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Analysis of Westside Bypass Freeway Corridor Using pcARC/INFO and IDRISI Geographic Information Systems

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ANALYSIS OF WESTSIDE BYPASS FREEWAY CORRIDOR USING pcARC/INFO AND IDRISI GEOGRAPHIC INFORMATION SYSTEMS

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INTRODUCTION

A variety of Geographic Information Systems (GIS) are in common use by public and private organizations today. Over the last decade, new and increasingly sophisticated, yet "user friendly" systems have evolved for use in the micro-computer environment. Computer hardware and data storage costs have declined while computing power, speed and flexibility has increased, making implementation of a GIS more cost effective. This has permitted many professions to select a GIS and associated hardware that serves their particular spatial analysis needs. Once implemented, Geographic Information Systems can provide an organization far superior and cost effective analysis capabilities in less time than has previously been possible.

One practical GIS application which recent advances have made possible is in siting a freeway through a rural area. This method of computer analysis can accurately inventory the size and distribution of geographical features within the freeway corridor and examine possible impacts by creating and manipulating a variety of computer-generated maps. Geographic Information Systems can perform sophisticated analyses accurately and efficiently such as, identifying fragile habitat, prime farmland and other areas which could be negatively impacted by the freeway. These many possibilities of environmental analysis using a GIS were instrumental in the selection of the Westside Bypass Freeway Corridor for this research project.

The proposed Westside Bypass Freeway is located on the western edge of the Portland Metropolitan area. There are several characteristics inherent to the freeway corridor which makes a sophisticated GIS suitable for an environmental analysis. The corridor passes through prime agricultural land, natural wetlands habitat and other areas with significant resources. An accurate inventory of these resources within the corridor is essential to determine a freeway alignment with minimum potential negative impacts. Much of the corridor is outside of the Metropolitan Urban Growth Boundary which protects farmland from urban development. It is thought that this freeway may create pressures for urban development outside of the UGB. It is some of these issues which make the Westside Bypass Freeway such a controversial project and which a GIS can best be used for preliminary environmental analysis.

This Westside Bypass Freeway study used two different Geographic Information Systems for environmental spatial analysis. The two systems, pcARC/INFO and IDRISI, differ in data structure and capability, but each can perform sophisticated analyses useful for the freeway study. Specific questions were designed to test the functionality, or performance of each system and determine which type of analysis the system is capable of and most suited to. The results of this study include both a discussion of how the two Geographic Information Systems should be used in further studies and a cursory analysis of potential freeway impacts. This analysis was not conducted a sufficient detail to recommend an alignment. However, an inventory of several resources or "themes" within three hypothetical freeway alignment buffers was developed and a series of computer-generated "potential impact maps" were created.

The Westside Bypass study showed that a number of freeway alignments may conflict with wetlands, prime farmland, steep terrain and the Tualatin River drainage system, but that the degree of impact can only be established with further research. Although only a few natural resources were considered, it appears that an alignment generally to the east side of the Freeway Corridor would be most appropriate. There are fewer acres of wetlands and prime farmland in this section of the Corridor, and it is closer to the Urban Growth Boundary. The rural land use zoning allows more large-lot rural residential uses near the UGB, so it is likely that an alignment in this area would not pass through the best farmland. However, population and land ownership in this section of the Corridor would likely be heavily impacted. Neither of these themes were considered in this research.

The study found that pcARC/INFO and IDRISI should be used together in any subsequent corridor study due to the unique capabilities inherent to each system. It was found that both systems are capable of translating data from various formats with little difficulty. The more powerful system, pcARC/INFO should be used for much of the overlay analysis and resource inventory. It can accurately calculate the size and area of spatial features and produce detailed tables and graphics. The IDRISI can perform cost surface and minimum cost pathway analyses with its value weighting capabilities inherent to a grid cell format. Finally, the output from this study can help focus further GIS research of the Westside Bypass Freeway. This can refine the analysis and better predict potential conflicts between valuable resources and the freeway corridor.

PROJECT DESCRIPTION

The purpose of this research project is to examine the functionality and interface of two Geographic Information Systems, and to perform a potential environmental assessment of the Westside Bypass Freeway corridor in suburban Portland. First is a discussion which describes elementary GIS concepts, data format and fundamental GIS operations. Next is a description of pcARC/INFO and IDRISI and an analysis of their functionality. Following this, a description of the methodologies used to analyze the Westside Bypass Freeway corridor, is presented. The inventory of resource themes and conflicts with the freeway alignments is discussed next, emphasizing some of the more interesting findings. Finally, an assessment of the capabilities of each GIS and their usefulness for preliminary environmental impact analyses on proposed transportation facilities such as the Westside Bypass is presented.

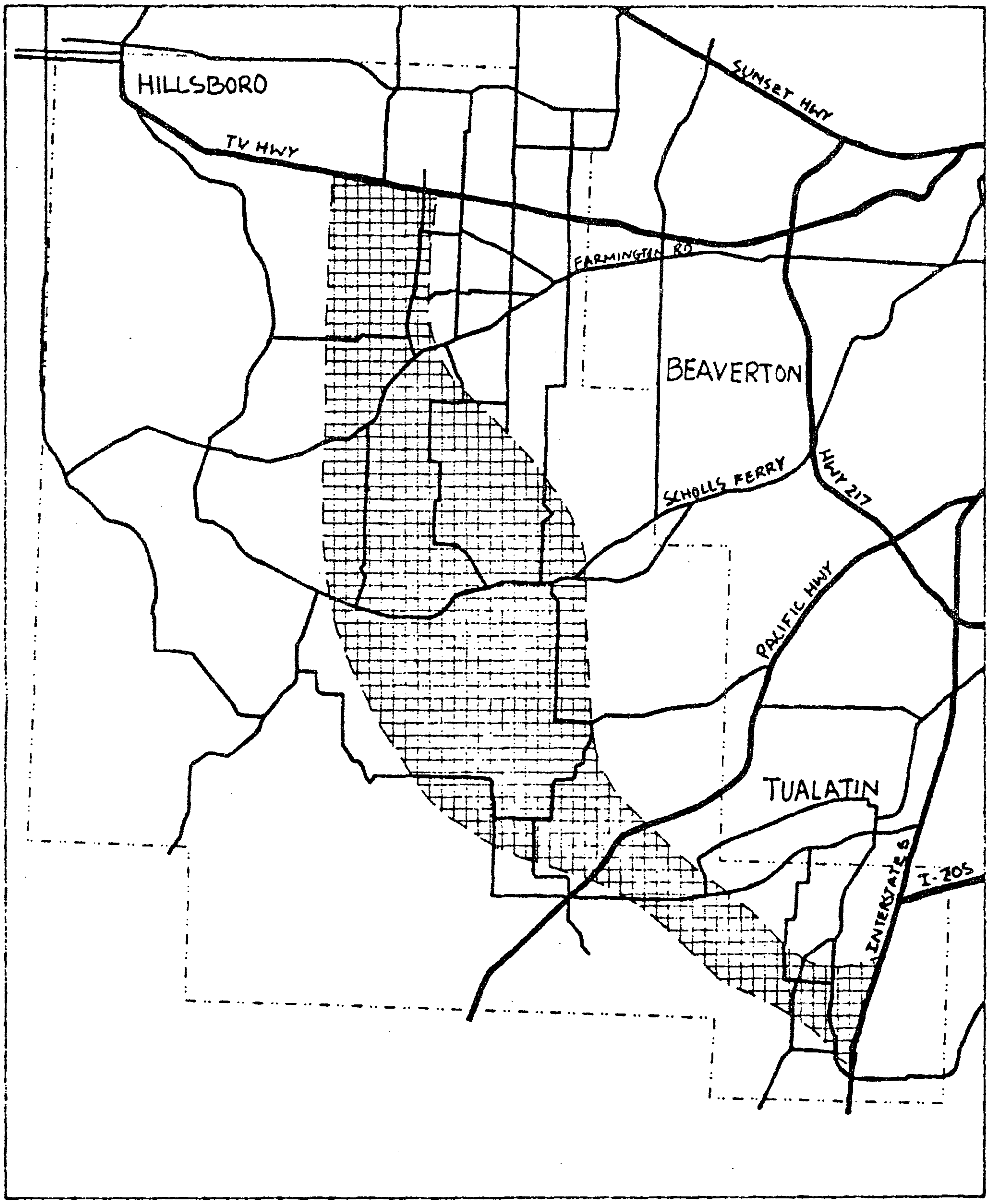
The most comprehensive method to compare Geographic Information Systems is to contrast their functionality. Dolton says that functionality is a "measure of overall performance of a system . . . determined by its data structure and command structure." Since two very different systems were compared, no effort was made to determine which system is superior. Instead, an assessment of which system is appropriate for various analyses was performed. This functionality analysis was designed to compare the two systems with respect to: command structure, level of sophistication, ease of operation, and capability translating data to and from other systems.

The GIS comparison was conducted on the proposed Westside Bypass Corridor for several reasons. It is a high priority highway proposal in the METRO Regional Transportation Plan; it is a controversial project due to it's potential environmental impacts; and the Westside Bypass study is original research. In addition, a GIS analysis performed at sufficient detail could assess potential environmental conflicts with a proposed freeway alignment and determine an optimal alignment (if one exists). It was not the intention of this research project to develop an impact analysis to the degree stated above. The purpose was to measure the functionality of two Geographic Information Systems on such a practical, timely application, and recommend scale and data requirements which would be necessary for such a preliminary impact analysis. See Map 1.

The two Geographic Information Systems that were tested are pcARC/INFO, developed by Environmental Systems Research Institute (Redlands, California) and IDRISI, developed by the Graduate School of Geography, Clark University (Worcester, Massachusetts). The two systems are quite different in design, purpose and functionality. In fact, the IDRISI designers call their system a "geographic analysis system" for academic research rather than a large-scale inventory tool (Eastman and Warren, 1987). In contrast, the pcARC/INFO Geographic Information System is a sophisticated software package used to "automate, manipulate, analyze and display geographic data" (pcARC/INFO manual).

The major difference between the two systems is the manner the data is structured and displayed. The pcARC/INFO program is a polygon-based system where geographic data is represented by points, lines and polygons. The IDRISI software package is a grid cell system

WESTSIDE BYPASS STUDY
TRANSPORTATION



LEGEND

HIGHWAYS

FREEWAY CORRIDOR

ARTERIALS AND OTHER ROADS

SCALE

1:100,000

SOURCE: WASHINGTON COUNTY, 1989

M. NEWMAN

MAP 1

where all data is stored in a matrix of equal-area cells. Each system has inherent limitations due to the data structure in which it is based, but both can be powerful analytic research tools. The two systems were run on an IBM-clone 386 micro-computer in the School of Urban and Public Affairs micro-computer laboratory at Portland State University. Following is a discussion of general GIS concepts, then specific pcARC/INFO and IDRISI structures.

GEOGRAPHIC INFORMATION SYSTEM CONCEPTS

The definition of a geographic information system is best stated by Dueker, (1987) as a "database (which) consists of (1) observations on spatially distributed features, activities, or events, which are definable as points, lines or areas; and (2) procedures to collect, store, retrieve, analyze, and display such geographic data." Spatial features are digitally captured, or "digitized" through a number of different processes. The computerized features are then linked to a database describing those features by a unique value assigned to both the digitized data and the database. The factor which makes a GIS such a powerful (and complex) tool is it's ability to manipulate spatial features as well as topological connections and corresponding descriptive attributes (Burrough, 1986). While a CAD system may be capable of producing a cartographically accurate map, it is not a GIS because it cannot link map features to a database. Similarly, an advanced information system is limited in that it is not linked to spatial features on a digital map. Only a geographic information system has both of these features in common (although recently some CAD systems have been updated with GIS capabilities).

There are several characteristics of geographic data common to a GIS. Dangermond identifies three such characteristics: locational data, typically represented by points, lines or areas registered by an (x,y) coordinate for control; non-locational data, its attributes which describe the locational features; and temporal dimensions, or change of these features over time. The ability to relate spatial features and their attributes over time make geographic information systems a powerful planning and programming analysis tool. See Diagram 1.

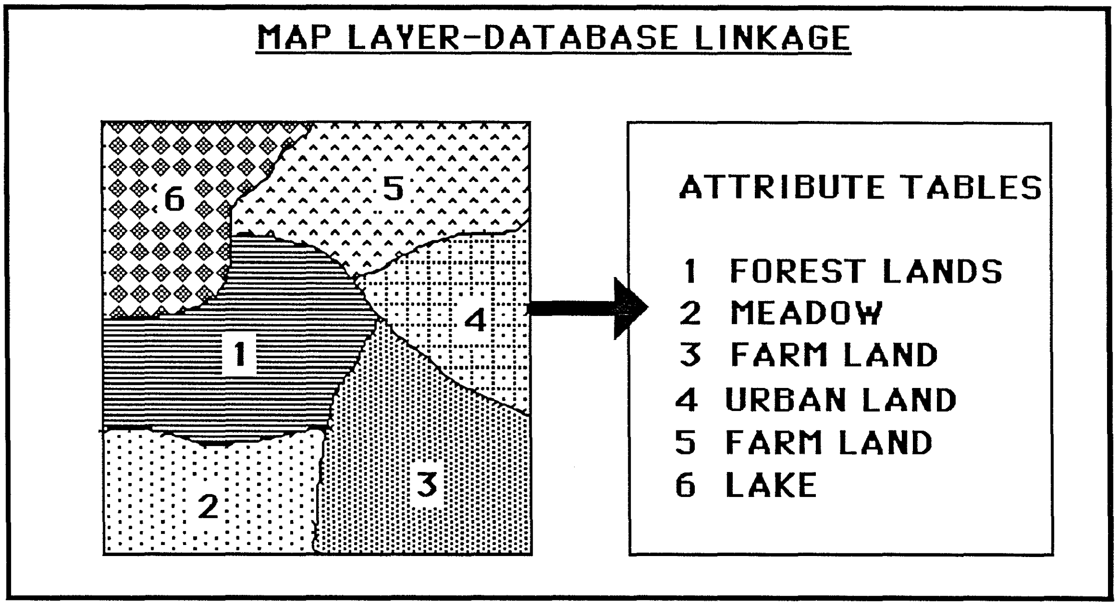


Diagram 1

There are two fundamental GIS data structures: the polygon-based, or vector format; and the grid cell, or raster format. Dueker, (1987) discusses a third format, Triangulated Irregular Network, but most analyses rely on either vector or raster formats. The vector format in which pcARC/INFO is based, stores spatial data in the form of (x,y) coordinate points, arcs (strings of points) and polygons (closed strings). Each point is a zero-dimensional object which has a corresponding attribute connecting the point to its description in a database. A line is a one-dimensional object between two points and an arc is a series of connected lines with a node at each end. Arcs also have a corresponding topology which maintains directionality in the form of a FROM NODE (beginning node), a TO NODE (ending node), a LEFT POLYGON and a RIGHT POLYGON identifier (areas to each side of the arc). Sophisticated analyses can be performed with arc, or line data, the simplest being length measurement (Dueker, 1987).

The closed string, or polygon maintains the directionality of one or more arcs with the first node sharing the same (x,y) coordinate as the last node. The closed polygon is assigned an attribute which matches an identifier in the database, thereby linking a two-dimensional spatial feature with it's descriptive information. The area and perimeter of the polygon is then calculated and displayed with the descriptive information in the attribute tables provided with vector-based systems. Once geographical information is joined to the database, pcARC/INFO or other vector format systems can be used to create new maps displaying spatial features of particular interest.

There are several GIS structural features which are unique to a vector based system. Vector data can be an extremely accurate representation of geographical features, but it requires substantial processing power to calculate each (x,y) coordinate and continually update the feature topology. The resolution capabilities of this data structure are far superior to a raster based system, but high resolution vector files require significant disk storage space and computation time. Vector systems are easily linked to a database with the capability of linking to a more complex relational database, thereby limiting redundancy. Another feature of the vector format is its networking capabilities. Because the topology (directionality and connectivity of intersecting arcs) is maintained, network analysis on streams or transportation systems is possible. Measurements of stream flow through a drainage system or routing traffic through a highway system are two practical applications. Finally, a vector system can be easily updated by editing digitized spatial features, their attributes and the database (Burrough). See Diagram 2.

Polygon Data Structures

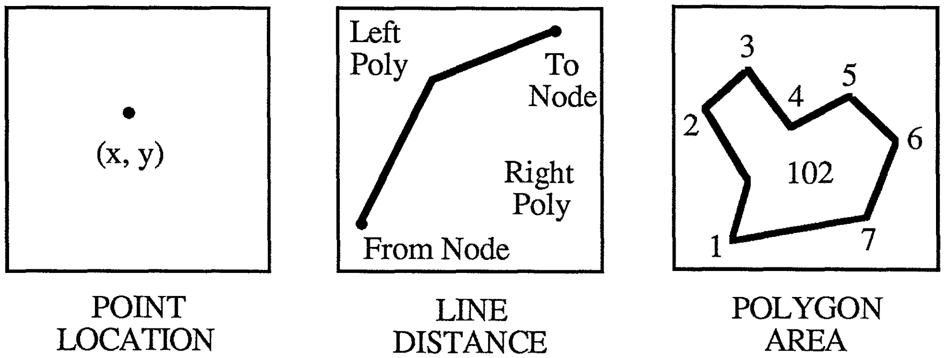


Diagram 2

The second fundamental GIS data structure is the grid cell, or raster format. This is the format in which IDRISI is based. This data structure consists of an (i,j) matrix of grid cells in which spatial data is represented by one number in each cell. This number can be a code that is referenced in a database, or simply a value that can be used for numeric calculation. Location of features in a raster format is maintained by column and row number, with the (1,1) cell typically in the northwest corner. Points, lines and areas are represented as a single or series of neighboring grid cells, but in contrast to vector data, raster systems include only one data type. A point is represented by a cell containing a different value than those which surround it. A line is represented by a series of similar value cells while an area is a cluster of cells containing the same value. The characteristic of this ridged grid structure is that spatial data is represented in equal dimension squares (but can be represented in rectangular form as well), as opposed to real-world features. Raster format data is more efficiently processed across layers due to its fixed structure. Arithmetic functions can be performed giving the system the ability to weight variables. Measurements of area or distance, however, result in a higher degree of error than that of polygon data due to the requirement of measuring whole cells. But the advantage of this system is that it is an efficient method for storing and manipulating data (Dolton, Burrough). See Diagram 3.

Grid Data Structures

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	3	0	0
0	0	0	0	0	0
0	0	0	0	0	0

POINT
LOCATION

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	3	3	3
0	0	3	0	0	0
0	3	0	0	0	0
3	0	0	0	0	0

LINE
DISTANCE

1	1	1	1	1	2
1	1	1	2	2	2
1	2	2	2	2	2
1	2	2	2	2	2
1	1	2	2	2	2
1	1	1	1	1	1

POLYGON
AREA

Diagram 3

pcARC/INFO

The pcARC/INFO GIS package is a collection of separate modules in which different operations are performed. The Automated Digitizing System (ADS), is the module in which all digitizing and limited editing can be done. It is in this module that coverages, or layers representing one feature type, are created. Maps are first registered on the digitizing tablet by identifying several locations where a known (x,y) coordinate exists. By calibrating the tablet, the coverage is created with the necessary .TIC and .BND files required for accurate processing (these files maintain the registration points and perimeter of the map). The operator can then drop points at desired intervals, tracing the map features to create either a point, line or polygon map (but only one data type per coverage). The ADS module permits the operator to assign attribute identifiers to points, lines or polygons during the digitizing procedure, otherwise the program will automatically assign attributes in the order the features were digitized. It is preferable for the operator to assign the attributes so they can match the descriptive database.

The digitizing of map features is the most critical procedure in implementing a GIS because it is here that the accuracy of the coverage can be controlled. Once digitized, subsequent editing, topology creation and database linking is required. The **CLEAN** command creates polygons from enclosed arcs, trims off unwanted dangling nodes and builds attribute topology (for polygon coverages only) in the **TABLES** module. Attribute topology for point and line coverages is created after running **CLEAN** using the **BUILD** command. Any required editing of the coverage can be accomplished in **ARCEDIT** module. Within the **TABLES** module descriptive data that is linked to the coverage features can be manipulated or reclassified to create new maps, assisting in the spatial analysis. The **TABLES** module allows only one-to-one, or flat file databases, but the more powerful **INFO** module allows import of relational databases and greater flexibility in data manipulation.

Once a coverage is edited and linked to it's database in pcARC/INFO, a great number of GIS analyses can be performed including overlay and network analysis, and new maps are created. Plotting and professional quality graphic display of the coverages are accomplished in the **ARCPLOT** module. For greater flexibility the program has the capability to import and export digital map coverages in vector or raster formats to a number of other systems. The **GRIDCONVERSION** module is one such capability in which vector format data files were "rasterized" for simple transfer into IDRISI. Finally, the newest version of pcARC/INFO will expand these capabilities further, allowing import of digital data which was digitized in other software packages such as AutoCAD (pcARC/INFO manual).

IDRISI

The IDRISI grid cell program is designed as an inexpensive, expandable research program which is a powerful spatial analysis system. The program requires only two files to operate. The **DOCUMENT** file describes the structure of the data and size of the matrix in IDRISI. The **IMAGE** file is the actual data in ASCII or binary format. Because the program operates in standard ASCII format, data can be easily imported from other sources. In fact, it is much simpler to import data which was digitized in vector format, then rasterized, than it is to digitize in IDRISI. Both the size of the grid cells and the total number of cells can be defined by the operator with few limitations except disk size and processing time. However, care must be taken to ensure that resolution of the grid cells is not higher than the accuracy of the original data.

The IDRISI program is quite simple to use and, generally, most commands are menu-driven requiring little key input from the operator. The commands are located in one of three classes of modules: The core modules for data management and display; the ring modules which include most analysis commands such as overlay; and the peripheral modules which include more sophisticated analysis commands. Display capabilities of IDRISI are not as advanced as other grid cell programs, but a 32 grey-tone map can be created by a standard printer. In this case, up to 32 values on an image can be displayed. Although the program cannot produce color output, color images can be displayed on the color monitor. The system can produce a series of statistical output necessary to assist in the analysis. Finally, the program has the capability to import satellite generated data or data from other raster and vector systems. The flexibility of the program allows new analysis modules to be added to the system (Eastman and Warren). See Figure 1.

pcARC/INFO and IDRISI OUTPUT

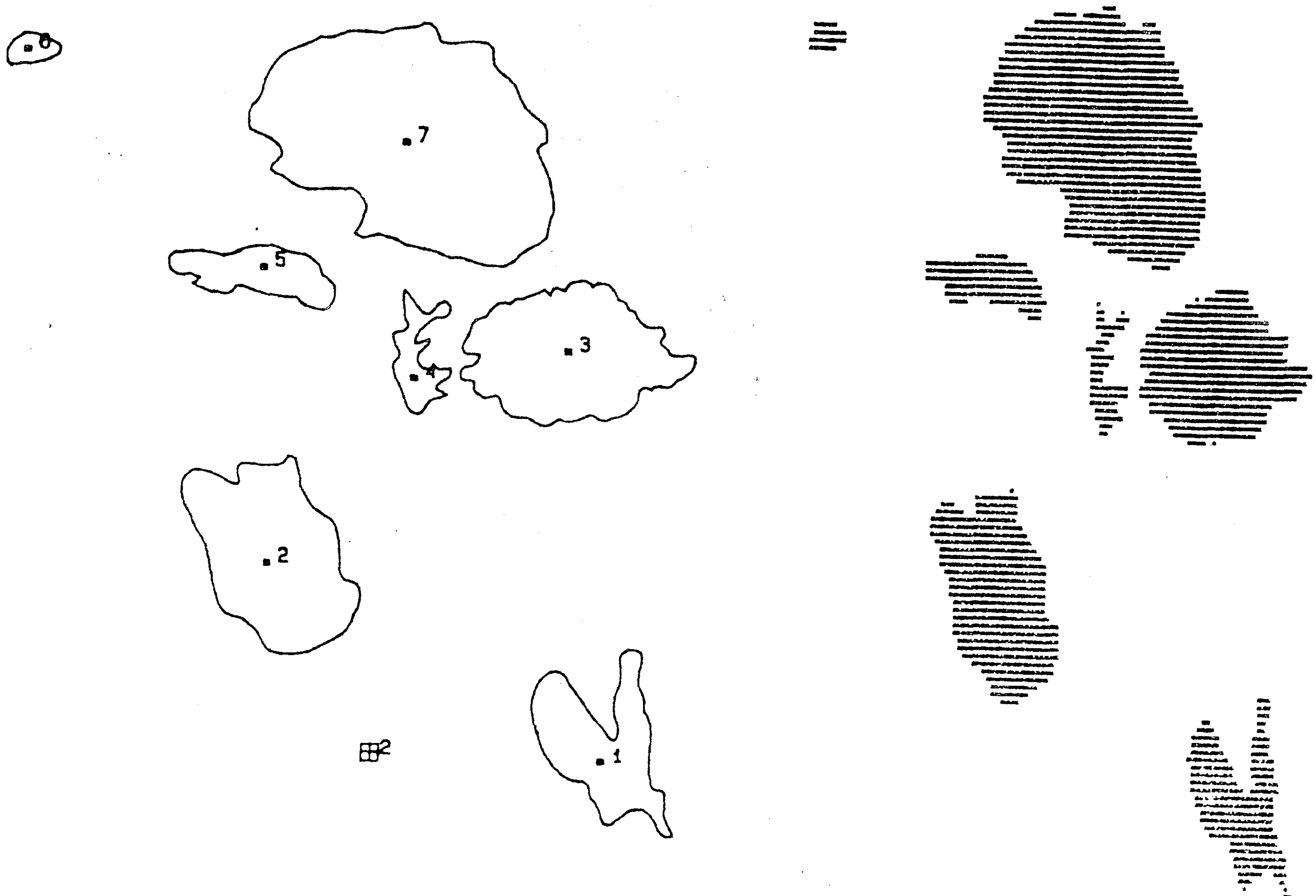


Figure 1

FUNDAMENTAL GIS OPERATIONS

There are four fundamental GIS analysis operations that can be performed in either vector or raster data formats. These are: Reclassify, Overlay, Distance, and Neighborhood. Each of these categories contains at least one command in pcARC/INFO and IDRISI, with the exception of neighborhood. This analysis operation can only be performed in a grid cell format.

RECLASSIFY

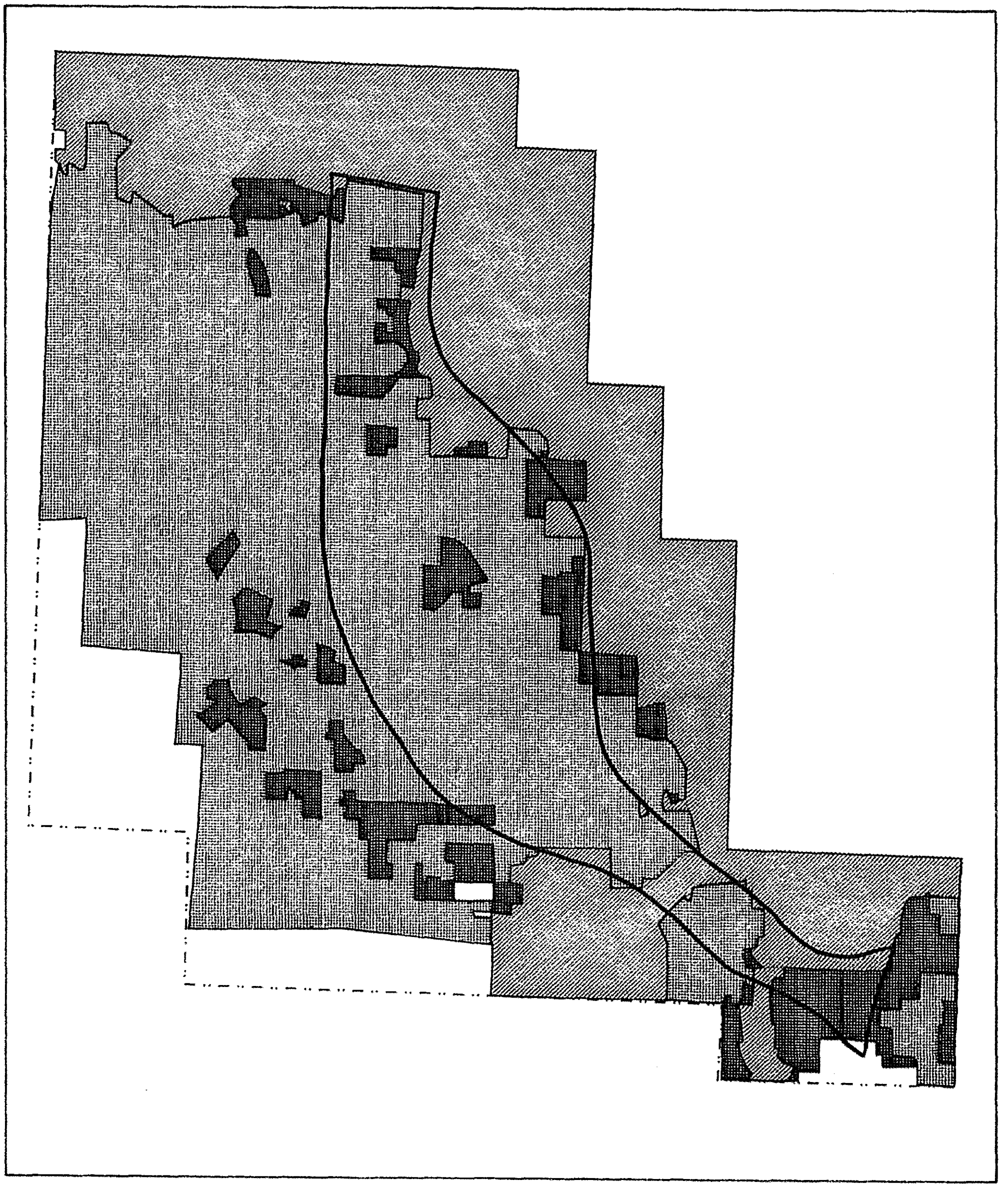
A map is reclassified to reorder existing data into new categories for analysis. This can be achieved by aggregating the number of categories from many to few. For example, a land use map was reclassified from eight uses to just three: Primary lands, Secondary lands, and Urban land. See map 2. Reclassification can increase the total number of categories as well. A map displaying only one category, wetlands, could be reclassified into several categories based on the acreage of each wetland. For example, the researcher might want to classify wetlands into two categories: those greater than 25 acres and those 25 acres or less. A series of new studies can be conducted by manipulating the classes of data without adding any new data to the map (Dolton).

A vector map is reclassified by assigning existing polygons with new attributes. Any neighboring polygons with similar attributes have common boundaries dissolved creating fewer, but larger polygons. Similarly, more classes (but never more total polygons) can be created by area differentiation, such as the above example. Line data can also be reclassified by dissolving unwanted segments, aggregating the attribute data to create fewer classes, or by creating more classes differentiated by length. In pcARC/INFO the attribute database must be reclassified, then the **RESELECT** command can be used to select a subset of data from a larger set. It is in the **TABLES** module that many of the reclassification procedures are performed (pcARC/INFO manual).

A raster format map is reclassified by assigning new values to the cells. In IDRISI the **RECLASS** command is used for this purpose. Another useful command, **HISTO**, generates a variable listing and statistics from which reclassification can be determined. This is a simple procedure in which the old value range (in real numbers or integers) is replaced with a new value. Each effected cell is then automatically assigned this new value. The advantage of reclassification in IDRISI is that features can be weighted to distinguish greater value or significance. While in a

WESTSIDE BYPASS STUDY

LAND USE CLASSIFICATION



LEGEND

PRIMARY FARMLAND

URBAN LAND

SECONDARY FARMLAND

SCALE
1:100,000

SOURCE: WASHINGTON COUNTY, 1989

M. NEWMAN

MAP 2

vector system all attributes on a map are considered nominal variables, IDRISI can reassign data to represent ratio or interval variables (Dolton).

A simple reclassification of streams from three classes to one was performed. The result was one class representing streams and one class representing background. This reclassification of values for these two variables could be used as either nominal or interval data. Nominal variables could be classified as a simple (1,0) classification showing change, but with no measurable value (stream, everything else). Conversely, an unclassified map showing streams could be classified by stream order. In this case, the operator would weight the streams by, say primary streams, secondary streams and non-streams, to indicate significance over surrounding cells (3, 2, and 0, showing no data). The values must be chosen carefully because they determine which arithmetic functions could most effectively be run on the data.

OVERLAY

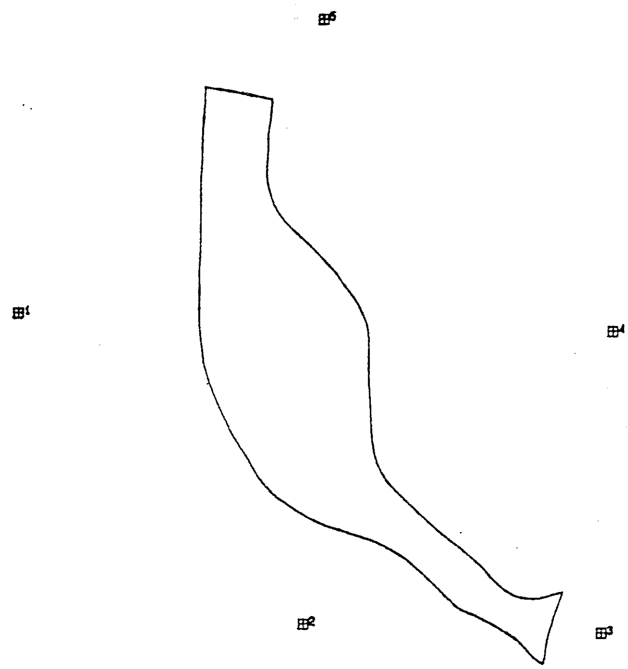
One of the most useful GIS analysis operations is to combine spatial data from two or more maps to create a third map. This procedure can be accomplished in both pcARC/INFO and IDRISI, but they vary significantly due to the different data structures. The overlay commands in pcARC/INFO can only generate a map showing the nominal combination of features from the previous maps. While the program does maintain the topology from all original polygons (or lines and points), it cannot calculate interval or ratio relationships from features on one map to those on another. Due to arithmetic capabilities inherent to a grid cell GIS, IDRISI can overlay two layers and derive a relational or weighting values. Dolton describes three overlay capabilities that are unique to grid cell systems: Relational overlays which can determine minimum and maximum values; arithmetic overlays which can add, subtract, multiply or divide values from the two maps; and cover overlays which allow features to show through the two maps. Although a polygon map cannot perform these types of analyses, the maintenance of multiple attribute topology and the precision area measurement make the overlay operation an extremely valuable polygon analysis.

The two major pcARC/INFO overlay commands are **INTERSECT** and **UNION**. In addition, the **RESELECT** command is highly useful for selecting individual attributes from the database and overlaying them on another coverage. The **INTERSECT** command finds the intersection of features common to both maps, and creates a new map showing only those polygons, lines, or points. The **UNION** command intersects the two maps, but all features from both maps remain, creating many more features on the third map. In both cases, topology from both coverages is maintained. See Figures 2 and 3.

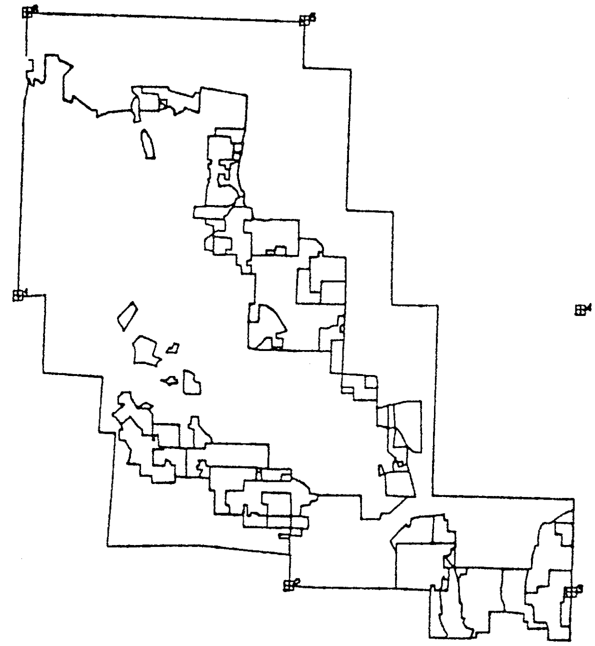
The IDRISI overlay command allows the researcher to perform arithmetic, normalized ratio and cover (logical) operations. In addition, these operations can be performed by weighting the values used in the overlay process. The advantages of these operations are many. For example, if a grid map showing "High Freeway Construction Costs" was to be made from a slope map and a 100 year floodplain map, the steepest slopes might be assigned a higher value than moderate slopes. Furthermore, since the cost of filling lowlands would be different from cutting into slopes, the variable '100 year floodplain' might be assigned a value reflecting it's relative weight. In overlaying the two maps, adding the values of both maps would result in a much different new map than if the values had been multiplied. Eastman and Warren (1987) detail some natural resource applications for the "ratio" operation in IDRISI. They say that it is "commonly used in the derivation of vegetation indices using the red and near-infrared band." The command structure is a simple **OVERLAY**, followed by the image names and arithmetic or other operations to be undertaken.

OVERLAY: pcARC/INFO

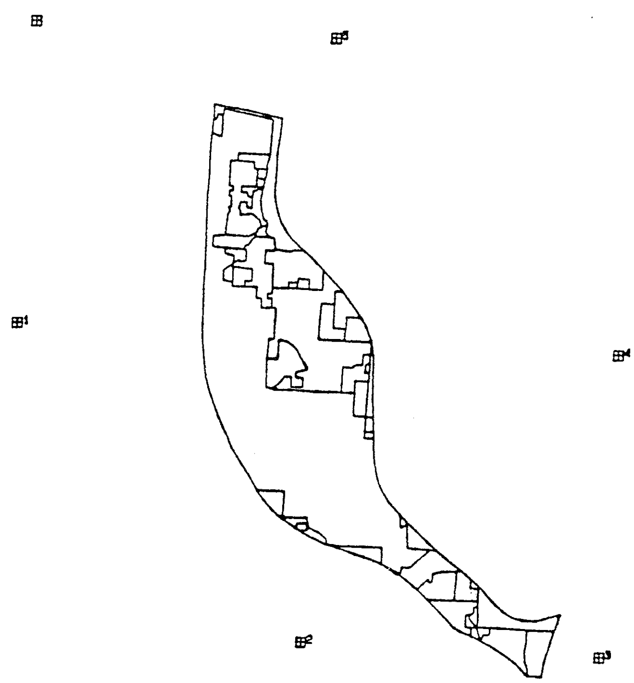
INTERSECTION: FREEWAY CORRIDOR AND LANDUSE USE



WESTSIDE BYPASS CORRIDOR



LAND USE



RURAL LAND USE WITHIN FREEWAY CORRIDOR

Figure 2

OVERLAY: pcARC/INFO

UNION: WETLANDS AND 100 YEAR FLOOD PLAIN

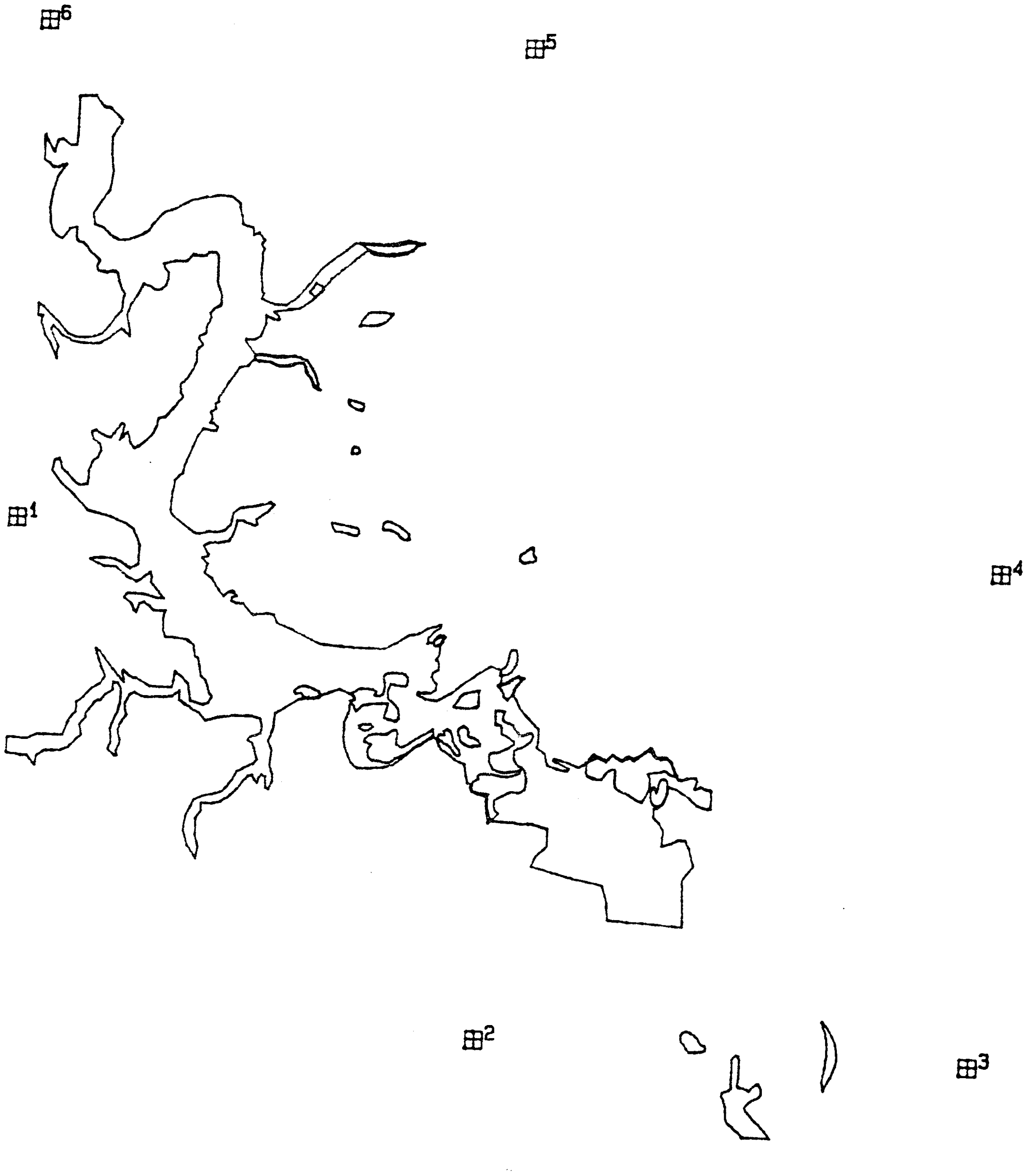


Figure 3

DISTANCE

Distance analysis is another important fundamental GIS operation that can be performed in both pcARC/INFO and IDRISI. Simple distance measurement between two points, the length of a line segment, or the perimeter of a polygon are automatically calculated in pcARC/INFO, pcARC/INFO manual). Another common distance operation is buffering of streams, roads or any other feature. Features can be buffered a set distance or the buffer area can vary when used in conjunction with an INFO Look-up Table created in the **TABLES** module. The system is also capable of network analysis, determining least-cost routine or length of a stream network. Distance can be measured with a high level of precision in a vector data format, but a raster system is limited by the size of the grid cell. The grid cell program must measure distance in grid cell units, creating a high level of error when measuring a diagonal through the grid space. A grid cell program can buffer a road or stream similar to a vector system, but it can also perform distance analyses of which a vector system is incapable. Because IDRISI can weight cells differently depending upon the criteria that is set up, it has the capability of cost surface analysis (Dolton).

The pcARC/INFO command structure for measuring distances and buffering roads and streams, is simple. Distances are automatically calculated in **TABLES** with the building of the topology during the **CLEAN** process. As shown in Figure 4, pcARC/INFO automatically numbered each line in the road network, but maintained the attribute number assigned it during the digitizing process. In addition, the length of each line segment is provided in the units specified by the operator. The noticeable limitation of the **TABLES** module with respect to distance measure is that it cannot add together individual line segments. The relational database module, **INFO,** has this capability, however.

DISTANCE: pcARC/INFO

TRANSPORTATION: MAINTAINED TOPOLOGY

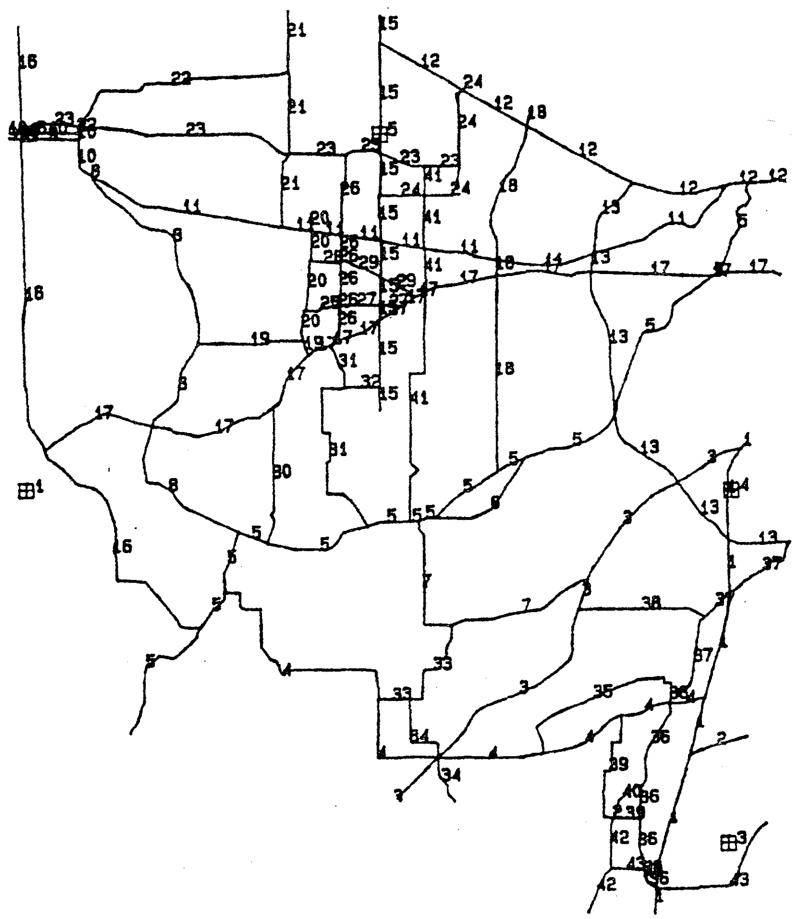
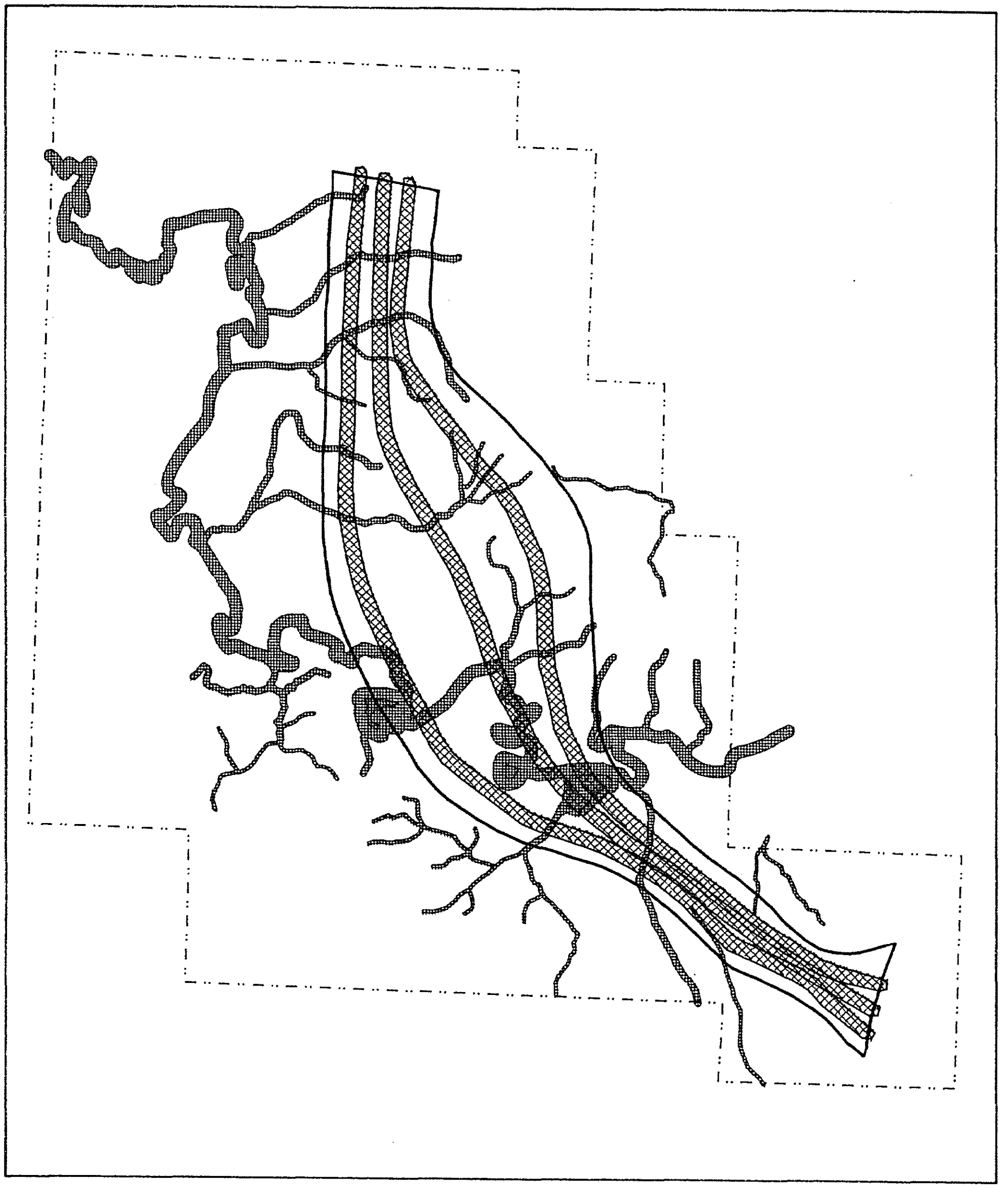


Figure 4

The **BUFFER** command will create polygons around a point, line or polygon at a selected distance, and generate topology for the new polygons. With the use of Look-up Tables, pcARC/INFO will buffer a feature to attribute specifications. For example, the Tualatin drainage basin was reclassified into Stream-Order classes 5-3, allowing a three-distance buffer, (400 ft., 200 ft., and 100 ft.) to be generated. See Map 3 and Figure 6. Finally, the Network capability of pcARC/INFO allows the researcher to model optimal highway routine and stream flow. Since the program maintains line topology in the form of connectivity and direction, Network analysis can be performed. This type of analysis was well beyond the scope of this study.

WESTSIDE BYPASS STUDY

TUALATIN RIVER WATERSHED



LEGEND

BUFFERED DRAINAGE PATTERN

FREEWAY ALIGNMENTS

1:100,000

MAP 3

BUFFERING: 3 STREAM-ORDER CLASSIFICATIONS

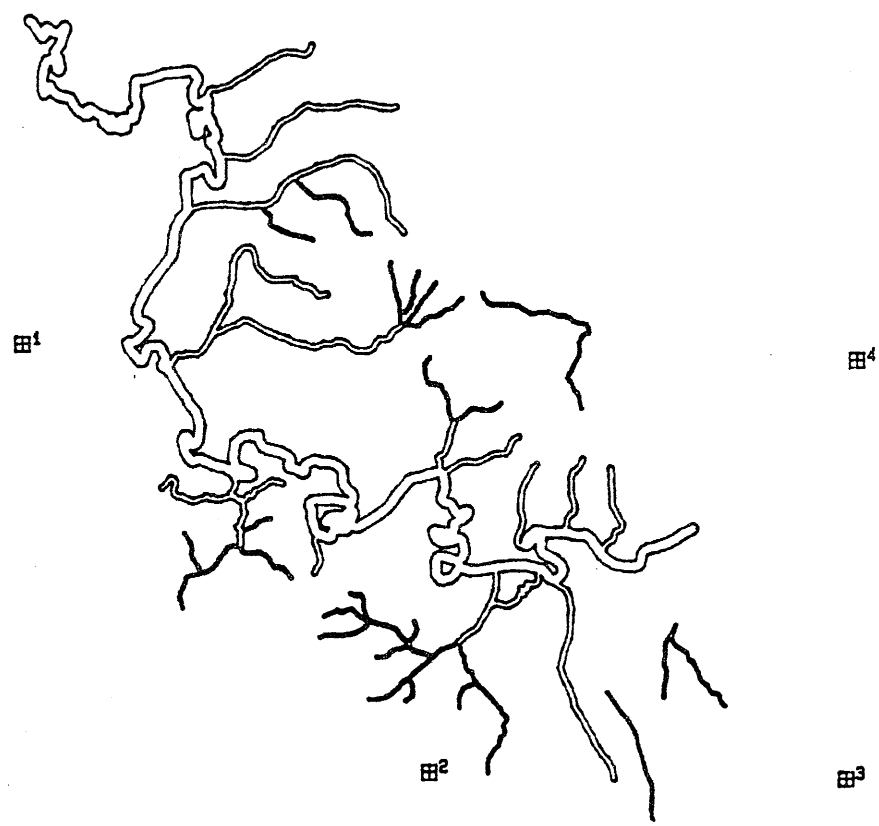


Figure 5

NEIGHBORHOOD

The final fundamental GIS operation is Neighborhood. This operation can only be performed in a grid cell format due to its weighting capability. There are several neighborhood commands available in IDRISI. The basis of this operation is performed in 9-cell blocks where the center cell is assigned the average value of the surrounding 8 values. In this manner a map feature can be smoothed or filtered. This is a valuable function when the operator is interested in deriving an average slope of a map feature, either to determine real-world geography such as terrain, or to derive a "cost surface." This operation can be performed on area features to determine an average slope and linear features, such as a stream, to derive a buffer area. Although similar to Distance operations in pcARC/INFO, these buffering capabilities average surrounding cells rather than buffering a set number of cells (IDRISI has that capability as well).

There are a number of useful neighborhood operations supported by IDRISI. The **SURFACE** command calculates slope from a digital elevation map. The **FILTER** command can either average surrounding cells to smooth the map in the case of the "mean filter" or it can exaggerate the change in values in the case of the "edge-enhancement filter." This feature is useful when the operator wishes to delineate regions with large changes in values. Another set of commands, **COST** and **PATHWAY** are useful to derive a "least cost" route between two or more points. This operation was performed on the Westside Bypass Corridor, but only two map features were used for simplicity. Other neighborhood commands available in IDRISI include **VIEWSHED**, **WATRSHED** and **HNTRLAND**. These features allow the operator to perform sophisticated analyses dealing with 3-dimensional digital elevation models. Sophisticated economic or marketing models can be performed with **HNTRLAND** (IDRISI manual). See Figure 6.

NEIGHBORHOOD: IDRISI

COST SURFACE MAP OF FREEWAY CORRIDOR

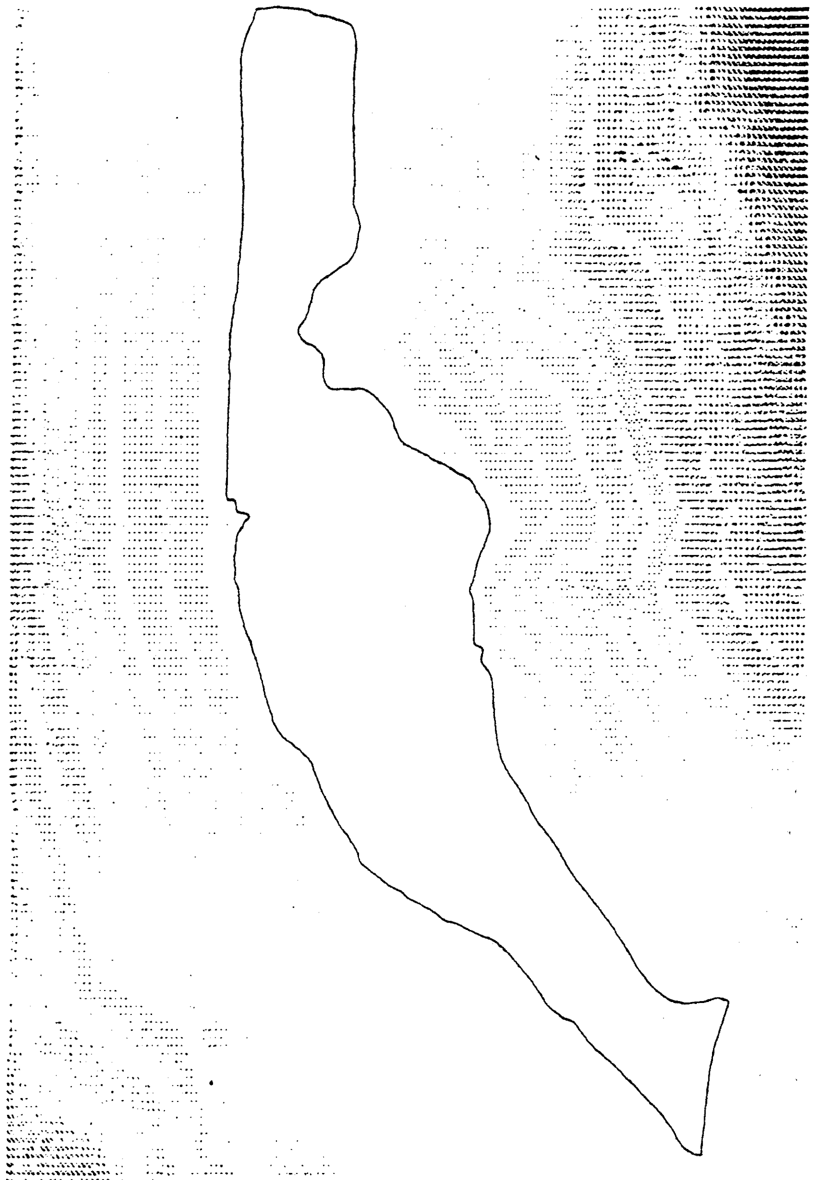


FIGURE 6

WESTSIDE BYPASS STUDY

This project was designed to evaluate the functionality of pcARC/INFO and IDRISI on a practical freeway environmental analysis application. All four of the fundamental GIS operations were tested using data digitized from map themes representing spatial features within the freeway corridor. The capabilities of each GIS package were evaluated by the series of criteria which includes: command structure, level of sophistication, ease of operation, and capability of translating data to and from other systems. In addition, the two systems' ability to answer a series of inventory and environmental questions concerning the freeway corridor were evaluated. The results of this study, then, include both a discussion concerning the possible uses of pcARC/INFO and IDRISI in a future Westside Bypass Freeway study and an inventory of potential environmental conflicts within the corridor.

The major challenge of this project was in preparing the freeway corridor map data for analysis. This involved map theme selection and digitizing, developing questions to test pcARC/INFO and IDRISI, setting up the map data and joining to small databases in pcARC/INFO, and manipulating the data for analysis. In addition, once the pcARC/INFO analysis was complete the data was translated into grid format for the IDRISI analysis. These and other procedures for the analysis were developed and are listed below. This is followed by a list of map features from the Westside Bypass Corridor used in the analysis. Next is a list of the questions to be addressed by each system. Finally, the results are presented, including a summary of the potential environmental impacts caused by the freeway and a discussion of how effectively each GIS performed in this corridor study.

ANALYSIS PROCEDURES

1. Develop a list of map themes showing natural resources and other features within the Westside Bypass Freeway Corridor.

   - **Selected 12 Map Themes**

2. Determine appropriate scale for analysis within digitizing tablet size and map availability constraints.

   - **Selected 1:60,000 scale Washington County maps**
   - **Minimum Mapping Unit: 4 acres (417 ft.)**

3. Propose three hypothetical alignments within corridor between I-5 and TV highway.

   - **Selected alignments in the center and each side of the corridor without bias to location of map features**

4. Digitize all map themes in pcARC/INFO, then edit, build topology and transform into State Plain coordinates.

   - **Digitized points, lines and polygons then created real and hypothetical attribute tables**

5. Generate a set of questions that will test the functionality of each GIS system.

   - **Questions tested the four fundamental GIS operations: Reclassify, Overlay, Distance, and Neighborhood**

6. Determine maximum environmental impact distance from freeway and buffer three alignments accordingly (given map scale constraints). This is necessary to inventory potential conflicts between freeway alignments and spatial features.

- **Buffered alignments 500 ft. from each side of the freeway center line**

7. Inventory each theme: Area of polygon features and length of line features within Perimeter, Corridor and each Alignment.
   - **Determined relative conflicts between themes and each freeway alignment then created a spread sheet for display**

8. Test other pcARC/INFO operations to assess the functionality of the system and create impact maps.
   - **Tested Reclassify, Overlay and Distance by creating potential impact maps including "High Resource Impact" and "High Construction Cost"**

9. Translate several themes into IDRISI and test functionality of grid cell system.
   - **Rasterized vector maps and imported into IDRISI. Tested fundamental operations with special focus on "neighborhood" operations including cost surface and minimum cost pathway analysis**

10. Evaluate the two systems in terms of usefulness as an analysis tool for a transportation or land use project of this type.
    - **Both systems are capable of sophisticated analyses and should be used together due to strengths inherent to each system**

11. Evaluate results from Corridor Study and recommend general procedures for future, more ambitious analyses.
    - **Future study should include additional map themes including Land Ownership, Population and Soils. All themes should be digitized at a maximum scale of 1:24,000 and be joined to existing databases.**

- **More realistic freeway alignment buffers such as the Right-of-Way width should be used. Analyses should go further than simple inventory to interactive modelling of various alignments.**

FEATURE SELECTION

The choice of geographic features to be included in the Westside Bypass Corridor analysis was based on a series of criteria. One consideration was the selection of major features that would be impacted by the freeway. These include: existing wildlife habitat, natural and historical features, and agricultural, industrial and other land uses. A second consideration was the inclusion of the transportation network to determine probable interchange locations, location of public institutions such as schools, and the location of steep slopes and the 100-year flood plain, which would increase freeway construction costs. Another consideration was the requirement of testing all three data structures: points, lines and polygons. Themes were also chosen on the basis of the availability of maps that include this information at a manageable, consistent scale for ease of digitizing and processing of data. A larger scale would increase the accuracy of the analysis, but would have required more digitizing than was warranted for this analysis. There are four important themes that were excluded from this analysis due to time constraints. The themes are: Vegetation, Soils, Land Ownership and population. Any subsequent large-scale analysis would need to include these themes. Furthermore, themes digitized at a map scale of at least 1:24,000 would be recommended for greater accuracy. The themes and their scale chosen for this project are as follows:

THEME		DATA TYPE/SCALE	
1.	Urban Growth Boundary	Polygon	1:60,000
2.	METRO defined Freeway Corridor	Polygon	1:60,000
3.	Rural Land Uses	Polygon	1:60,000
4.	100 Year Floodplain	Polygon	1:60,000
5.	Transportation	Line	1:60,000
6.	Mineral Extraction	Polygon	1:60,000
7.	Resources and Habitat	Polygon	1:60,000
8.	Cultural and Historic Features	Polygon	1:60,000
9.	Wetlands	Polygon	1:60,000
10.	Rivers and Streams	Line	1:60,000
11.	Steep Slopes	Polygon	1:62,500
12.	Schools	Point	1:62,500

STUDY QUESTIONS

Reclassify and Overlay:

1. What is the area of primary and secondary farmland within each buffer? (polygon data)
2. What is the area of residential, commercial, industrial, historic/cultural, and mineral land use within each buffer?
3. What is the area of wetland, wildlife habitat and other environmentally sensitive lands within each buffer?
4. What is the area within each buffer that is outside the Urban Growth Boundary?
5. How many schools are within the buffer? (point data)

Distance and Overlay:

6. What is the distance of streams within each buffer? (line data)
7. What is the distance of roads within each buffer, and which ones may require freeway access (and a larger buffer)?

Neighborhood and Overlay:

8. What type of terrain (slope) is within each buffer?
9. Can a cost surface map be created for the corridor?

PROJECT ANALYSIS

The GIS analysis using pcARC/INFO and IDRISI to study potential environmental impacts of the Westside Bypass freeway has provided some interesting results worthy of further analysis. Both systems produced graphic and tabular data which could be useful in a preliminary impact study, provided that the data were further refined. The major system used in this study, pcARC/INFO, produced overlay maps and tables indicating potential conflicts between freeway alignments and resources within the corridor. The system also demonstrated it's interactive capabilities, such as the ease in which a map feature can be manipulated to create new maps.

The IDRISI system demonstrated the importance of weighting variables to indicate relative importance. The cost surface and minimum cost routing maps are two capabilities inherent to a grid cell program that would be quite useful for a freeway corridor study. In addition, both programs demonstrated the ease in which they can import and export data from a variety of different formats. This is important for a study of this type so existing data can be translated into different formats. Following is a discussion of the corridor resource inventory which was created in pcARC/INFO. This is followed by an examination of the output from each GIS used in this study. Finally, some conclusions are presented.

The most useful output from this Westside Bypass Corridor Study were the many overlay maps created to indicate potential conflicts between resources and freeway alignments and the tables which detail these conflicts. The "Theme Coverage Inventory" table lists the area of all themes used in the study and their intersection or "conflict" with the Study perimeter, the corridor and the three hypothetical freeway alignment buffers. For simplicity, the alignments are identified by Numbers 1, 2 and 3. They represent the western, center and eastern alignments, respectively. No effort was made to rank alignments by relative impact since the data was captured from a small scale map nor were the themes ranked by relative importance. However, the table is an effective graphic representation of these potential conflicts. Some of the more interesting findings are as follows:

- **The area of the corridor is 15,509 acres**
- **Alignment buffers vary in area from 1,580 to 1,744 acres and are about 13.5 miles long**
- **Alignment 3 includes 335 acres of steep terrain**
- **Approximately 90% of the Corridor is outside of the Urban Growth Boundary**
- **About 500 acres of Alignment 2 are within the 100-year flood plain**
- **There are 722 acres of wetlands within the Corridor and Alignment 2 impacts 100 of these acres**
- **There are 33 miles of major roads within the Corridor**

- **There are 11,512 acres of "Primary Lands" within the Corridor and Alignment 1 impacts the greatest on this farm and forest land.**

A large amount of computer generated output was created during this research project. Of great importance were the many printouts created from the attribute tables. These tables listed data from each polygon, line or point from every map theme. This data included polygon area, perimeter or arc distance, and attribute identifier. Although this project did not join any map theme to an existing descriptive database, small databases were created to identify particular attributes, such as Land Use classifications and Tualatin River drainage basin Stream order. Hypothetical databases were joined to the wetlands to show whether they were the primary habitat for ducks, geese or beaver. The purpose of this procedure was to show that an inventory of each user could be made (providing an accurate database on these wetlands could be accessed). Further study would require the linkage with existing databases for more refined analyses. See "Theme Coverage Inventory" tables and adjoining map for a listing and display of 'conflicts' between the corridor or three 1000 ft. alignment buffers and the resource themes.

There were also dozens of maps created in both pcARC/INFO and IDRISI from the various overlay analyses. The process of inventorying all of the map themes requires that these features are intersected. Many of these maps were not included in this paper, however two potential impact maps generated in pcARC/INFO are of special note. These maps are titled "High Construction Cost" and "High Resource Impact." They were created by overlaying particular map themes together. While no specific conclusions about the impacts from a freeway can be drawn from these maps due to the generalized data source, the maps do indicate that there will be conflicts within the freeway corridor and, therefore, a more refined study should be performed. There are many advantages of using pcARC/INFO for a more refined study of the freeway corridor. This includes the highly accurate digitizing and inventorying capabilities of the system. Tables and graphics can be easily produced showing the spatial features interactively. Overlay and Network analyses can be performed providing mapping and analysis capabilities not possible in a grid cell format.

The IDRISI program produced a series of interesting maps of the freeway corridor as well. While the grid analysis was not performed with all of the resource themes used in pcARC/INFO due to time constraints, a series of overlay maps in which values from two features were combined, were created. In addition, a cost surface and a minimum path map of the freeway corridor were also created. Although only the "Corridor" and "Slope" maps were used in this analysis, the procedure demonstrated that cost surface analysis and other "neighborhood" analysis can be quite useful in a subsequent freeway corridor study. In this case, additional themes should be assigned values to represent their relative importance within the freeway corridor. For example, values representing a slope map would increase with steeper terrain and therefore, would be more expensive build a freeway through. Wetlands, the 100-year flood plain and other features should be assigned a value which represents their relative cost. These are just some advantages of using grid cell analysis of a freeway corridor.

In summary, the pcARC/INFO package should be used for the most of an impact study, including the data capture, feature area inventory and much of the overlay analysis. In addition, the database using the more powerful **INFO** module, should be joined to the theme coverages in the vector-based system. The pcARC/INFO program can also be used for Network analysis or address matching of a population database using the TIGER file (street file with address ranges set up by the U.S. Census), if a sophisticated analysis was required. Additional map themes at a larger scale should be included in this subsequent study. The **GRIDCONVERSION** module can easily rasterize vector data, but care should be taken to ensure that the grid cells are not smaller than the minimum mapping unit of the original data. If some existing data is available in grid format, pcARC/INFO can vectorize it. This is very useful if the researcher wishes to utilize the sophisticated data manipulation capabilities available in pcARC/INFO.

The IDRISI analysis package should be used for a freeway corridor study as well, with rasterized data imported from pcARC/INFO. The major advantage of this program, or any raster analysis package, is that variables can be weighted for relative significance. Some overlay analysis can be performed more effectively in IDRISI if the operator wishes to assign map features a weight representing it relative importance. Another advantage of using IDRISI, is that many analysis capabilities similar to cost surface analysis can be performed including viewshed and watershed, which analyze elevation contour data. Cost surface analysis should be used in conjunction with overlay and other analyses to assess a variety of models. This might include one analysis showing minimum freeway construction costs while another would show minimum environmental impact costs. Finally, IDRISI should be used to compare analyses with those performed in pcARC/INFO. The different analyses will provide more useful information for decision makers. With the GIS capabilities inherent to these two software packages, a sophisticated analysis on the Westside Bypass freeway corridor using higher resolution data should be performed. The advantages of a more sophisticated and thorough analysis on such a controversial project warrants a continue of this study.

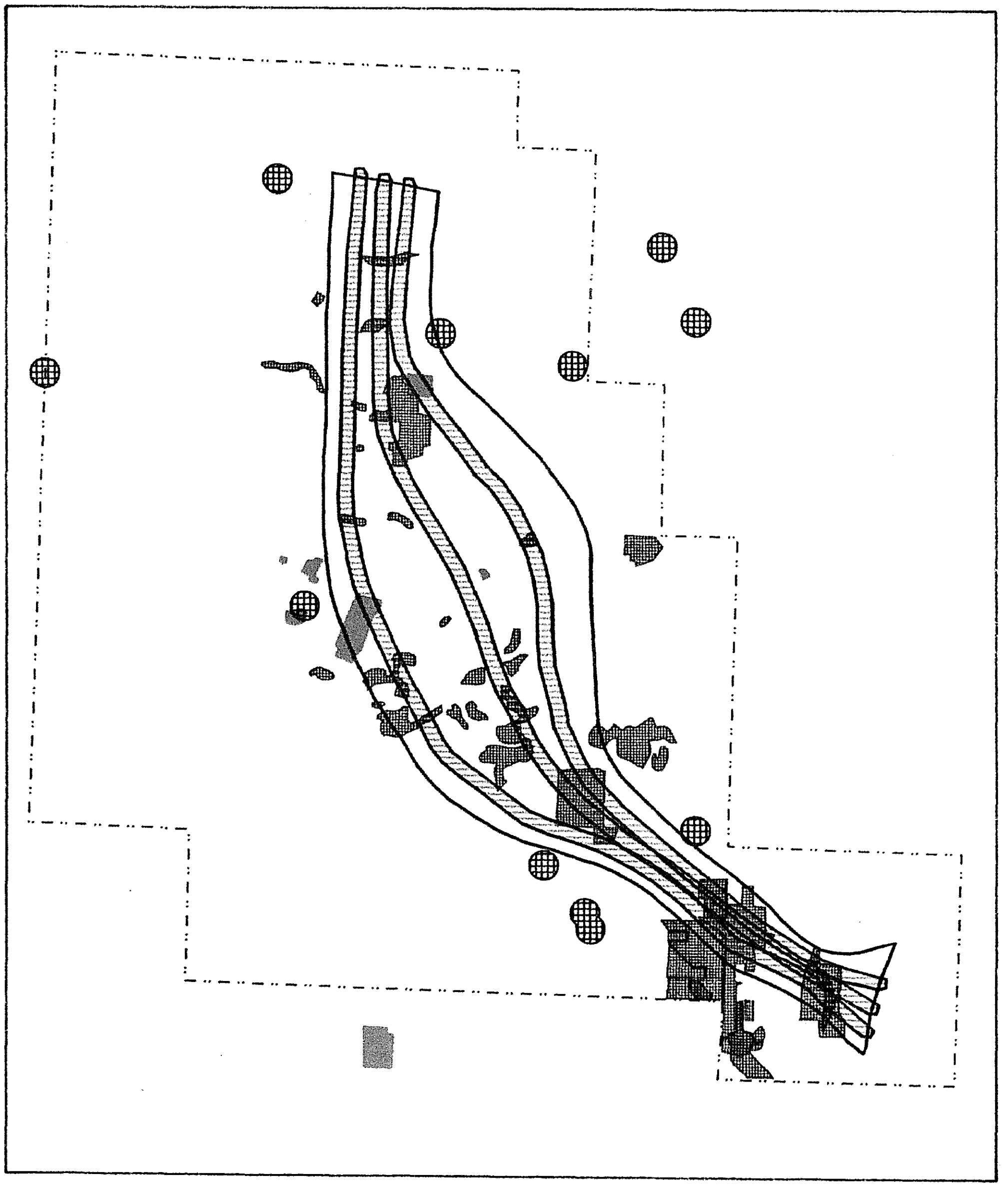
WESTSIDE BYPASS THEME COVERAGE INVENTORY

Coverage Description			Area of Polygons in Acres or Lengths of Lines in Miles				
Coverage Name	Attributes	# of Polys/ Lines/Points	Perimeter	Corridor	Alignment 1	Alignment 2	Alignment 3
Perimeter	None	1 Polygon	65.672				
Corridor	None	1 Polygon	15.509	15.509			
Alignment 1	None	1 Line			14.4		
1000 ft. Buffer	None	1 Polygon	1,744	1,744	1,744		
Alignment 2	None	1 Line				13.4	
1000 ft. Buffer	None	1 Polygon	1,628	1,628		1,628	
Alignment 3	None	1 Line					13.1
1000 ft. Buffer	None	1 Polygon	1,580	1,580			1,580
Culture / Historic	None	7 Polygons	367	178	29	0	35
Mineral / Aggreg.	None	8 Polygons	1,231	929	91	237	134
Slope Gradient	Non-Steep	1 Polygon	56,535	12,004	1,646	1,461	1,173
	Low	1 Polygons	300	300	0	0	43
	Moderate	4 Polygons	2,514	742	98	34	29
	Steep	2 Polygons	6,323	2,463	0	133	335
	Total	8 Polygons	65,672	15,509	1,744	1,626	1,580
Urban Growth Boundary	Metro	1 Polygon	19,699	1,412	123	137	182
	Wilsonville	1 Polygon	380	380	0	0	0
	Non-Urban	1 Polygon	45,593	14,079	1,621	1,491	1,390
	Total	3 Polygons	65,672	15,509	1,744	1,628	1,580
100 Year Flood Plain	None	1 Polygon	9,931	3,360	369	501	298
Schools	None	11 Points	11	2	0	0	0
Wetlands Habitat Seasonal	Duck	12 Polygons	216	102	2	0	14
	Geese	4 Polygons	130	93	19	30	1
	Beaver	0 Polygons	0	0	0	0	0
	Sub-Total	16 Polygons	346	195	21	30	15
All - Year	Duck	3 Polygons	474	98	10	0	0
	Geese	1 Polygon	46	46	0	14	13
	Beaver	5 Polygons	387	383	39	57	0
	Sub-Total	9 Polygons	907	527	49	71	13
	TOTAL	25 Polygons	1,253	722	70	101	28

Coverage Description			Area of Polygons in Acres or Lengths of Lines in Miles				
Coverage Name	Attributes	# of Polys/ Lines/Points	Perimeter	Corridor	Alignment 1	Alignment 2	Alignment 3
Resources	None	4 Polygons	863	393	101	114	90
Transportation	Freeway	5 Lines	3.9	1.5	0.2	0.2	0.2
	Highway	8 Lines	10.7	2.5	0.4	0.4	0.4
	Arterial	46 Lines	48.1	10.5	1.6	1.2	1.1
	Other	47 Lines	49.7	18.6	1.3	1.5	2.2
	Total	106 Lines	112.4	33.1	3.5	3.5	3.9
Land Use High Impact	EFC	3 Polygons	796	598	60	94	92
	EFU	7 Polygons	27,382	8,383	1,155	776	642
	AF-20	9 Polygons	4,201	2,531	83	251	294
	Sub-Total	19 Polygons	32,379	11,512	1,298	1,121	1,028
Moderate Impact	AF-10	16 Polygons	2,265	856	53	151	117
	AF-5	35 Polygons	3,709	1,122	152	195	140
	Sub-Total	51 Polygons	5,974	1,978	205	346	257
Low Impact	RR-5	8 Polygons	1,082	600	107	0	100
	R-IND	3 Polygons	398	56	13	10	3
	Urban	1 Polygon	25,839	1,363	114	122	162
	Sub-Total	12 Polygons	27,152	2,019	234	132	265
	Total	82 Polygons	65,672	15,509	1,737	1,599	1,550
Hydrography Stream Order	Order 5	15 Lines	33.1	9.1	0.9	1.4	0.2
	Order 4	28 Lines	32.2	13.8	1.6	1.6	1.2
	Order 3	36 Lines	28.6	7.9	0.7	0.7	1.3
	Total	79 Lines	93.9	30.8	2.2	3.7	2.7

WESTSIDE BYPASS STUDY

SIGNIFICANT MAP THEMES



LEGEND

SIGNIFICANT RESOURCES

MINERAL AND AGGREGATE RESOURCES

WETLANDS

HISTORIC AND CULTURAL SITES

SCHOOLS

SCALE

1:100,000

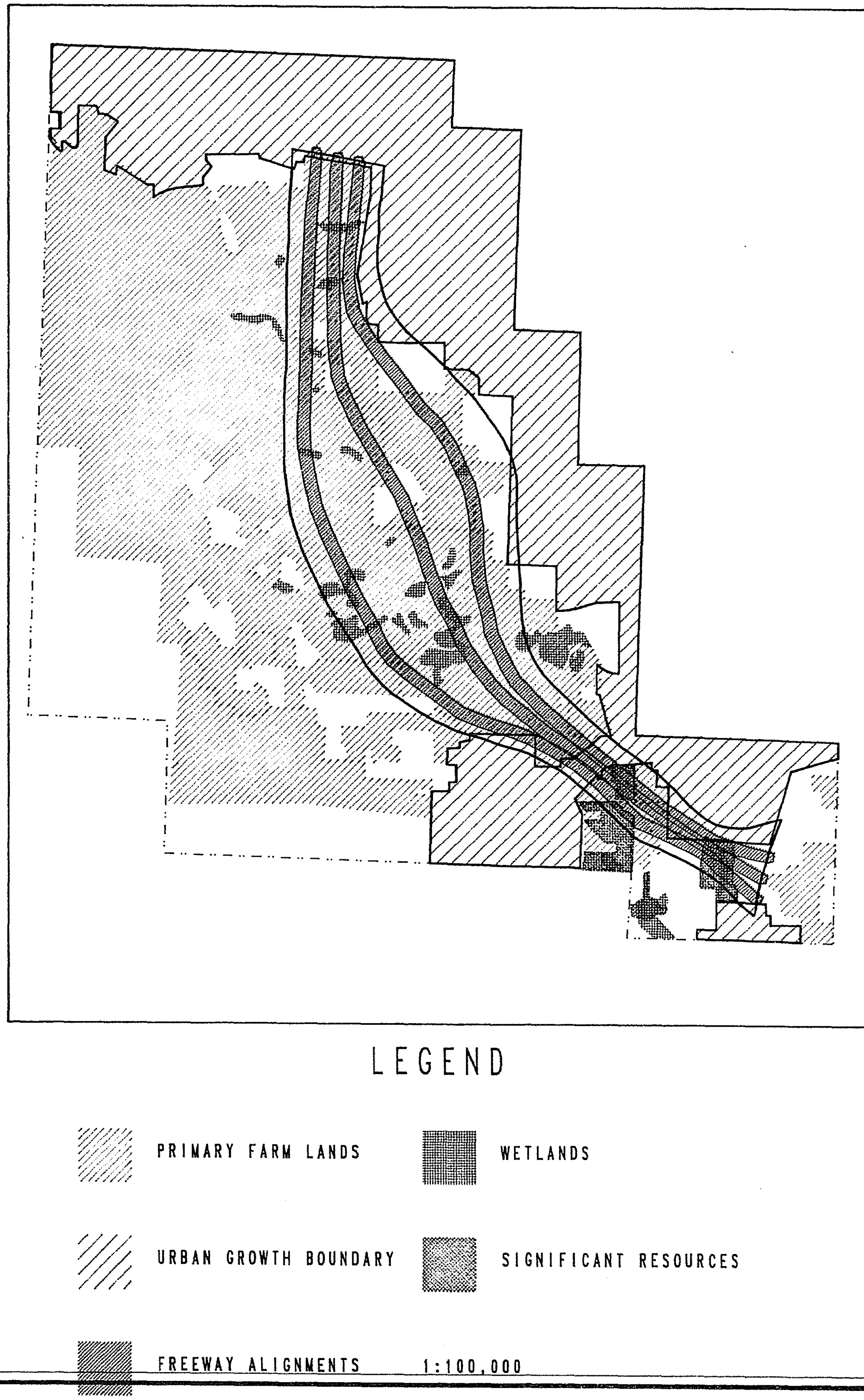
SOURCE: WASHINGTON COUNTY, 1989

M. NEWMAN

MAP 4

WESTSIDE BYPASS STUDY

HIGH RESOURCE IMPACT



MAP 5

WESTSIDE BYPASS STUDY

HIGH CONSTRUCTION COST

LEGEND

- STEEP SLOPE GRADIENT
- 100 YEAR FLOOD PLAIN
- MODERATE SLOPE GRADIENT
- FREEWAY ALIGNMENTS
- LOW SLOPE GRADIENT

SCALE

1:100,000

SOURCE: WASHINGTON COUNTY, 1989

M. NEWMAN

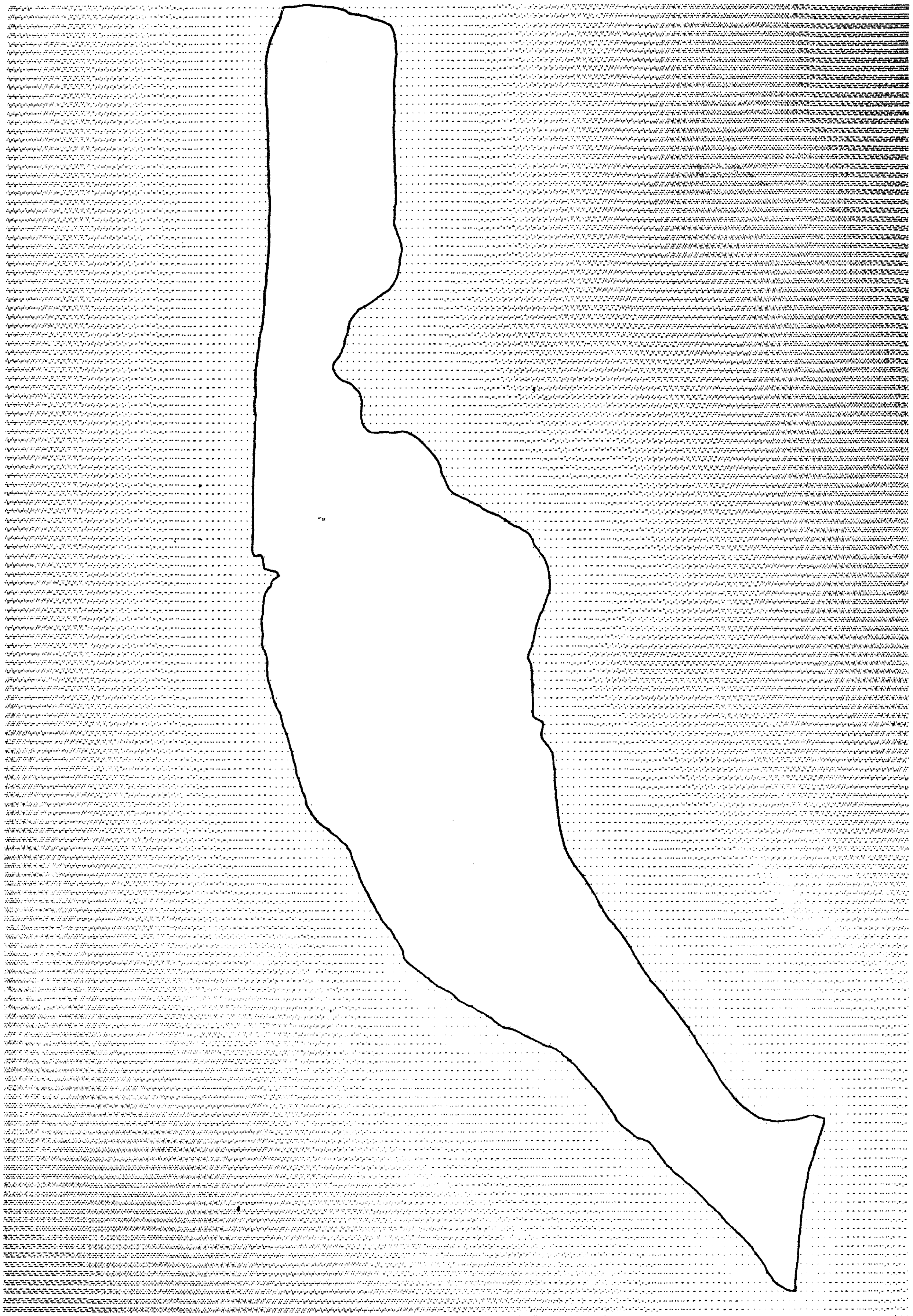
MAP 6

CORRIDOR + SLOPE

IDRISI OVERLAY

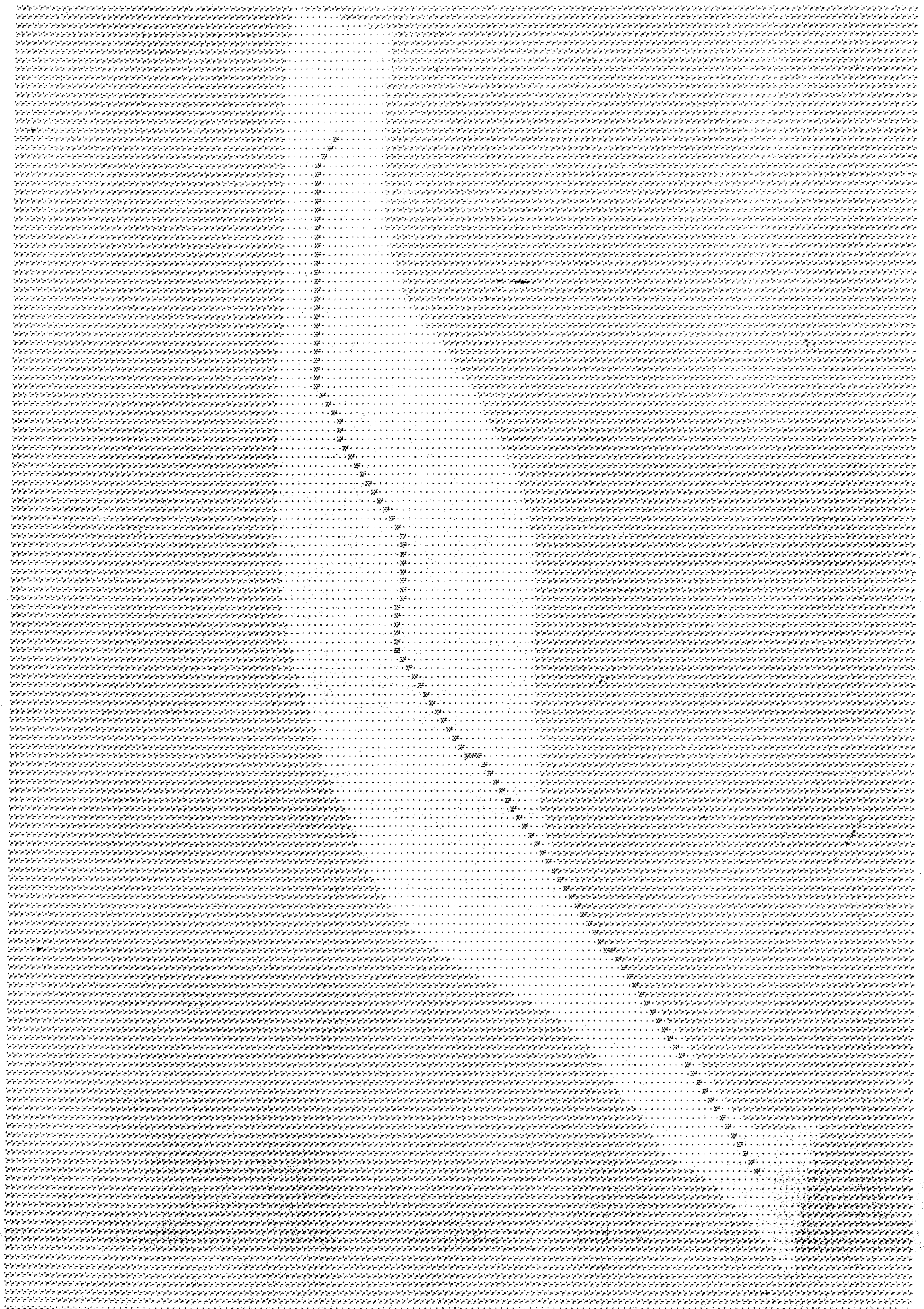
MAP 7

COST SURFACE



MAP 8

MINIMUM COST PATHWAY



MAP 9

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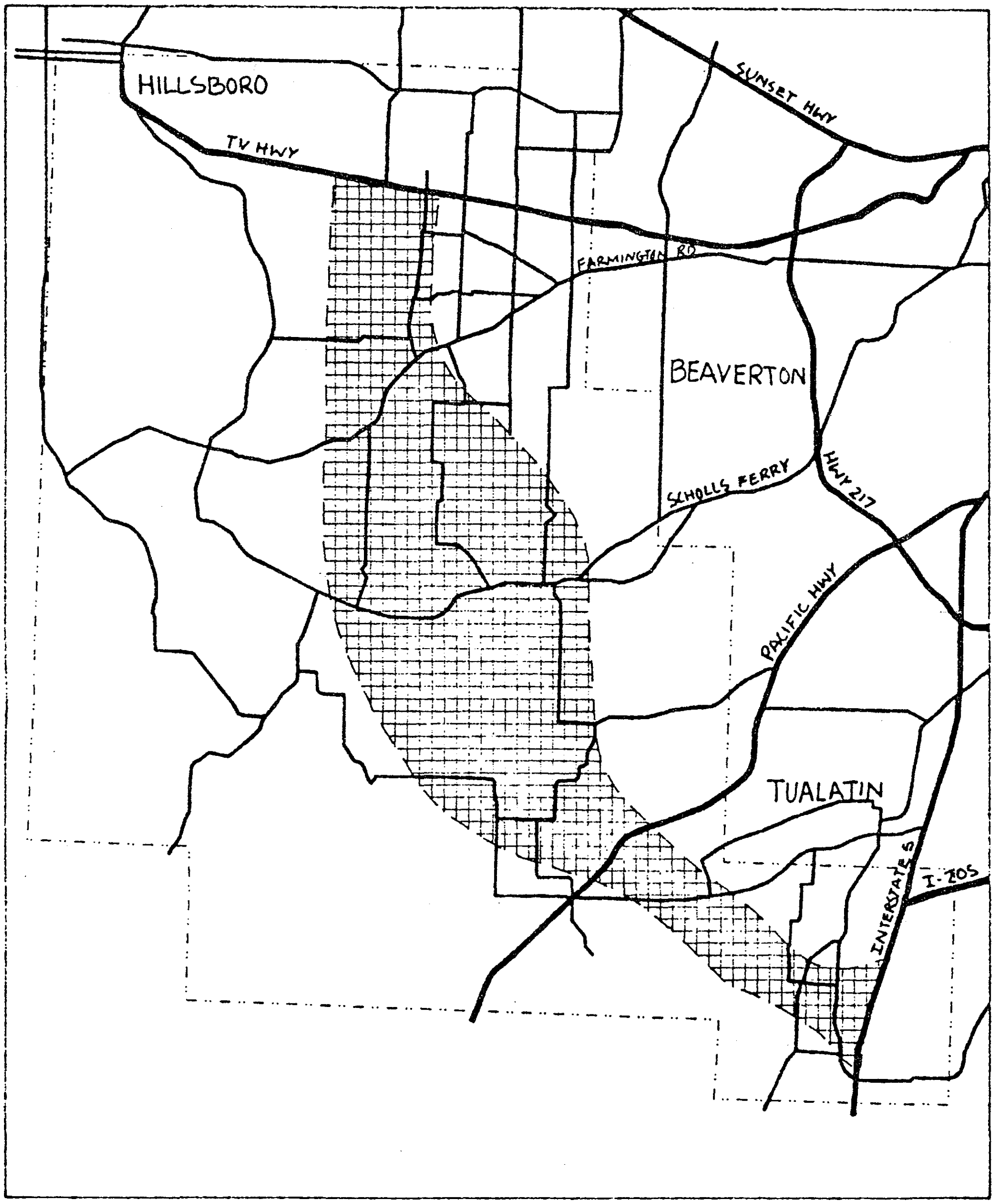
WESTSIDE BYPASS STUDY
TRANSPORTATION



LEGEND

HIGHWAYS

FREEWAY CORRIDOR

ARTERIALS AND OTHER ROADS

SCALE

1:100,000

SOURCE: WASHINGTON COUNTY, 1989

M. NEWMAN

MAP 1

pcARC/INFO and IDRISI OUTPUT

Figure 1

FUNDAMENTAL GIS OPERATIONS

There are four fundamental GIS analysis operations that can be performed in either vector or raster data formats. These are: Reclassify, Overlay, Distance, and Neighborhood. Each of these categories contains at least one command in pcARC/INFO and IDRISI, with the exception of neighborhood. This analysis operation can only be performed in a grid cell format.

OVERLAY: pcARC/INFO

INTERSECTION: FREEWAY CORRIDOR AND LANDUSE USE

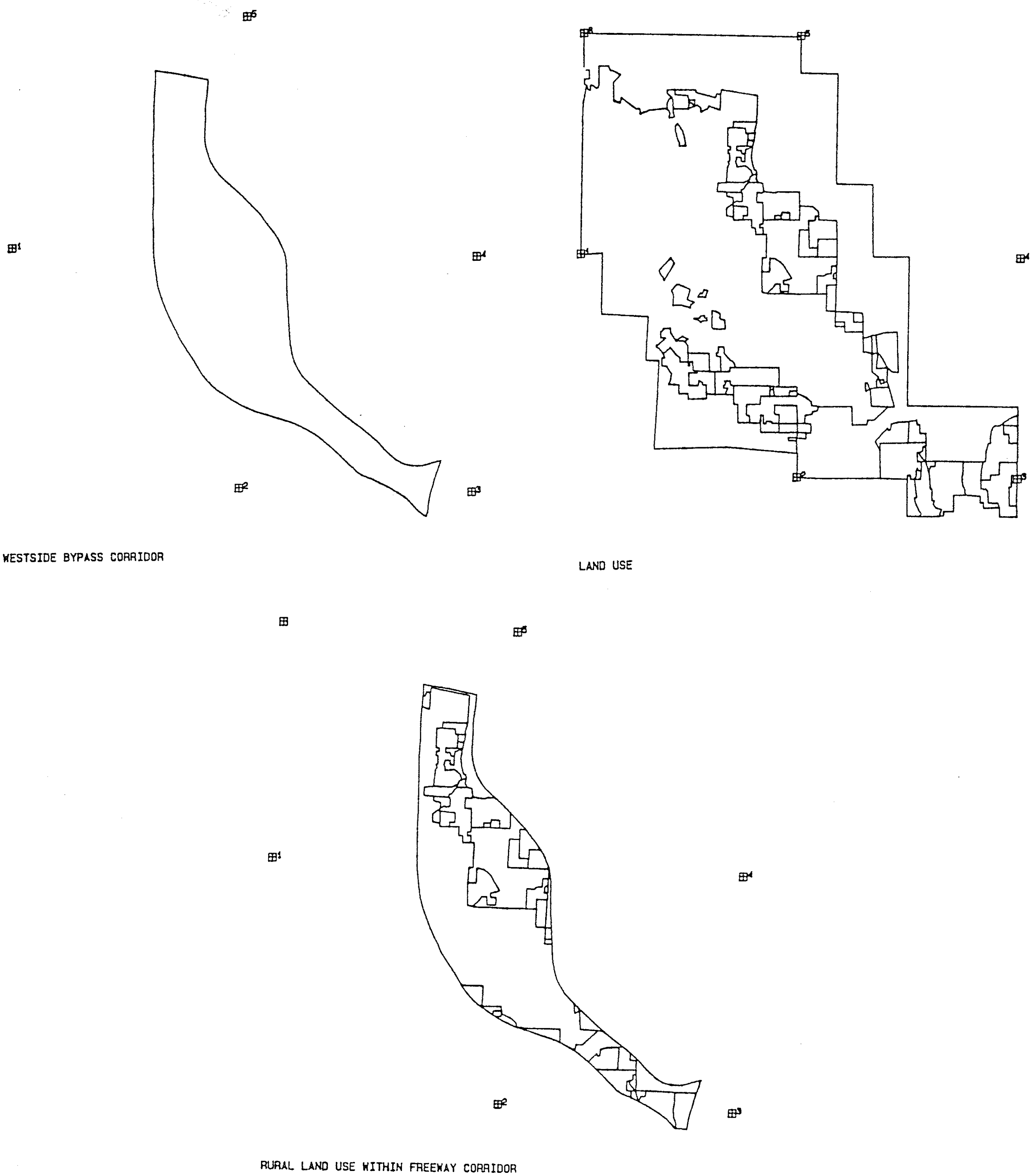


Figure 2

OVERLAY: pcARC/INFO

UNION: WETLANDS AND 100 YEAR FLOOD PLAIN

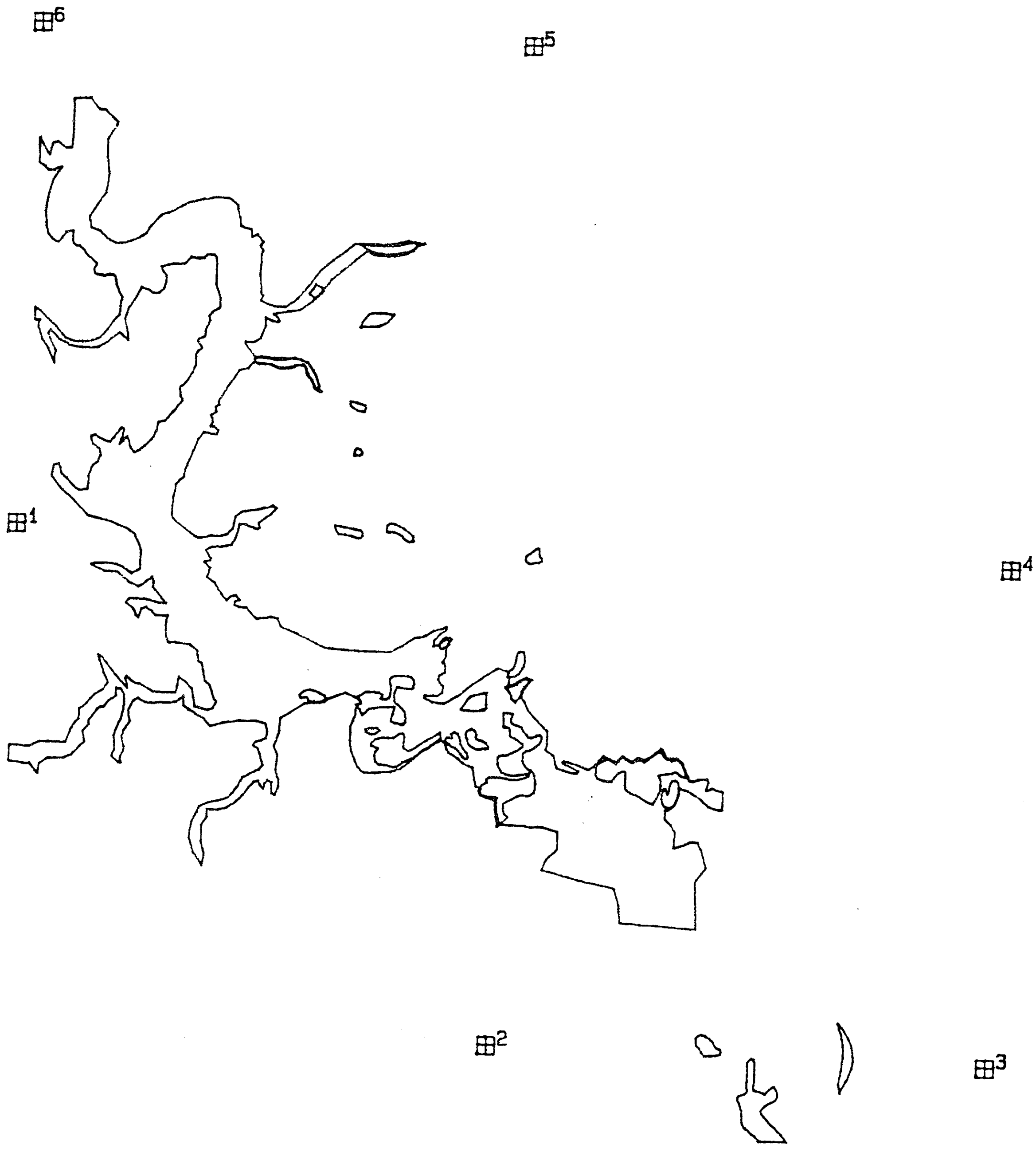


Figure 3

DISTANCE: pcARC/INFO

TRANSPORTATION: MAINTAINED TOPOLOGY

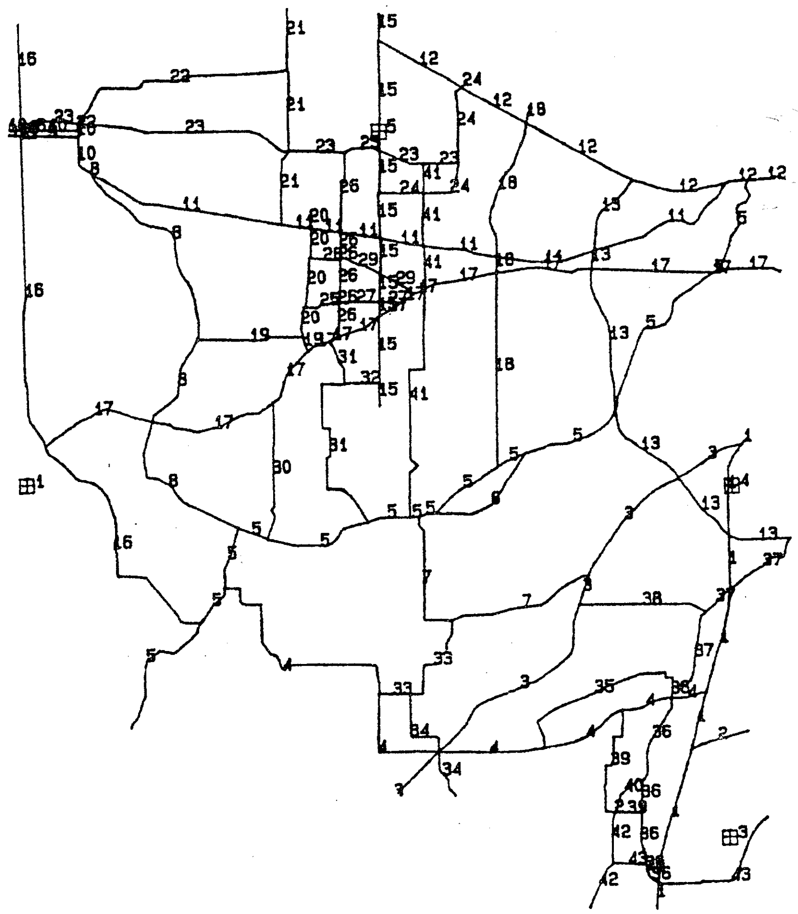


Figure 4

The **BUFFER** command will create polygons around a point, line or polygon at a selected distance, and generate topology for the new polygons. With the use of Look-up Tables, pcARC/INFO will buffer a feature to attribute specifications. For example, the Tualatin drainage basin was reclassified into Stream-Order classes 5-3, allowing a three-distance buffer, (400 ft., 200 ft., and 100 ft.) to be generated. See Map 3 and Figure 6. Finally, the Network capability of pcARC/INFO allows the researcher to model optimal highway routine and stream flow. Since the program maintains line topology in the form of connectivity and direction, Network analysis can be performed. This type of analysis was well beyond the scope of this study.

BUFFERING: 3 STREAM-ORDER CLASSIFICATIONS

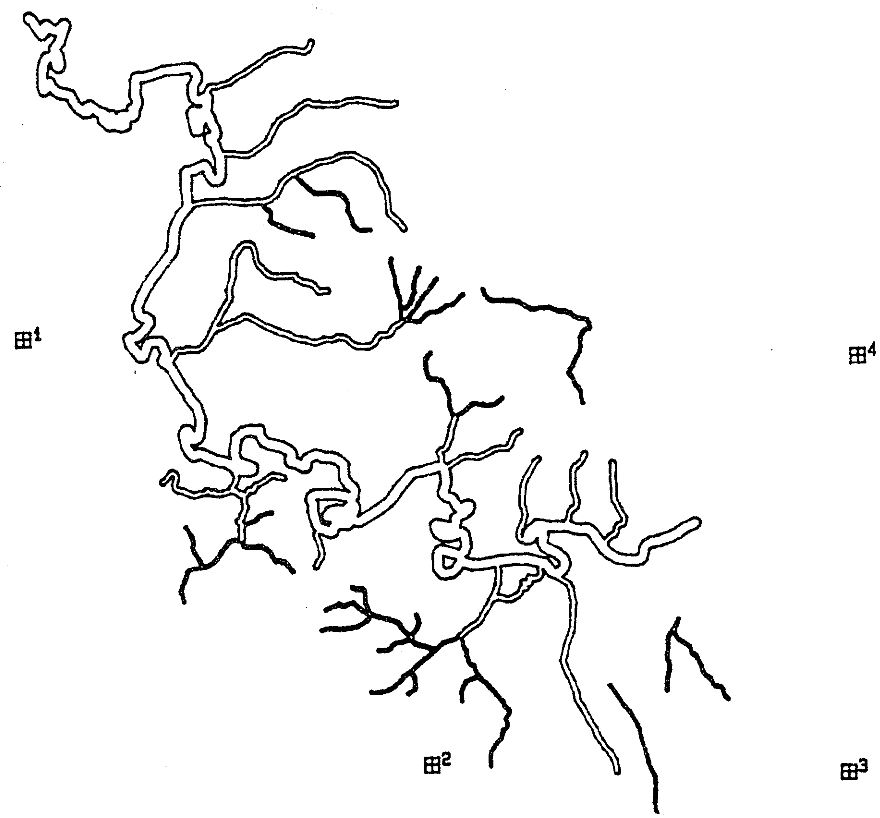


Figure 5

NEIGHBORHOOD

The final fundamental GIS operation is Neighborhood. This operation can only be performed in a grid cell format due to its weighting capability. There are several neighborhood commands available in IDRISI. The basis of this operation is performed in 9-cell blocks where the center cell is assigned the average value of the surrounding 8 values. In this manner a map feature can be smoothed or filtered. This is a valuable function when the operator is interested in deriving an average slope of a map feature, either to determine real-world geography such as terrain, or to

NEIGHBORHOOD: IDRISI

COST SURFACE MAP OF FREEWAY CORRIDOR

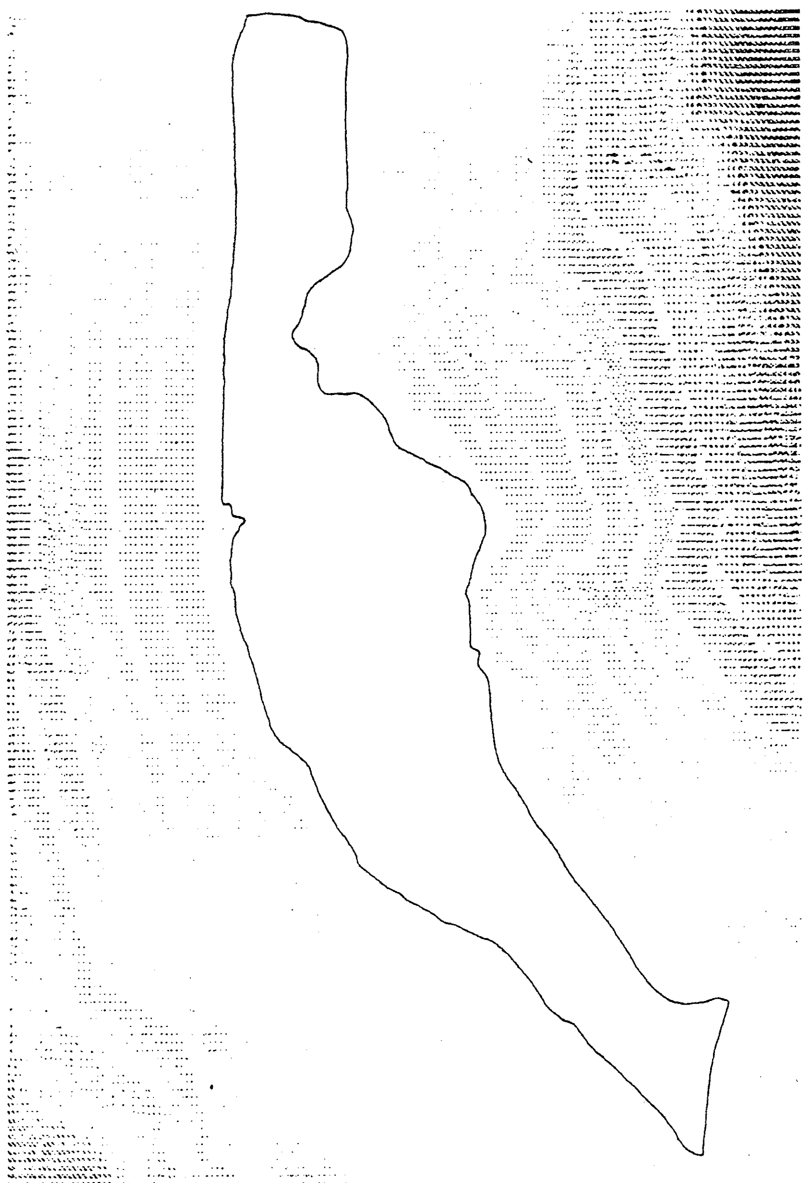


FIGURE 6