



US Army Corps  
of Engineers

AD-A214 676



MISCELLANEOUS PAPER GE 3024

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# A GEOGRAPHIC INFORMATION SYSTEM (GIS) FOR THE SOUTHERN LOUISIANA DELTAIC ENVIRONMENTS

by

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October 1989  
Final Report

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Prepared for US Army Engineer District, New Orleans  
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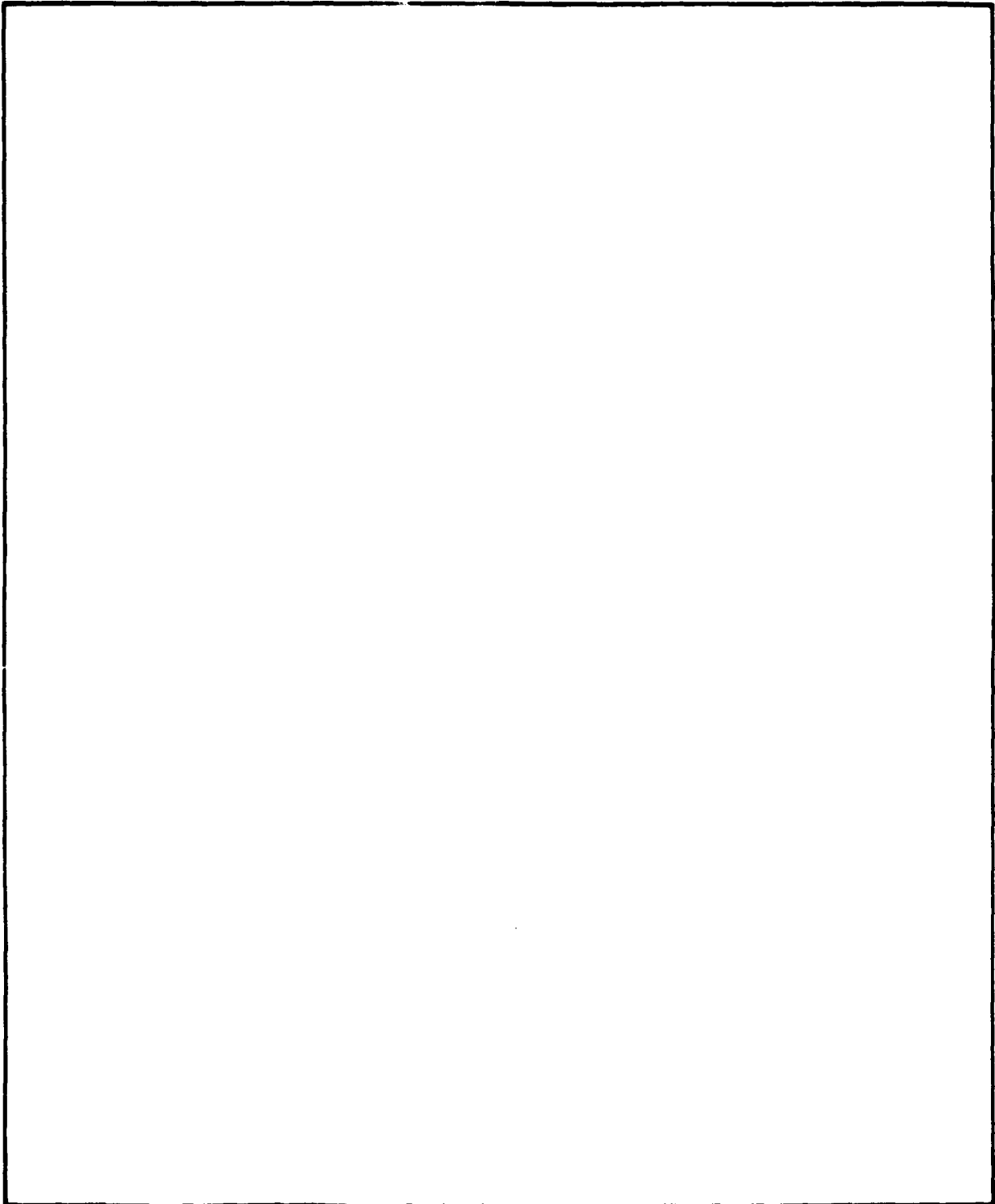
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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited			
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE		5. MONITORING ORGANIZATION REPORT NUMBER(S)			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Miscellaneous Paper GL-89-25		7a. NAME OF MONITORING ORGANIZATION			
6a. NAME OF PERFORMING ORGANIZATION USAEWES Geotechnical Laboratory	6b. OFFICE SYMBOL (if applicable) CEWES-GG-YG	7b. ADDRESS (City, State, and ZIP Code)			
6c. ADDRESS (City, State, and ZIP Code) 3909 Halls Ferry Road Vicksburg, MS 39180-6199		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION US Army Engineer District, New Orleans	8b. OFFICE SYMBOL (if applicable) CELMN-ED-FG	10. SOURCE OF FUNDING NUMBERS			
8c. ADDRESS (City, State, and ZIP Code) PO Box 60267 New Orleans, LA 70160-0267		PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
11. TITLE (Include Security Classification) A Geographic Information System (GIS) for the Southern Louisiana Deltaic Environments					
12. PERSONAL AUTHOR(S) Williamson, A. N. and Britsch, L. D.					
13a. TYPE OF REPORT Final report	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) October 1989	15. PAGE COUNT 27		
16. SUPPLEMENTARY NOTATION Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.					
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary, and identify by block number)			
FIELD	GROUP	SUB-GROUP	Geographic Information System Information management		
			Land-loss Microcomputer application		
			Louisiana deltaic plain		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Concern for the coastal zone throughout the United States has prompted implementation of geographic information systems (GIS) that can store the vast amounts of information on the infrastructure of these delicate environments, access and use the stored data to analyze changes that are occurring, and portray the results of analyses in the form of tables and/or maps and map overlays. A specific GIS of interest to the US Army Engineer Waterways Experiment Station has been one that can be used to analyze land-loss conditions within the deltaic environments of Southern Louisiana. This GIS will allow Zenith, Model 248, or equivalent, microcomputers to be used to portray depletion in terms of the time period over which it has been occurring, where it has occurred, and the rate at which it is, or has been, occurring. This paper discusses some of the basic decisions that were made prior to implementing the GIS, the structure of the GIS, and some capabilities provided by the GIS using the stored data.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL	

SECURITY CLASSIFICATION OF THIS PAGE



SECURITY CLASSIFICATION OF THIS PAGE

PREFACE

This paper was prepared for presentation at the 1989 Annual Convention of the American Society for Photogrammetry and Remote Sensing (ASPRS) and the American Congress on Surveying and Mapping (ACSM) during 2-7 April 1989 and presented by Mr. A. N. Williamson at the session, entitled "Geographic Information Systems-III Applications," held on 5 April 1989.

Data preparation and development of the GIS were accomplished by personnel of the Geologic Environments Analysis Section (GEAS), Engineering Geology Branch (EGB), Earthquake Engineering and Geosciences Division (EEGD), Geotechnical Laboratory (GL), Waterways Experiment Station (WES), under the general supervision of Drs. William F. Marcuson, III, Chief, GL, Arley G. Franklin, Chief, EEGD, and Lawson M. Smith, Chief, EGB, and direct supervision of Mr. Robert J. Larson, Chief GEAS. Data preparation and GIS development are being accomplished by Messrs. L. D. Britsch and A. N. Williamson, respectively.

COL Larry B. Fulton, EN, was Commander and Director of WES during the preparation of this report. Dr. Robert W. Whalin was Technical Director.

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A GEOGRAPHIC INFORMATION SYSTEM (GIS) FOR THE SOUTHERN  
LOUISIANA DELTAIC ENVIRONMENTS

PART I: INTRODUCTION

Background

1. One of the primary areas of concern to the US Army Corps of Engineers is that portion of the coastline of the State of Louisiana that has been formed as a result of the changing course of the Mississippi River. Beginning with the Maringouin delta complex which began forming approximately 7,000 years ago, Mississippi River sedimentation has extended the Louisiana shoreline southward through the formation of delta lobes (Frazier 1967). Over a period ranging from 500 to 2,000 years, each delta lobe that formed was abandoned as the River shifted its course in search of a more direct route to the sea. The result has been the formation of the five major delta complexes, shown in Figure 1, that combine to form the deltaic plain of coastal Louisiana.

2. Repeated shifts in the centers of deposition resulted in the distribution of deltaic sediments along the Louisiana coastline. Soon after each delta lobe was abandoned, marine encroachment began as a result of compaction of deltaic sediments and other processes involved in regional subsidence. The net result of advancing and retreating deltas has been an overall increase in the size of the deltaic plain.

3. Within the past 50 years, however, abnormal changes have been observed in the long-term trend of deltaic growth. In lieu of a continuing net increase in size, the land area has been diminishing as natural events (sea level rise) and man's activities (e.g., levee construction) have subjected the area to erosion and a reduction in the sediment supply. Concern over this reversal has resulted in detailed investigations of the geology of the area in order to better understand the relationships existing between the areas of land loss and local conditions.

4. Geologic investigations have shown that the deltaic plain is generally underlaid by a stable subsurface Pleistocene horizon that is overlaid by a less stable layer of Holocene sedimentary material. The top of the

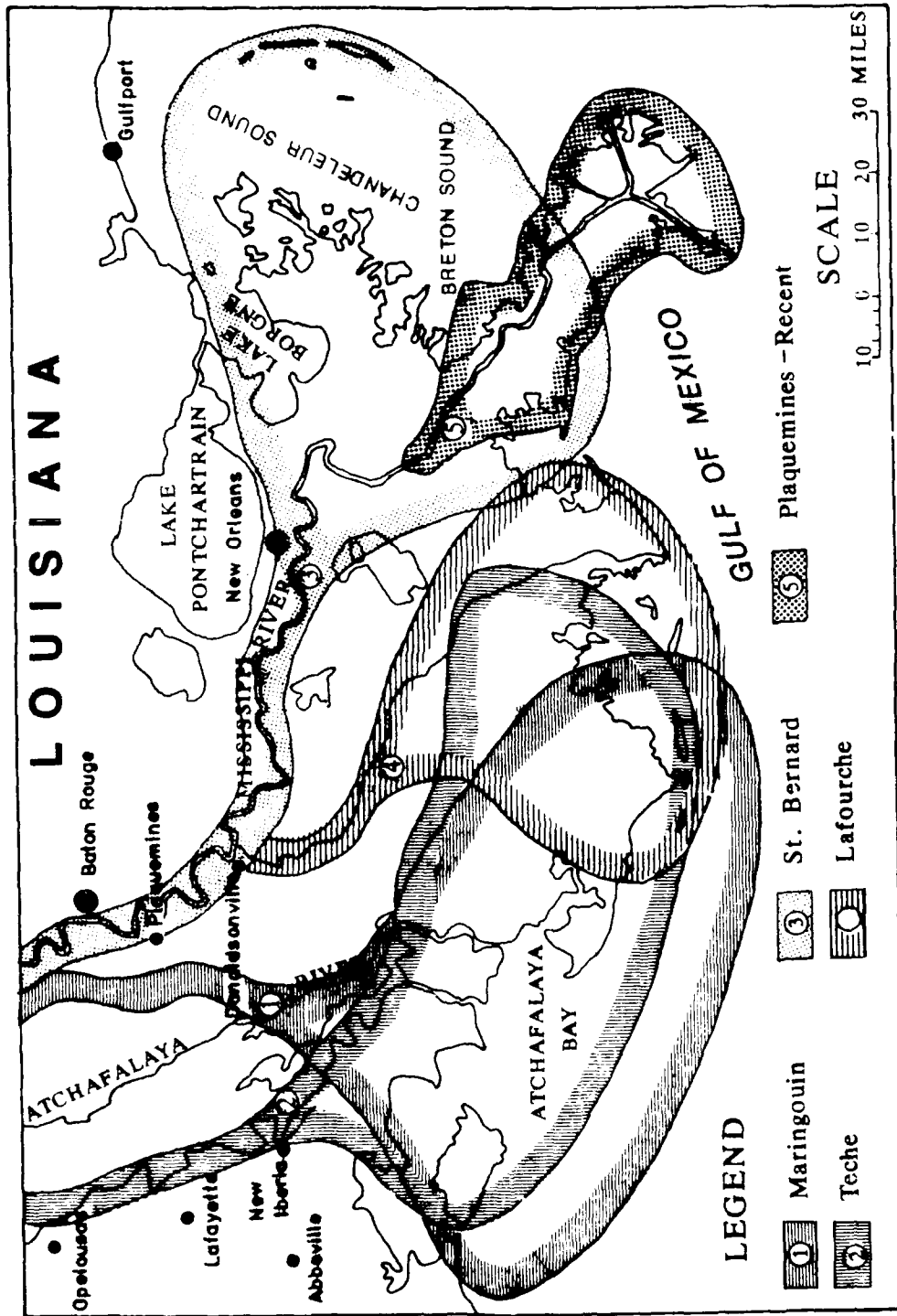


Figure 1. Delta complexes comprising the Louisiana Deltaic Plain. (Adapted from Kolb, C. R., and Van Lopik, J. K., "Depositional Environments of the Mississippi River Deltaic Plain, Southeastern Louisiana," 1966, In M. L. Shirley and J. A. Ragsdale, eds., Deltas, pp 16-62, Houston, TX)

Pleistocene layer is found at depths ranging from 0 to -500 ft and is generally characterized by a high bulk density, low water content, and resistance to erosion. This layer provides the most stable horizon in the study area for foundation support. In addition, the depth to the Pleistocene layer appears to have a significant effect on the extent of compaction of overlying deltaic deposits.

5. For engineering applications, areas comprised primarily of sedimentary materials are described in terms of environments of deposition, or geologic environments. A geologic environment may be characterized by its water content, compressive strength, and material grain size; all of which affect its erodibility and, in turn, its susceptibility to land loss.

6. A conscientious effort to better understand the interrelationships between the depth to the Pleistocene, the environments of deposition and the effects of natural and man-made activities on land-loss necessitated their characterization. Thus, a large-scale data collection effort was undertaken.

7. The depth to the shallowest Pleistocene horizon was more clearly defined by collecting and interpreting all available boring information. Sources of this information were State and Federal agencies, private engineering companies, and oil and gas companies; all of whom had substantial boring information. The Pleistocene surface was defined by interpreting the boring data and plotting the depth to Pleistocene for each boring on 15-min quadrangle maps. Contours were then defined from the elevation points to show the depth to the Pleistocene layer. An example of a top-of-Pleistocene map is shown in Figure 2.

8. Maps indicating surface engineering geology were produced by interpretation of 1955-1958 black-and-white aerial mosaics and 1974 false-color infrared (FCIF) photography. The geologic environments that were identified included natural levees, inland swamps, abandoned distributaries, abandoned courses, crevasse channels, point bars, backswamps, lacustrine, lacustrine deltaic, mangrove swamps, barrier beaches, abandoned tidal channels, salt domes, Pleistocene Prairie terraces, abandoned channels, and crevasse splays. Once identified on the photographs, the engineering geologic environments were transferred to USGS 15-min quadrangle maps. The individual environments were represented as polygons with identifying attribute codes, as shown in Figure 3.



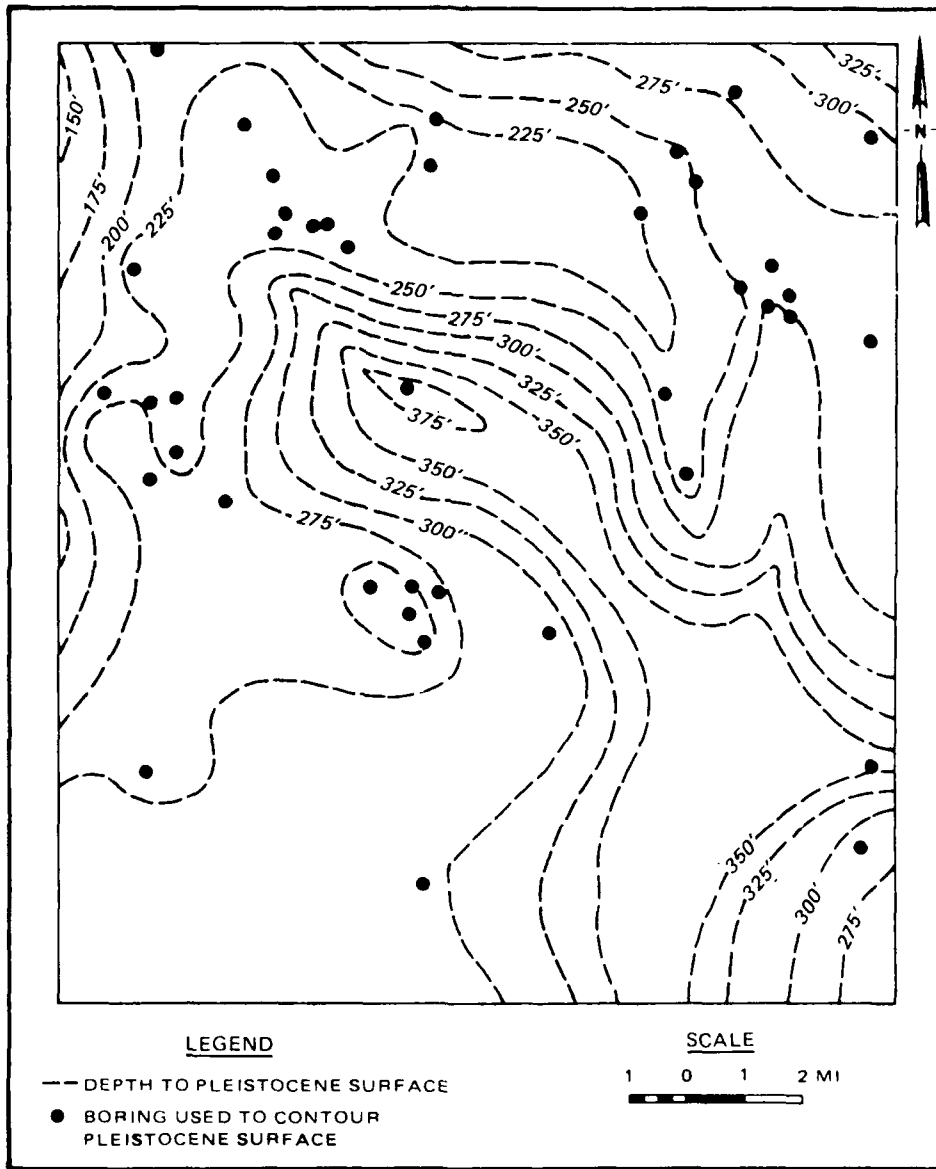


Figure 2. Example of depth to Pleistocene map

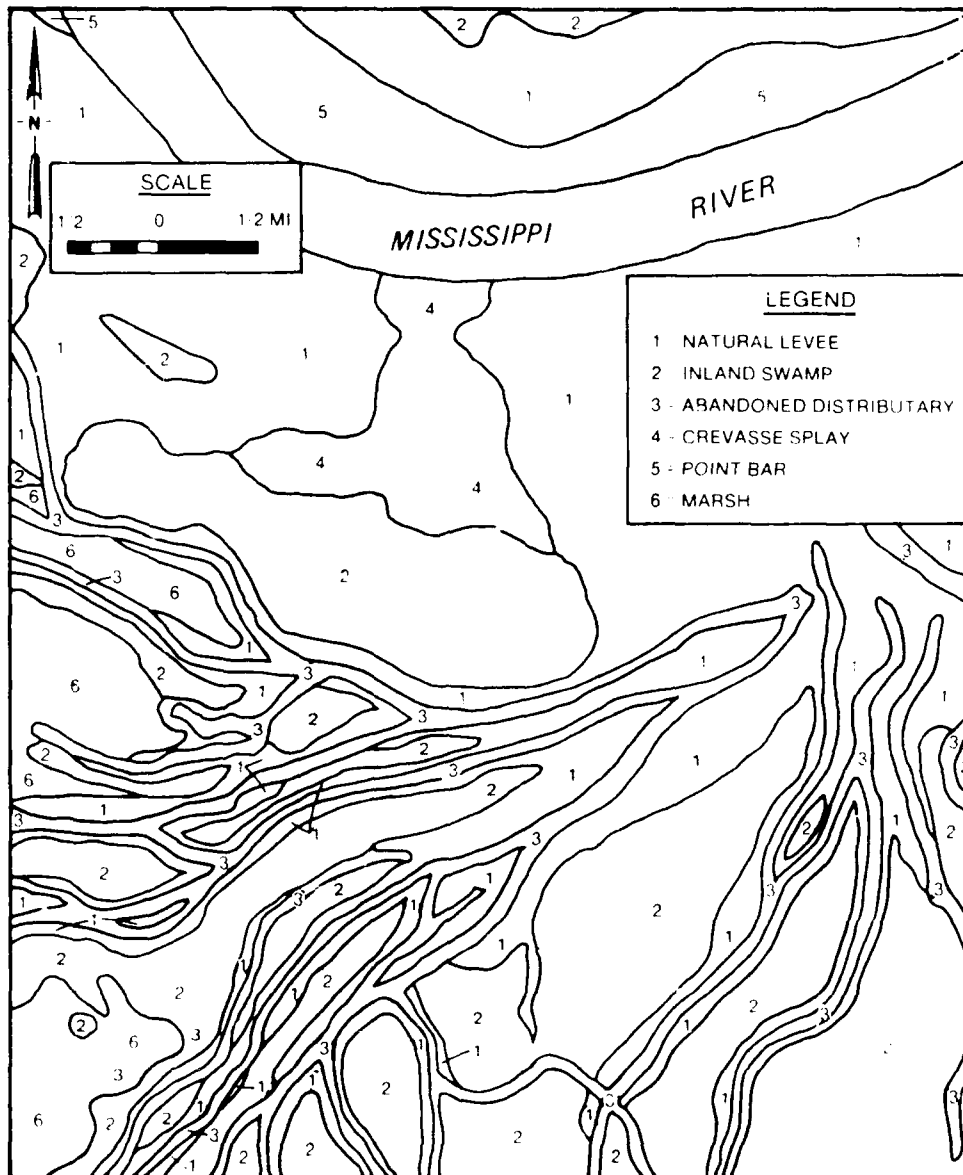


Figure 3. Example of engineering geology map

9. For the purpose of this study, land loss was defined as any land area that can be seen in early-vintage photographs that, over a period of time, has been submerged by water. The areas interpreted as water are those areas that are either surrounded by, or surround marsh or swamp areas, and have no permanent marsh vegetation visible at the surface. (Permanent vegetation is defined as vegetation attached to the substrate, as opposed to vegetation, such as hydrilla or water hyacinth, that is not attached to any substrate.) Maps showing land-loss were developed by comparing photographic coverage of the study area for 1955-1958, 1974, and 1983 with 1932 US Coast and Geodetic Survey Air Photo Compilation Maps. For mapping purposes, natural and direct man-made land-loss were differentiated and mapped separately. The result is a map for natural land-loss and a map for man-made land-loss for each of three time intervals (1932-1933 to 1955-1958, 1955-1958 to 1974, and 1974 to 1983) for each map in a set of eighty-five 15-min quadrangle maps covering the area of interest. A typical land-loss map is shown in Figure 4.

10. To date, 26 depth-to-Pleistocene, 26 engineering-geology, and 120 land-loss maps have been completed. However, completion of this project will require development of a total of 85 engineering geologic maps, 85 Pleistocene maps, and as many as 510 land-loss maps (eighty-five 15-min quadrangle maps for the area where land-loss is occurring for three time periods for man-made and for natural land-loss). The enormous volume of data to be assembled in connection with this study has dictated that a system be developed to facilitate assimilation, management, and constructive use of the data for the purpose of studying the causes and evaluating the impact of land-loss.

#### Purpose

11. The purpose of the work discussed herein has been to develop and implement a geographic information system (GIS) for archiving the vast amount of information being accumulated and providing a way to retrieve and manipulate the data for solution of planning and engineering problems, and portraying the results in easy-to-use forms.

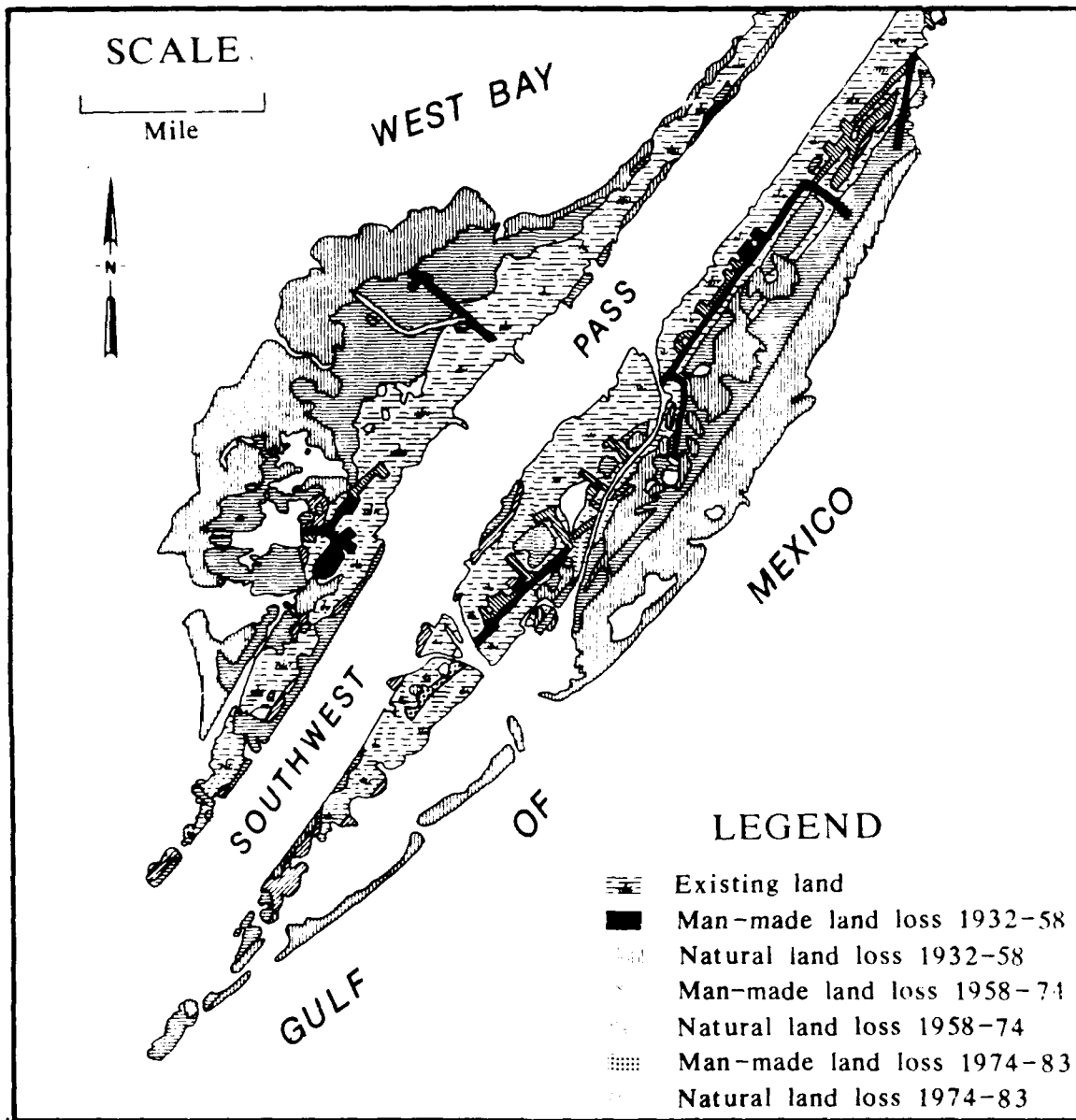


Figure 4. Example of typical land-loss map

## Scope

12. The paragraphs that follow contain a discussion of the rationale for development of the land-loss GIS and present an example of the capabilities provided by the GIS as it is currently configured.

## PART II: GEOGRAPHIC INFORMATION SYSTEM DEVELOPMENT

13. The basic functions of any GIS are to receive and store spatial information and to provide a systematic way to access the stored information for subsequent use. The land-loss GIS was intended to facilitate decision making using the stored information and accommodation for portrayal of information as color maps, map overlays, tables, or graphs. In addition, the data base and associated computer programs were to be designed to operate on a standard Zenith, Model ZWX-248, or equivalent, microcomputer available in many Corps of Engineers offices. Inclusion of these additional capabilities dictated that a GIS be designed especially for the land-loss study project. In the paragraphs that follow, items that were considered in developing the data base are presented.

### Factors Considered

#### Encoding capabilities

14. The map manuscripts containing information to be included in the data base can be encoded in-house by the process of scanning microdensitometry (drum scanning) or by use of a conventional digitizing table. The drum scanner can accommodate manuscripts up to 17- by 20-in. in size and, in less than 10 min, produce a replication of the map defined as an orthogonal array of grid cells (pixels). Each pixel would be represented in the data by a number between 0 and 255 depending upon the information on the manuscript. A line or a black area on the map would be represented by a high number while white areas are represented by low numbers. However, substantial interactive editing would be required to insert attribute codes into the data base for maps that had been scanned or to repair erroneous line discontinuities, line junctures, etc. when needed.

15. On the other hand, by manually digitizing on a tablet, much larger maps could be digitized, but the digitizing process would take substantially longer. The result would be a digital replication of the map containing an attribute code and a string of x,y values for points along each line on the map.

### Characteristics of input data

16. The tabulation below gives some of the salient features of the data to be initially included in the data base.

<u>Factor</u>	<u>Source</u>	<u>Vintage</u>
Land-loss	US Coast and Geodetic Survey	1932-1933
	Air-Photo Compilations	
	FCIR Imagery	1974 and 1983
	B & W Photo Mosaics	1955-1958
Pleistocene maps	Borings	
Engineering geologic	B & W Photo Mosaics	1955-1958
	FCIR imagery	1974 and 1983

In addition to the variations in information source and vintage indicated above, variations also existed in map projection. The engineering geology and Pleistocene contour maps had been transferred to 15-min quadrangle maps having a polyconic projection. However, land-loss maps were produced using aerial photography that had a projection that was a function of the aircraft attitude at the time the imagery was acquired, projection sometimes referred to as "aircraft oblique."

### Output requirements

17. The requirement for output products could be adequately filled by a variety of printers and plotters. Graphs and charts could be printed using standard dot-matrix printers without the need for additional software development. On the other hand, the requirement for color-coded maps and map overlays necessitated use of a plotter capable of printing on acetate or some other transparent material. Two candidate ink-jet printers were available that could adequately fill this requirement. One printer can produce output products up to 8.5- by 11.0-in. in size while the other printer can produce outputs up to 22- by 34-in. in size. The large-format printer operates only off-line and requires a formatted computer-compatible tape for input. The small format printer can operate on-line with IBM/AT-compatible microcomputers, such as the Zenith microcomputers.

### Analytical requirements

18. It was acknowledged at the inception of the project that identification of all the possible analytical requirements that might be imposed upon the GIS would be virtually impossible. However, the various types of analysis could be conveniently separated into at least four general groups, as follows:

- a. Locational - information developed and portrayed in terms of geographic or Universal Transverse Mercator (UTM) coordinates, or map name.
- b. Areal - determination of the area of coverage by land-loss period, Pleistocene or engineering geology category.
- c. Absolute merits - location of all areas within a selected geographic area that have a certain specified attribute.
- d. Relative merits - the relationship of the attribute of an area on one map (e.g. land-loss) to the attribute of the corresponding area on another map (e.g. engineering geology).

### Design Specifications

19. The design of the data base considered the GIS as a single unit comprised of closely related parts. Each part dealt with a critical function in the data management scheme and, therefore, had to be entirely compatible with the other functional parts. In the design, the first step, was to establish the basic data base parameters. This step was probably the single most critical step since the results would impact heavily on the manner in which the information contained on over 400 maps would be managed and the utilitarian value of the archived data. Once the data base parameters were set, limitations of time and available funds would not permit change. It was within this framework that the following data base specifications were established.

- a. Map projection - Universal Transverse Mercator (UTM).
- b. Scale - 1:62,500.
- c. Resolution - 12.5 m (on the ground).
- d. Format - grid array.

Obviously, much of the data to be included in the data base was not as accurate as specification c above might imply. However, these specifications are consistent with anticipated future requirements and could be incorporated at the onset of the project at much less cost than at some later time.



## Data Flow Plan

20. Having established the basic specifications for the land-loss GIS, the flow of data into and out of the GIS and data utilization could be accomplished in five steps--data encoding, pre-processing, storage/retrieval, analysis, and portrayal.

### Encoding

21. The data to be encoded were to include land-loss maps, depth-to-Pleistocene maps, and engineering geologic maps. On the land-loss maps, areas where land-loss had occurred are represented as solid black polygons drawn on stable-based material in order to preserve the spatial integrity of the data. Pleistocene maps are contour maps that show the depth to the Pleistocene surface. Engineering geology is represented as homogeneous areas, each of which is identified by an attribute code. Tic marks are included at the four corners of each map to enable the maps to be edge-matched and geo-referenced in the data base.

22. The procedure used for encoding was a function of the map type and the effort required to edit and correct the results of encoding. Since land-loss was represented as solid polygons, drum scanning was the encoding method of choice. The results would require only minimal editing and digitizing could be accomplished rapidly. On the other hand, Pleistocene and engineering geology maps would be digitized manually using a digitizing tablet to avoid the time-consuming procedures required to edit drum-scanned data.

### Pre-processing

23. Data pre-processing would be required to prepare the data for subsequent entry and storage in the GIS. In this step, all data to be entered would be corrected for any errors due to translation, rotation, and/or distortion and then converted to the UTM projection. Any erroneous line discontinuities would then be located and corrected. In addition, information derived from tablet digitization would be converted to a grid array. In the process, lines would, in effect, be removed by re-defining the pixel values for each half of the line width with the attribute code of the area adjacent to that half of the line.

24. Data for contour lines would be pre-processed in a somewhat different manner. After geometric corrections have been completed, a linear interpolation between contour lines in both the east-west and the north-south

direction would be used to fill the grid cells defining the area with appropriate elevation values.

25. All land-loss data would be stored in the data base in one layer and depth to Pleistocene would be stored in another layer. Engineering geologic information would be stored in the third layer, as shown in Figure 5. Each layer would be co-registered geographically and contain exactly the same number of rows and columns of grid cells. Each grid cell would correspond to an area on the ground 12.5- by 12.5 m in size. Each cell in the land-loss layer would have an attribute code that would differentiate man-made and natural land-loss and would specify the chronological period within which the loss occurred. Each cell in the depth to Pleistocene layer would contain a value for depth.

#### Storage/retrieval

26. The storage/retrieval step would compress the data for storage, and decompress stored data prior to use. On the basis of previous experience, the decision was made to compress the data by run-length encoding. This process would not significantly reduce the storage required for contour data but would reduce the storage required for the other data by as much as 90 percent.

#### Analysis

27. Initially, the geographic information system would be designed to support those applications particularly useful in the solution of land-loss problems--study area selection, area calculations, display of attributes of selected areas, and determination of the interrelationships among land-loss, depth to Pleistocene, and/or engineering geology. However, the design of the analytical capability would permit expansion as new problems and their solutions emerge.

#### Portrayal

28. At the option of the computer operator, all or any selected portion of the study area or the result of any analyses could be portrayed as a color-coded map or as a map overlay. Colors assigned to the different attributes would be operator selectable. Portrayals could be directed to the monitor screen or to an ink-jet printer. The results of area calculations could be generated in tabular form and printed on the monitor screen or a printer.

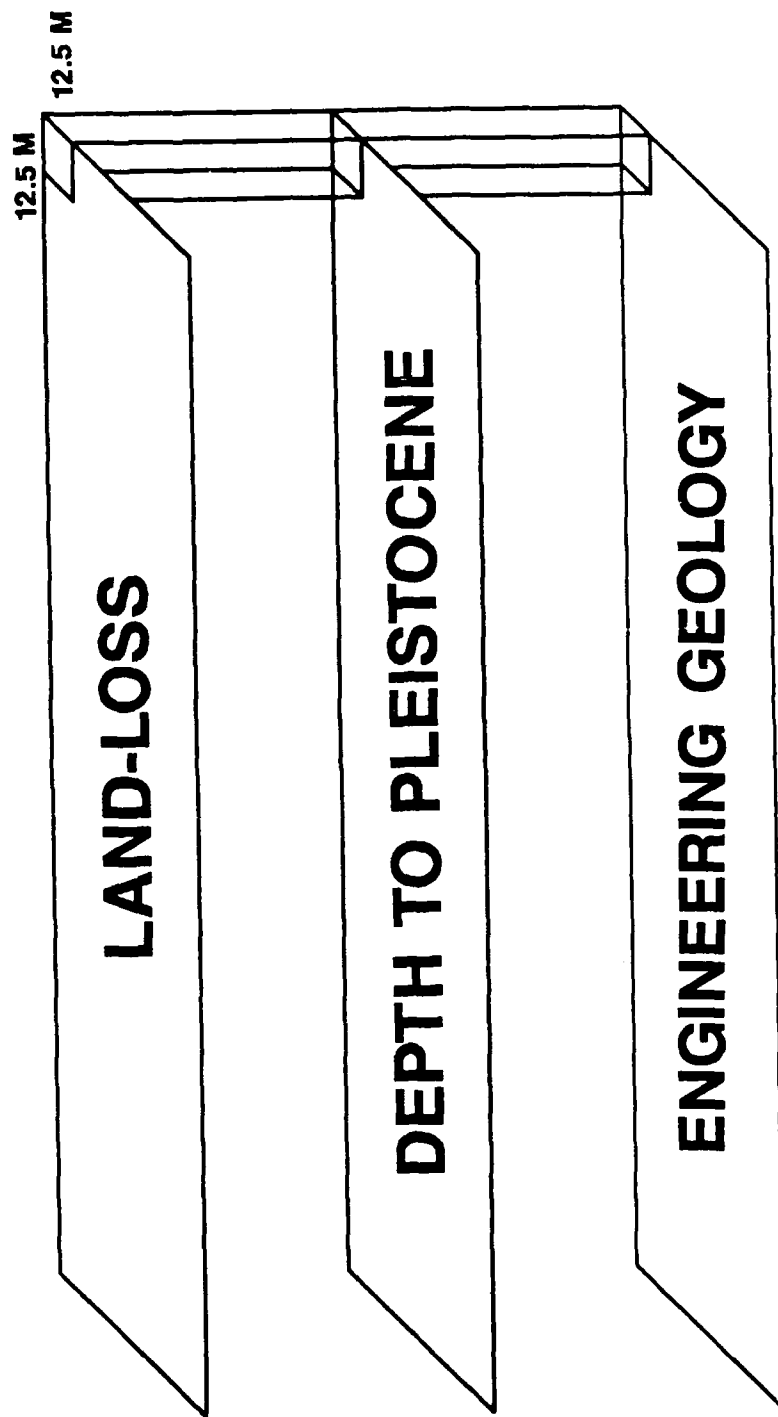


Figure 5. Configuration of data in land-loss geographic information system

## PART III: GIS OPERATION

### Current Status

29. Development of the capabilities of the land-loss GIS to perform the various functions envisioned is still in its infancy. Computer programs have been developed that will allow an engineer or scientist to select an area for study, portray the area on the computer monitor, select the feature or combination of features to be viewed, calculate the area of coverage for each selected feature, and portray the results of any of these operations on the computer monitor or as a hard copy color-coded map. All computer operations are accomplished through use of menus or screen prompts. As a result, no specific computer skills are needed in order to use the land-loss GIS for analytical processes.

#### Site selection

30. When the GIS program is first initiated, a 19 by 7 array of boxes appears on the monitor screen. Each box in the array corresponds to one of the quadrangle maps that cover the Louisiana coastline. By depressing the up-down or left-right keys, the highlight can be moved from box to box within the array. The name of the highlighted map appears at the bottom of the screen and changes as the highlight is moved over the array. To select a map for analysis, the map of interest is highlighted and the space bar is depressed. The highlight color of that box changes from green to red. This procedure is repeated until all maps of interest have been selected.

31. An alternate procedure allows map selection by map name. To do this, the letter on the keyboard corresponding to the first letter of the map name must be depressed. When this is done, the first map in alphabetical order with a name beginning with the depressed letter is highlighted. Selection can then be made by depressing the space bar. If the first map is not the map of interest, then depressing the letter again will cause the second map in the alphabetical order to be highlighted. This process can be repeated until all maps of interest have been selected.

#### Feature selection

32. Once the map(s) of interest has been selected, depressing the Alternate-(V)iew keys will erase the current screen and display the following list of options:

- a. Define new combination.
- b. View combination.
- c. View Pleistocene data.
- d. View land loss data.
- e. View Engineering Geology data.
- f. Quit.

Option 1 erases the screen and presents a menu for selection of a combination of attributes to be used in an analysis. This is the option that would be selected if a map of land-loss, for example, is to be overlaid on a map of the depth to Pleistocene for analysis. Selection of option 2 through 5 causes the screen to be erased and the selected feature to be displayed on the monitor screen as a color-coded replication of the selected area. Default colors are used to differentiate among the mapped attributes for the selected feature. Option 6 terminates the land-loss program, erases the monitor screen and causes display of the system prompt.

#### Aids for data analysis

33. Once a viewing option (option 2-5) has been selected, a menu containing a choice of 16 analytical aids can be selected by depressing function key (F1). Analytical aids are as follows:

- A - Increase cursor speed
- C - Change screen colors
- D - Decrease cursor speed
- G - Display latitude and longitude of the cursor
- H - Generate histogram
- M - Select new map area
- P - Pan to the cursor
- P - Print image
- R - Restore to last polygon
- R - Restore to original map
- Sp - Turn cursor off/on
- U - Display UTM coordinates of the cursor
- V - Display attribute code of area under the cursor
- X - Select polygon points
- Z - Zoom

## Analysis Procedures

34. The procedures used for analyses of the information stored in the land-loss GIS will vary somewhat from problem to problem depending upon the stored information needed to solve the problem and the desired output. Therefore, the example described in the paragraphs that follow should be considered only as an example, and not as THE procedure to be followed to solve every problem that is encountered.

35. In the problem described, we are interested in validating the pre-supposition that a relationship exists between the depth to Pleistocene and land-loss. For this purpose, data stored for the area covered by the Empire quadrangle map will be used, since the data for land-loss and depth to the Pleistocene for this area are both available in the data base. (New information is continually being added.)

36. The land-loss GIS permits maps to be overlaid and compared on the basis of the relationships between the map attributes. For the case in point, the land-loss layer was digitally compared to the depth to the Pleistocene layer. The following four conditions were then established as bases for comparison:

- a. Natural land-loss for depths to Pleistocene between 126 and 150 ft.
- b. Natural land-loss for depths to Pleistocene between 151 and 175 ft.
- c. Natural land-loss for depths to Pleistocene between 176 and 200 ft.
- d. Natural land-loss for depths to Pleistocene between 201 and 225 ft.

37. The result of this comparison is shown in Figure 6. The depth to Pleistocene can be seen to increase from a low of 126 ft in the north to a high of 225 ft in the south and southwest.

38. Land-loss can be seen to have occurred over almost the entire area, but is especially prevalent in those areas where the depth to Pleistocene is greater than 150 ft.

39. In addition to the graphic output, the land-loss GIS will calculate the number of acres for each feature displayed on the map. For the area shown in Figure 6, natural landloss between 1932 and 1983 had occurred over 25,365 acres or 14.4 percent of the area shown.



Scale 1:177165  
 Tic at N29°30'00" 89°45'00"W

and less  
 126ft to 147ft  
 151ft to 175ft

176ft to 213ft  
 207ft to 225ft

Figure 6. Comparison of land loss with depth to Pleistocene

40. Obviously, interpretation of land-loss over an area as small as this example should not be accepted without a similar study of the land-loss/depth-to-Pleistocene relationships over a much larger area. However, the example does demonstrate one of the ways the land-loss GIS can be used to better understand and, perhaps, predict the future occurrence of land-loss in an area that is susceptible to this destructive process.



#### PART IV: DISCUSSION

41. Since the data are formatted in a grid array and stored in co-registered stacks, analyses using the stored data require relatively simplistic computer programs that can operate on most desk-top microcomputers. All analysis procedures using the land-loss GIS are facilitated through use of prompts and menus, thereby obviating the need for a high level of computer proficiency to produce meaningful and useful results.

42. There are many commercially available GIS systems. However, most require additional hardware (e.g., high resolution monitor, graphics adaptors, joy stick or mouse) and/or software. In keeping with the requirement for this GIS to be operable on a Zenith microcomputer and in the interest of cost containment, the land-loss GIS was developed using much of the hardware and software that had been developed and utilized in connection with the Computerized Environmental Resources Data System (CERDS), a GIS that was previously developed in connection with the Corps of Engineers Lower Mississippi River Environmental Program. Thus, by carefully matching available resources for data encoding, archival, retrieval, and portrayal with the structure of information required for analyses and the output products required to present the results of analyses, a powerful capability is being successfully developed to perform detailed analyses of land-loss over time and the factors contributing thereto.

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