERROR ('Search for label point failed during FNDLAB',0)
25    CONTINUE
      RETURN
      END
```

Attachment J.--Fortran program NFLATE listing

```
      PROGRAM NFLATE
C
C CALCULATE AN INITIAL GUESS FOR THE NUMBER OF CELLS WHEN SELECTING SITES
C WITH ITERATING GRIDS.  THE INITIAL GUESS IS BASED UPON THE RATIO OF CATEGORY
C AREA TO STUDY UNIT AREA SCALED BY THE NUMBER OF SITES TO BE SELECTED.
C NORMALLY, THIS GUESS TO TOO HIGH.
C JONATHON SCOTT, LAST MODIFIED MARCH 27, 1990
C
      CHARACTER  DIRECT*128, CATIDX*32
      CHARACTER  CATVAL*16,  NAMITM*16
      CHARACTER  USER*4,     STRING*16
      CHARACTER  INFEXP*80
      CHARACTER  QUOTE*1,    MSG*80
C
      INTEGER    ITEMAR(4),    INREC(1024)
      INTEGER    EVLEXP(2,80), EXPTYP
      DOUBLE PRECISION REALLY
C
      PARAMETER (USER='ARC',CATIDX='CATIDX',QUOTE='''',IONE=1)
C
C1 -- INITIALIZE ARC LIBRARY ROUTINES
      CALL MESINI
      CALL LUNINI
      CALL MINIT
      CALL INFINT
C
C2 -- GET DATA FROM THE CALLING PROGRAM
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)') DIRECT
      CALL PRMSTR ('Category is ',12)
      READ (*,'(A)') CATVAL
      CALL PRMSTR ('Number of primary sites is ',27)
      READ (*,*)     NOSAMP
      CALL PRMSTR ('Number of alternate sites is ',29)
      READ (*,*)      ITOL
      ITOL = ITOL + 1
```

Attachment J.--Fortran program NFLATE listing--Continued

```
C
C3 -- OPEN THE POINT ATTRIBUTE TABLE INFO FILE
      CALL INFOPN (CATIDX,DIRECT,USER,IONE,NFCAT,NUMCAT,ICATLN,IER)
      IF (IER .NE. 0) CALL ERROR ('Unable to open category-index',0)
C
C4 -- COMPOSE THE RECORD SELECTION EXPRESSION
      INFEXP = 'CATEGORY EQ ' // QUOTE // CATVAL // QUOTE
      CALL INFTRN (NFCAT,INFEXP,EVLEXP,EXPTYP,IER)
C
C5 -- FIND THE RECORD THAT DESCRIBES THE CATEGORY
      NAMITM = 'FRACTION'
      CALL INFEXI (NFCAT,NAMITM,ITEMAR,IEXIST)
      DO 10 ICAT = 1,NUMCAT
         CALL INFSEL (NFCAT,ICAT,EVLEXP,IEXIST)
         IF (IEXIST .EQ. 1) THEN
             CALL INFGET (NFCAT,ICAT,INREC,IER)
             CALL INFDEC (INREC,ICATLN,ITEMAR,REALLY,STRING,IER)
             FRACTN =  REALLY
             NAMITM = 'NUMPTS'
             CALL INFEXI (NFCAT,NAMITM,ITEMAR,IEXIST)
             CALL INFDEC (INREC,ICATLN,ITEMAR,REALLY,STRING,IER)
             NLEAST = ITOL * NOSAMP
             IF (REALLY .LT. NLEAST) THEN
                WRITE(MSG,'(A,2(A,I8),A)')'Insufficient ',
     1          'population (',REALLY,') to select ',NLEAST,' sites.'
                CALL INFORM (MSG,0)
                GOTO 15
             ENDIF
             GOTO 20
         ENDIF
10    CONTINUE
      CALL ERROR ('Category does not exist',0)
15    FRACTN = 1
      NOSAMP = 0
C
C6 -- WRITE THE INFLATED NUMBER OUT FOR THE GRIDDING PROGRAM
20    CALL INFCLS (NFCAT)
      NOSAMP = INT (FLOAT (NOSAMP) / FRACTN)
      CALL ACREAT (LUN,'INFLATED',IER)
      WRITE (LUN,'(I10)') NOSAMP
      ENDFILE     (LUN)
      CALL ACLOSE (LUN)
      CALL AEXIT
      END
```

Attachment K.--Fortran program SAMINF listing

```
      PROGRAM SAMINF
C
C SAMINF IS RUN ITERATIVELY TO DETERMINE IF THE CORRECT GRID HAS
C  BEEN PREPARED FOR AN AREALLY-DISTRIBUTED RANDOM SELECTION OF SITES.
C  WHEN THE CORRECT GRID HAS BEEN PREPARED, THE SELECTION IS PERFORMED.
C  THE VARIABLE 'CHOSEN' IN THE PAT FILE IS SET TO THE SELECTION-ROUND
C  FOR SELECTED SITES AND SET TO ZERO FOR SITES NOT SELECTED.
C AN OUTPUT FILE IS WRITTEN WITH ONE RECORD INDICATING A NEW TARGET GRID
C  POPULATION WHEN ITERATION IS NEEDED, OR A ZERO IF SELECTION HAS BEEN
C  PERFORMED BECAUSE THE ALGORITHM CONVERGED.
C JONATHON SCOTT, LAST MODIFIED SEPTEMBER 27, 1989
C
      CHARACTER  DIRECT*128, PIDCOV*32, FILE*32
      CHARACTER  NAMITM*16,  GRDITM*16, CATVAL*16, CATITM*16
      CHARACTER  USER*4,     STRING*16
      CHARACTER  INFEXP*80,  MSG*80
      CHARACTER  QUOTE*1
```

```
C
      INTEGER    ITEMAR(4),    INREC(1024)
      INTEGER    EVLEXP(2,80), EXPTYP
      DOUBLE PRECISION REALLY
C
      PARAMETER (USER='ARC',QUOTE='''',ITWO=2)
C
$INSERT SAMPLE.INSERT
      INTEGER    NPOP   (MAXCEL)
      INTEGER    SAMREC (MAXPOP), INGRID (MAXPOP)
      INTEGER    CHOSEN (MAXPNT), ISAMPL (MAXPNT)
      COMMON     CHOSEN, ISAMPL,  SAMREC, INGRID, NPOP
C
C1 -- INITIALIZE ARC LIBRARY ROUTINES
C
      CALL MESINI
      CALL LUNINI
      CALL MINIT
      CALL INFINT
C
C2 -- GET DATA FROM THE CALLING PROGRAM
C
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)') DIRECT
      CALL PRMSTR ('Coverage of iteration results is ',33)
      READ (*,'(A)') PIDCOV
      CALL PRMSTR ('Cell-variable name is ',22)
      READ (*,'(A)') GRDITM
      CALL PRMSTR ('Category-variable name is ',26)
      READ (*,'(A)') CATITM
      CALL PRMSTR ('Category is ',12)
      READ (*,'(A)') CATVAL
      CALL PRMSTR ('Number of primary sites is ',27)
      READ (*,*)      NOSAMP
      CALL PRMSTR ('Current number of cells is ',27)
      READ (*,*)      INFSAM
      CALL PRMSTR ('Number of alternate sites is ',29)
      READ (*,*)      ITOL
      ITOL = ITOL + 1
      CALL PRMSTR ('Percentage required for convergence is ',39)
      READ (*,*)      PERCNT
      CALL PRMSTR ('Damping factor is ',18)
      READ (*,*)      DAMPER
C
C3 -- DESCRIBE CELL POPULATIONS IN THE CURRENT GRID
C
C3A -- OPEN THE (PAT) INFO-FILE DESCRIBING THE POPULATION
C
      FILE = PIDCOV (1:LENGTH(PIDCOV,32)) // '.PAT'
      CALL INFOPN (FILE,DIRECT,USER,ITWO,NFPID,NUMPNT,IPNTLN,IER)
      IF (IER .NE. 0)
     *    CALL ERROR ('Unable to open population coverage PAT',0)
C
C3B -- COMPOSE CATEGORY-SELECTION EXPRESSION, DESCRIBE CELL ITEM,
C        AND INITIALIZE POPULATION OF EACH CELL (NPOP) TO ZERO.
C
      INFEXP = CATITM // ' EQ ' // QUOTE // CATVAL // QUOTE
      CALL INFTRN (NFPID,INFEXP,EVLEXP,EXPTYP,IER)
      CALL INFEXI (NFPID,GRDITM,ITEMAR,IEXIST)
      DO 20 IGRID = 1,MAXCEL
          NPOP (IGRID) = 0
20    CONTINUE
C
C3C -- FOR SITES IN THE CATEGORY:
C        COUNT THE TOTAL NUMBER OF SITES          (ISAM,NUMSAM)
C        RECORD NUMBER IN INFO-FILE               (SAMREC)
C        WHICH GRID CELLS THEY ARE LOCATED IN     (INGRID)
C        NUMBER OF SITES IN EACH CELL             (NPOP)
C
```

```
      IGRIDE = 0
      ISAM = 0
      DO 30 IPNT = 1,NUMPNT
          CALL INFSEL (NFPID,IPNT,EVLEXP,IEXIST)
          IF (IEXIST .EQ. 1) THEN
              CALL INFGET (NFPID,IPNT,INREC,IER)
              CALL INFDEC (INREC,IPNTLN,ITEMAR,REALLY,STRING,IER)
              ISAM = ISAM + 1
              IF (ISAM .GT. MAXPOP) THEN
                 CALL INFCLS (NFPID)
                 CALL ERROR ('Resizing needed for MAXPOP',0)
              ENDIF
              SAMREC (ISAM) = IPNT
              INTGER        = REALLY
              INGRID (ISAM) = INTGER
              IF (INTGER .GT. MAXCEL) THEN
                 CALL INFCLS (NFPID)
                 CALL ERROR ('Resizing needed for MAXCEL',0)
              ENDIF
              NPOP (INTGER) = NPOP (INTGER) + 1
              IF (INTGER .GT. IGRIDE) IGRIDE = INTGER
          ENDIF
30    CONTINUE
      NUMSAM = ISAM
      CALL INFCLE (EVLEXP)
C
C4 -- FIND OUT HOW MANY CELLS HAVE AT LEAST 'ITOL' POINTS          (NGDPOP),
C     HOW MANY SITES ARE IN GRID CELLS W/ LESS THAN 'ITOL'         (LSTPOP),
C     AND AVERAGE NUMBER OF SITES IN POPULATED CELLS               (AVGPOP).
C
      NGDPOP = 0
      LSTPOP = 0
      AVGPOP = 0
      IAVG   = 0
      DO 40 IGRID = 1,IGRIDE
         IF (NPOP(IGRID) .GE. ITOL) THEN
             NGDPOP = NGDPOP + 1
         ELSE
             LSTPOP = LSTPOP + NPOP (IGRID)
         ENDIF
         IF (NPOP (IGRID) .NE. 0) THEN
             AVGPOP = AVGPOP + NPOP (IGRID)
             IAVG   = IAVG + 1
         ENDIF
40    CONTINUE
      AVGPOP = AVGPOP / FLOAT (IAVG)
C
C5 -- CONVERGENCE IS DETERMINED BASED UPON POPULATIONS OF THE GRID CELLS
C
      ICHECK = NOSAMP * PERCNT
      ILEAST = ITOL * (NOSAMP - NGDPOP)
      IF (NGDPOP .EQ. NOSAMP) THEN
C
C5A --    AT LEAST ITOL POINTS IN EXACTLY NOSAMP CELLS
C
          IREM = 0
      ELSEIF (NGDPOP .GE. ICHECK .AND. LSTPOP .GE. ILEAST .AND.
     1        NGDPOP .LT. NOSAMP) THEN
C
C5B --    AT LEAST PERCNT, BUT NO MORE THAN NOSAMP, CELLS HAVE ITOL POINTS;
C         AND THERE ARE SUFFICIENT REMAINING SITES FOR SELECTION
C
          IREM = NOSAMP - NGDPOP
      ELSE
C
C5C --    MUST ITERATE TO GET BETTER GRID
C
```

Attachment K.--Fortran program SAMINF listing--Continued

```
            PORTON = FLOAT (NGDPOP) / FLOAT (NOSAMP)
            IF (PORTION .LT. 0.60 .OR. PORTION .GT. 1.4) DAMPER = 1.0
            ITRY = DAMPER * (NOSAMP-NGDPOP) * INFSAM / NGDPOP
            ITRY = ITRY + INFSAM
            WRITE (MSG,'(80(1H*))')
            CALL INFORM (MSG,80)
            WRITE (MSG,'(A,I6,A)') 'Iteration failed to converge using',
     1         INFSAM, ' cells'
            CALL INFORM (MSG,0)
            WRITE (MSG,'(A,F5.1,A)') 'Average populated cell contained',
     1          AVGPOP,' sites'
            CALL INFORM (MSG,0)
            WRITE (MSG,'(I4,A,I4,A)') NGDPOP,' cells contained at least',
     1          ITOL,' sites.'
            CALL INFORM (MSG,0)
            WRITE (MSG,'(A,I6,A)') 'Next iteration will use at least ',
     1       ITRY,' cells'
            CALL INFORM (MSG,0)
            WRITE (MSG,'(80(1H*))')
            CALL INFORM (MSG,80)
            GOTO 900
        ENDIF
C
C6 -- CONVERGENCE HAS OCCURRED, PROCEEDING WITH SITE SELECTION
C
        ITRY = -99998
C
C6A -- SELECT SITES FOR EACH GRID CELL THAT HAS ITOL POINTS
C
        DO 300 IGRID = 1, IGRIDE
           IPICK = 0
           IPNT = 0
           ISAMSZ = NPOP (IGRID)
           IF (ISAMSZ .GT. MAXPNT) THEN
              CALL INFCLS (NFPID)
              CALL ERROR ('Resizing needed for MAXPNT',0)
           ENDIF
           IF (ISAMSZ .LT. ITOL) GOTO 300
C
C6A1 --  LOAD THE ISAMPL ARRAY WITH THE RECORD NUMBERS OF THE SITES
C
           DO 110 ISAM = 1, NUMSAM
              IF (INGRID(ISAM) .EQ. IGRID) THEN
                  IPNT = IPNT + 1
                  IF (IPNT .GT. MAXPNT) THEN
                     CALL INFCLS (NFPID)
                     CALL ERROR ('Resizing needed for MAXPNT',0)
                  ENDIF
                  ISAMPL (IPNT) = SAMREC (ISAM)
              ENDIF
110        CONTINUE
           IPICK = ITOL
C
C6A2 --  RANDOMLY PICK ITOL SITES FROM THE SAMREC ARRAY
C
120        CALL RNDSEL (ISAMSZ,IPICK)
C
C6A3 --  UPDATE THE POINT ATTRIBUTE TABLE TO SET CHOSEN TO ROUND NUMBER
           NAMITM = 'CHOSEN'
           CALL INFEXI (NFPID,NAMITM,ITEMAR,EXISTS)
           DO 200 ISAM = 1, ISAMSZ
               CALL INFGET (NFPID,ISAMPL(ISAM),INREC,IER)
               REALLY = FLOAT (CHOSEN (ISAM))
               CALL INFENC (ITEMAR,REALLY,STRING,IPNTLN,INREC,IER)
               CALL INFPUT (NFPID,ISAMPL(ISAM),INREC,IER)
200        CONTINUE
300     CONTINUE
```

```
C
C6B -- PICK THE REMAINING SITES FROM THE SPARSELY POPULATED CELLS
C
      NOSAMP = ITOL*IREM
      IPNT   = Ø
C
C6B1 -- LOAD THE ISAMPL ARRAY WITH THE LEFT-OVER SITES' RECORD NUMBERS
C
      DO 4ØØ ISAM = 1,NUMSAM
         IF ( NPOP (INGRID (ISAM) ) .LT. ITOL) THEN
            IPNT = IPNT + 1
            IF (IPNT .GT. MAXPNT) THEN
               CALL INFCLS (NFPID)
               CALL ERROR ('Resizing needed for MAXPNT',Ø)
            ENDIF
            ISAMPL (IPNT) = SAMREC (ISAM)
         ENDIF
4ØØ   CONTINUE
      IF (LSTPOP .GT. MAXPNT) THEN
         CALL INFCLS (NFPID)
         CALL ERROR ('Resizing needed for MAXPNT',Ø)
      ENDIF
C
C6B2 -- SELECT SITES FROM THE LEFT-OVERS
C
      CALL RNDSEL (LSTPOP,NOSAMP)
C
C6B3 -- SAVE ROUND NUMBER IN THE CHOSEN ITEM IN THE PAT
C
         DO 5ØØ ISAM = 1, LSTPOP
             CALL INFGET (NFPID,ISAMPL(ISAM),INREC,IER)
             REALLY = FLOAT (CHOSEN (ISAM))
             CALL INFENC (ITEMAR,REALLY,STRING,IPNTLN,INREC,IER)
             CALL INFPUT (NFPID,ISAMPL(ISAM),INREC,IER)
5ØØ      CONTINUE
C
C7 -- WRITE RESULTS OUT TO FILE TO BE READ BY CALLING PROGRAM
C
9ØØ   CALL INFCLS (NFPID)
      CALL ACREAT (LUN,'INFLATED',IER)
      WRITE (LUN,'(I9)') ITRY
      ENDFILE     (LUN)
      CALL ACLOSE (LUN)
      CALL AEXIT
      END
C
      SUBROUTINE RNDSEL (NUMSEL,NOSAMP)
C
C SUBROUTINE TO PERFORM RANDOM SELECTION...
C PICKS 'NOSAMP' SITES FROM 'ISAMPL' CHOICES RETURNING PICKS INTO 'CHOSEN'
C FROM A POPULATION OF 'NUMSEL'.  CHOSEN = Ø -> NOT SELECTED
C
$INSERT SAMPLE.INSERT
      INTEGER CHOSEN (MAXPNT)
      COMMON CHOSEN
C
C1 -- SEED RANDOM NUMBER FUNCTION, & INITIALIZE THE CHOSEN ARRAY
C
      CALL IRSEED (SSMID)
      RAND  = RND (SSMID)
      DO 2ØØ I=1,NUMSEL
2ØØ      CHOSEN (I) = Ø
      IF (NOSAMP .EQ. Ø) RETURN
      NFOUND = Ø
C
C2 -- CALL PRIMOS RANDOM NUMBER FUNCTION & SCALE RESULTANT
C
```

Attachment K.--Fortran program SAMINF listing--Continued

```
300   RAND = RND (Ø.)
      RAND = RAND * FLOAT(NUMSEL) + Ø.5
      IRAND = RAND
      IF (IRAND .LT. 1) IRAND = 1
C
C3 -- CHECK TO MAKE SURE WE HAVEN'T ALREADY CHOSEN THAT ONE
C
      IF (CHOSEN (IRAND) .NE. Ø) GOTO 3ØØ
C
C4 -- GOT ONE, SAVE ROUND NUMBER
C
      NFOUND = NFOUND + 1
      CHOSEN (IRAND)  = NFOUND
      IF (NFOUND .LT. NOSAMP) GOTO 3ØØ
      RETURN
      END
```

Attachment L.--Fortran program UPTIDX listing

```
      PROGRAM UPTIDX
C
C UPTIDX IS RUN EACH TIME SITES ARE SELECTED FOR A CATEGORY
C THE PROGRAM UPDATES THE CATEGORY INDEX FILE (CATIDX) IN INFO
C THE NUMBER OF SITES SELECTED FOR THE CATEGORY IS STORED IN NOSAMP
C JONATHON SCOTT, LAST MODIFIED MARCH 27, 199Ø
C
      CHARACTER DIRECT*128, CATIDX*32
      CHARACTER CATITM*16,  NAMITM*16,  CATNAM*16,  STRING*16
      CHARACTER USER*4
      CHARACTER INFEXP*8Ø
      CHARACTER QUOTE*1
C
      INTEGER   ITEMAR(4),    INREC(1Ø24)
      INTEGER   EVLEXP(2,8Ø), EXPTYP
      DOUBLE PRECISION REALLY
C
      PARAMETER (USER='ARC',CATIDX='CATIDX',ITWO=2,QUOTE='''')
      PARAMETER (CATITM='CATEGORY')
C
C1 -- INITIALIZE ARC LIBRARY ROUTINES
      CALL MESINI
      CALL LUNINI
      CALL MINIT
      CALL INFINT
C
C2 -- GET DATA FROM CALLING PROGRAM
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)')     DIRECT
      CALL PRMSTR ('Category is ',12)
      READ (*,'(A)')     CATNAM
      CALL PRMSTR ('Number of primary sites is ',27)
      READ (*,'(I1Ø)')  NOSAMP
C
C3 -- OPEN THE CATEGORY INDEX INFO FILE (CATIDX)
      CALL INFOPN (CATIDX,DIRECT,USER,ITWO,IDXNUM,NUMCAT,IDXLEN,IER)
      IF (IER .NE. Ø)
     1    CALL ERROR('Unable to open category-index file',Ø)
C
C4 -- FIND THE RECORD FOR THE CATEGORY
      INFEXP = CATITM // ' EQ ' // QUOTE // CATNAM(1:LENGTH(CATNAM,16))
     1                           // QUOTE
      CALL INFTRN (IDXNUM,INFEXP,EVLEXP,EXPTYP,IER)
      DO 5Ø ICAT = 1,NUMCAT
          CALL INFSEL (IDXNUM,ICAT,EVLEXP,IEXIST)
          IF (IEXIST .NE. Ø) GOTO 1ØØ
5Ø        CONTINUE
```

Attachment L.--Fortran program UPTIDX listing--Continued

```
      CALL INFCLE (EVLEXP)
      CALL INFCLS (IDXNUM)
      CALL ERROR ('Category not found in category-index',0)
C
C5 -- WRITE TO THE CATIDX FILE THE NUMBER OF SITES SELECTED FOR THE CATEGORY
100   CALL INFGET (IDXNUM,ICAT,INREC,IER)
      NAMITM = 'NOSAMP'
      REALLY =  NOSAMP
      CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
      CALL INFENC (ITEMAR,REALLY,STRING,IDXLEN,INREC,IER)
      CALL INFPUT (IDXNUM,ICAT,INREC,IER)
C
C6 -- FINISHED.
      CALL INFCLS (IDXNUM)
      CALL AEXIT
      END
```

Attachment M.--Fortran program CATRPT listing

```
      PROGRAM CATRPT
C
C PREPARES DATA FOR A REPORT ON SITES WHICH HAVE BEEN SELECTED
C JONATHON SCOTT, LAST MODIFIED JULY 26, 1990
C
      CHARACTER DIRECT*128,COVER*32,FILE*32,USER*8,QUOTE*1,CATITM*16
      CHARACTER ITEM*16, POLNAM*16, STRING*1, INFEXP*80, CELITM*16
      CHARACTER FILNAM*128, CATVAL*16, SRTIN*128, SRTOUT*128
      INTEGER FNUM,NUMREC,RECLEN,ITEMAR(4),INREC(1024),CHOSAR(4)
      INTEGER LABBUF(8), EVLEXP(2,80)
      INTEGER NSTART(2), NEND(2)
      DOUBLE PRECISION REALLY, XCOORD, YCOORD
C
      EQUIVALENCE (XCOORD,LABBUF(3)),(YCOORD,LABBUF(5))
      PARAMETER (USER='ARC',QUOTE='''',SRTIN='SAMPTS',SRTOUT='SAMSRT')
      PARAMETER (IONE=1,ITWO=2)
      DATA NSTART(1),NEND(1)/ 1,10/
      DATA NSTART(2),NEND(2)/11,20/
C
C1 -- INITIALIZE ARC/INFO LIBRARIES
      CALL MESINI
      CALL MINIT
      CALL LUNINI
      CALL INFINT
      CALL VINIT
C
C2 -- GET DATA FROM CALLING PROGRAM
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)') DIRECT
      CALL PRMSTR ('Coverage of population is ',26)
      READ (*,'(A)') COVER
      CALL PRMSTR ('Category-variable name is ',26)
      READ (*,'(A)') CATITM
      CALL PRMSTR ('Category is ',12)
      READ (*,'(A)') CATVAL
      CALL PRMSTR ('Cell-variable name is ',22)
      READ (*,'(A)') CELITM
C
C3 -- OPEN THE SITE POPULATION INFO-FILE AND THE SITE COORDINATE FILE
      CALL INFNAM  (COVER,IONE,FILE)
      CALL INFOPN (FILE,DIRECT,USER,ITWO,FNUM,NUMPNT,RECLEN,IER)
      CALL INFEXI (FNUM,CATITM,ITEMAR,IEXIST)
      LENCAT = ITEMAR(2)
      CALL LABOPN (NFLAB,COVER,IONE,IONE,IER)
      IF (IER.NE.0) THEN
          CALL INFCLS (FNUM)
          CALL ERROR ('Unable to open LAB file.',24)
      ENDIF
```

Attachment M.--Fortran program CATRPT listing--Continued

```
C
C4 -- OPEN SEQUENTIAL FILE TO CONTAIN THE COORDINATES OF THE SELECTED SITES
      FILNAM = 'SAMPTS'
      CALL ACREAT (LUN,FILNAM,IER)
C
C5 -- COMPOSE AND TRANSLATE SELECTION EXPRESSION, DESCRIBE CHOSEN ITEM
      INFEXP = CATITM // ' EQ ' // QUOTE //
     1          CATVAL(1:LENCAT) // QUOTE // ' AND CHOSEN > 0'
      CALL INFTRN (FNUM,INFEXP,EVLEXP,IEXTYP,IER)
      IF (IER .NE. 0) THEN
         CALL INFCLS (FNUM)
         CALL ACLOSE (LUN)
         CALL LABCLS (NFLAB)
         CALL ERROR ('Error occurred during INFTRN',0)
      ENDIF
      CALL INFEXI (FNUM,CELITM,ITEMAR,IEXIST)
      ITEM = 'CHOSEN'
      CALL INFEXI (FNUM,ITEM,CHOSAR,IEXIST)
C
C6 -- EXAMINE EVERY SITE IN THE POPULATION
      ISAM = 0
      DO 20 IPNT=1,NUMPNT
         CALL INFSEL (FNUM,IPNT,EVLEXP,IEXIST)
C
C6A --   WHEN THE SITE IS IN THE CATEGORY AND SELECTED...
         IF (IEXIST .NE. 0) THEN
            ISAM = ISAM + 1
C
C6B --      GET THE CELL AND ROUND NUMBER, AND COORDINATES OF SITE
            CALL INFGET (FNUM,IPNT,INREC,IER)
            IF (CELITM .NE. '') THEN
               CALL INFDEC (INREC,RECLEN,ITEMAR,REALLY,STRING,IER)
               ICELL = REALLY
            ELSE
               ICELL = 0
            ENDIF
            CALL INFDEC (INREC,RECLEN,CHOSAR,REALLY,STRING,IER)
            ICHOSE = REALLY
            CALL LABRDR (NFLAB,IPNT,LABBUF,IER)
C
C6C --      RECORD THESE DATA IN THE SEQUENTIAL FILE
            WRITE (LUN,'(2I10,2F15.3)') ICELL, ICHOSE, XCOORD, YCOORD
         ENDIF
20    CONTINUE
C
C7 -- CLOSE SEQUENTIAL FILE, INFO-FILE, COORDINATE FILE
      ENDFILE (LUN)
      CALL INFCLS (FNUM)
      CALL ACLOSE (LUN)
      CALL LABCLS (NFLAB)
C
C8 -- SORT THE SITES BY THEIR CELL AND ROUND NUMBERS, THEN EXIT
      CALL ISRTFL (SRTIN,SRTOUT,ITWO,NSTART,NEND,NPASS,NITEM)
      CALL AEXIT
      END
```

Attachment N.--Fortran program FCATRP listing

```
      PROGRAM FCATRP
C
C FCATRP FORMATS A REPORT CONTAINING THE CHOSEN SITES FOR
C EACH POLYGON LISTING THE POINTS IN LAT-LONG.  THIS PROCESS IS
C PRECEDED BY EXTRACTING THE POINTS, AND PROJECTING THEM TO LAT-LONG
C ONE REPORT IS PREPARED FOR EACH CATEGORY.
C JONATHON SCOTT, LAST MODIFIED APRIL 2, 1990
C
```

Attachment N.--Fortran program FCATRP listing--Continued

```
      CHARACTER CATVAL*16, FILE*32, LINE*40, STRING*16, NAMITM*16
      CHARACTER DIRECT*128, CATIDX*32, USER*4, QUOTE*1
      CHARACTER INFEXP*80
      INTEGER   ICOORD(6), EVLEXP(2,80), EXPTYP, INREC(1024), ITEMAR(4)
      REAL      COORD (6)
      DOUBLE PRECISION REALLY
      PARAMETER (CATIDX='CATIDX',USER='ARC',ITWO=2,QUOTE='''')
C
C1 -- INITIALIZE ARC/INFO SUBROUTINE PACKAGES
      CALL MESINI
      CALL LUNINI
      CALL MINIT
      CALL INFINT
C
C2 -- GET DATA FROM THE CALLING PROGRAM
      CALL PRMSTR ('Directory of INFO data base is ',31)
      READ (*,'(A)') DIRECT
      CALL PRMSTR ('Category is ',12)
      READ (*,'(A)') CATVAL
      CALL PRMSTR ('Number of primary sites is ',27)
      READ (*,*)      NOSAMP
      CALL PRMSTR ('Number of alternate sites is ',29)
      READ (*,*)      ITOL
C
C3 -- GET RECORD OF POLYGON CATEGORY FROM THE 'INFO' INDEX FILE
      CALL INFOPN (CATIDX,DIRECT,USER,ITWO,IDXNUM,NUMCAT,IDXLEN,IER)
      IF (IER .NE. 0) CALL ERROR ('Unable to open category-index',0)
      INFEXP = 'CATEGORY EQ ' // QUOTE // CATVAL(1:LENGTH(CATVAL,16))
     *                         // QUOTE
      CALL INFTRN (IDXNUM,INFEXP,EVLEXP,EXPTYP,IER)
      DO 44 ICAT = 1,NUMCAT
         CALL INFSEL (IDXNUM,ICAT,EVLEXP,IEXIST)
         IF (IEXIST .NE. 0) GOTO 66
44       CONTINUE
      CALL INFCLE (EVLEXP)
      CALL INFCLS (IDXNUM)
      CALL ERROR ('Unable to find specified category in index',0)
66    CONTINUE
      CALL INFGET (IDXNUM,ICAT,INREC,IER)
      CALL INFCLE (EVLEXP)
C
C4 -- READ THE CATEGORY DESCRIPTORS:  NUMBER OF POLYGONS, TOTAL AREA,
C       NUMBER OF SITES IN THE CATEGORY
      NAMITM = 'NUMPOLY'
      CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
      CALL INFDEC (INREC,IDXLEN,ITEMAR,REALLY,STRING,IER)
      NPOLY = REALLY
      NAMITM = 'AREA'
      CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
      CALL INFDEC (INREC,IDXLEN,ITEMAR,REALLY,STRING,IER)
      AREA = REALLY
      NAMITM = 'NUMPTS'
      CALL INFEXI (IDXNUM,NAMITM,ITEMAR,IEXIST)
      CALL INFDEC (INREC,IDXLEN,ITEMAR,REALLY,STRING,IER)
      NPTS = REALLY
      CALL INFCLS (IDXNUM)
C
C5 -- OPEN REPORT FILE AND WRITE A HEADING DESCRIBING THE CATEGORY
      FILE = 'SITE.REPORT.' // CATVAL
      CALL AOPEN  (LUIN,'SAMSRT.GEO',IER)
      CALL ACREAT (LUOUT,FILE,IER)
      WRITE (LUOUT,1001)
     1 'RESULTS OF RANDOM SELECTION FOR CATEGORY ', CATVAL,
     2 '      Total area of category          = ',AREA,
     3 '      Number of areal subsets         = ',NPOLY,
     4 '     Number of potential sites        = ',NPTS,
     5 '  Number of primary sites selected    = ',NOSAMP,
     6 ' Number of alternate sites selected   = ',ITOL
```

Attachment N.--Fortran program FCATRP listing--Continued

```
1001  FORMAT (1H1,A,1H',A,1H',//,1X,A,G15.6E3,4(/,1X,A,I10))
      IPNT  = 1
      ICELL = 0
C
C6 -- LOOP THROUGH THE COORDINATE DATA FROM THE PRE-REPORT FILE
      IMAX = ITOL + 1
      NTOT = NOSAMP * IMAX
      DO 100 ISAM = 1,NTOT
         READ (LUIN,'(A)') LINE
C
C6A --    FOR A NEW CELL:  WRITE A HEADING SHOWING THE SITE NUMBER
         IF ( IPNT .EQ. 1) THEN
              ICELL = ICELL + 1
              WRITE (LUOUT,1002) ICELL
1002          FORMAT (/,1X,13(1H-),' SITE #',I4,1X,13(1H-),
     *                /,1X,' ROUND      LATITUDE        LONGITUDE')
         ENDIF
C
C6B --    READ, FORMAT AND PRINT THE LOCATIONS SELECTED IN EACH GRID CELL
         READ (LINE,'(2(F5.0,F3.0,F6.2))') (COORD(I),I=1,6)
         COORD(3) = COORD(3) + 0.5
         COORD(6) = COORD(6) + 0.5
         DO 35 I = 1, 6
            ICOORD(I) = COORD(I)
35       CONTINUE
         CALL RNDDMS (ICOORD(1),ICOORD(2),ICOORD(3))
         CALL RNDDMS (ICOORD(4),ICOORD(5),ICOORD(6))
         WRITE (LUOUT,'(I5,7X,3I3.2,6X,3I3.2)') IPNT,(ICOORD(I),I=4,6),
     1                                                (ICOORD(I),I=1,3)
         IPNT = IPNT + 1
         IF (IPNT .GT. IMAX) IPNT = 1
100   CONTINUE
C
C7 -- ALL DONE: CLEAN HOUSE
      CALL ACLOSE (LUIN)
      ENDFILE      (LUOUT)
      CALL ACLOSE (LUOUT)
      CALL AEXIT
      END

      SUBROUTINE RNDDMS (IDEG,IMIN,ISEC)
      IF (ISEC .GE. 60) THEN
          ISEC = ISEC - 60
          IMIN = IMIN + 1
      ENDIF
      IF (IMIN .GE. 60) THEN
          IMIN = IMIN - 60
          IDEG = IDEG + 1
      ENDIF
      RETURN
      END
```

Attachment O.--Example projection-file listing

```
INPUT
PROJECTION UTM
FORMAT '(20X,2F15.3)'
ZONE 14
UNITS METERS
PARAMETERS
OUTPUT
PROJECTION GEOGRAPHIC
QUADRANT NW
UNITS DMS
PARAMETERS
END
```