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16. Abstract <p>This is the first of three interim reports to be prepared on a four-year study to develop an Interactive Graphics Aided Design System. In addition to documenting the accomplishments of the first ten months of the study, it is also intended to document some of the reasoning behind development of an interactive graphics design system for roadway design and to discuss the conceptual design.</p> <p>The overall objective for the study is the development of a roadway design system utilizing graphics cathode ray tubes as an interface between the designer and the computer with emphasis on graphics input and output. The development is to use as a base existing engineering design systems and specifically the Roadway Design System (RDS) developed by the Texas Highway Department (now the State Department of Highways and Public Transportation). In addition to the engineering design systems, the Interactive Graphics Aided Design System will utilize the digital geographic data base produced by the Texas Automated Mapping System (also developed by the Texas Highway Department) for the base survey information.</p>			
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CONCEPTUAL DESIGN OF AN INTERACTIVE  
GRAPHICS AIDED DESIGN SYSTEM

by

William L. Crawford

Research Report 520-1

Development of an Interactive  
Graphics Aided Design System

Research Study 1-19-75-520



Conducted by  
Division of Automation  
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and Public Transportation  
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## IMPLEMENTATION

The Roadway Design System (RDS) and the Texas Automated Mapping System (TAPS) both developed by the Texas Highway Department (now the Texas State Department of Highways and Public Transportation) are available for implementation by an interested agency. The first phase of the Interactive Graphics Aided Design System is recommended for implementation by this Department when completed.

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# CONCEPTUAL DESIGN OF AN INTERACTIVE GRAPHICS AIDED DESIGN SYSTEM

## I. Introduction

This report is the first of three interim reports to be prepared on this four-year study. In addition to documenting the accomplishments of the first ten months of the study, it is also intended to document some of the reasoning behind development of an interactive graphics design system for roadway design and to discuss the conceptual design.

The overall objective for the study is the development of a roadway design system utilizing graphics cathode ray tubes (see Figure 6 for an example of a Graphics Cathode Ray Tube) as an interface between the designer and the computer with emphasis on graphics input and output. The development is to use as a base existing engineering design systems and specifically the Roadway Design System (RDS) (1) developed by the Texas Highway Department (now the State Department of Highways and Public Transportation and referred to as DHT in this report). In addition to the engineering design systems, the Interactive Graphics Aided Design System will utilize the digital geographic data base produced by the Texas Automated Mapping System for the base survey information. The concepts of the Texas Automated Mapping System is explained in detail in research report numbered THD-1-19-73-40-1F, entitled "Implementation of an Automated Mapping System" (2).



## II. Background

DHT has developed computer systems to aid transportation engineers design highways since the mid 1950's and since engineers have always utilized graphics in their design process for visually reviewing their survey information and displaying the results of their design calculations, DHT has developed hard copy plots as a by product of these engineering design computer systems. The development of computer graphics in DHT began as early as 1965 when approximately 13 miles of terrain cross-sections were plotted as the Department's first production experience in digital plotting. The experience gained from these first terrain cross-section plots created an interest in the Department's design engineers for graphical representation of their design calculations resulting in the extensive use of graphical output in all of the Department's design systems. The plots are used for drafting, detection of input errors and visual review of design calculations to determine needed adjustments for more economical design.

Transportation engineers have discussed the need for a more direct graphic interface with the computer. (See Bibliography Items 4-10 for an example list of reports and papers on the subject of using interactive graphics in transportation.) Graphics display tubes which provide this interface with the computer were introduced many years ago into other disciplines such as aircraft and automobile, textile weaving, and circuit board design. This was economically sound in these disciplines since design is highly centralized; however, in highway engineering in Texas and in many other agencies, the design of transportation facilities is performed by individuals in design offices located throughout the state (Figure 1). This



decentralized design and the high cost of the early graphic display tubes and required supporting computer made the use of graphic CRT's in the highway profession, at least in Texas, impractical. The development of storage graphic display devices and the miniaturization of computer components resulting in the development of minicomputer systems and reduced equipment costs have made the development of an interactive graphics design system now practical.

To understand how interactive graphics is proposed to be used in highway design, it is perhaps expedient to compare some of the phases of the current design process in DHT to the projected Interactive Graphics Aided Design System.

The first phase or step in any highway design, once the highway route is determined, is the conduct of a reconnaissance survey where the geographic position of all topographic features is determined. This traditionally was obtained through the use of a survey party and a work map was then manually drafted. However, in recent years the surveys are performed more economically through the use of aerial photogrammetry. The resulting work map is a more accurate and complete representation of the topographic features.

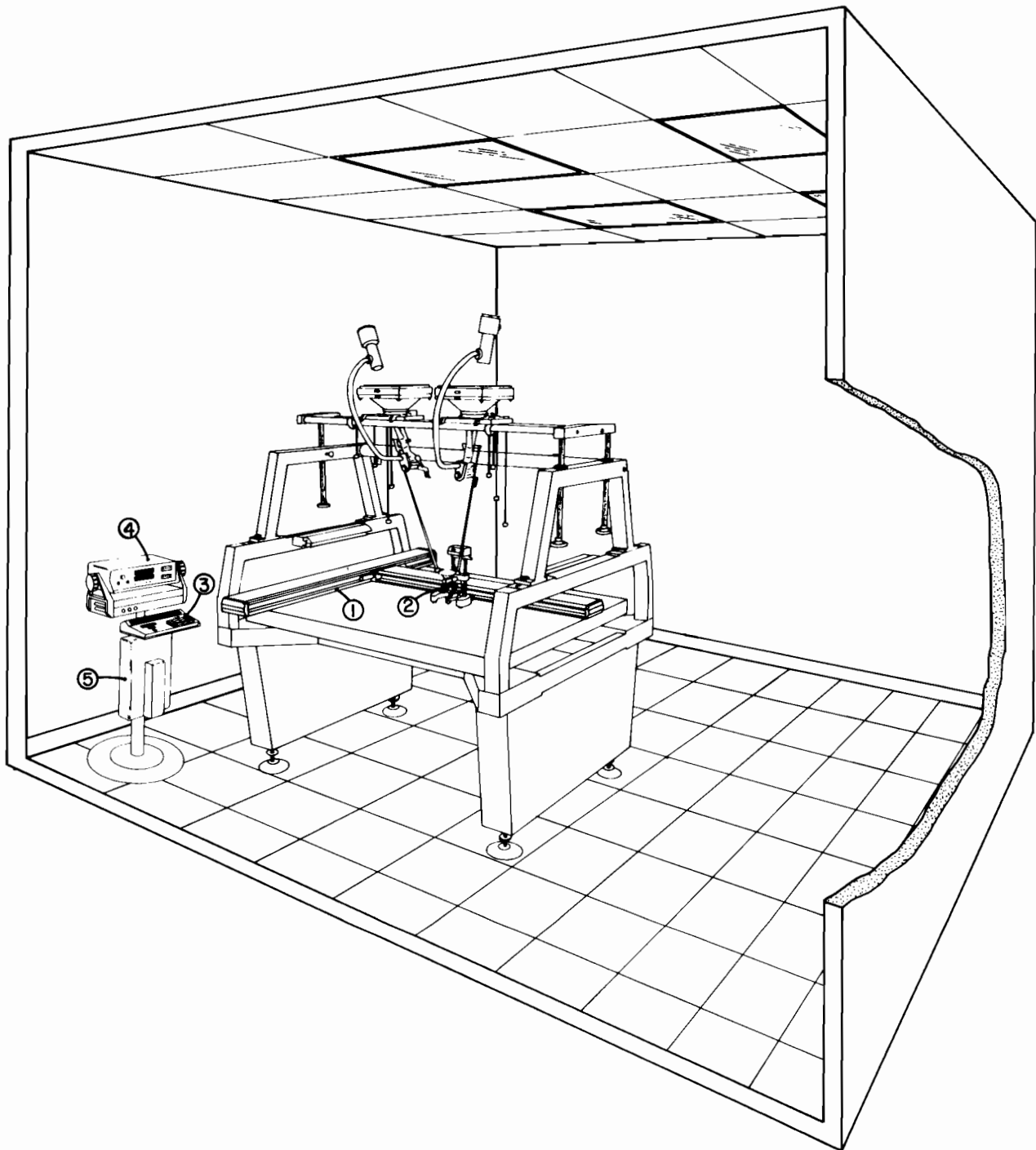
#### Texas Automated Mapping System

Originally, these design maps were drawn on a stable base manuscript from the aerial photographs. In DHT the penciled lines were scribed by a draftsman and a film positive was photographically produced from the base manuscript. These were used by the designer as a work map. In order to provide more map flexibility and to reduce manpower requirements, DHT developed and has implemented the Texas Automated Mapping System (2). In this system the topographical features are captured as a digital geographic data base. To create this

geographic data base the stereoplotter operator digitizes (Figure 2) the X-Y coordinate positions of the photographs' principal points (photograph centers) and control points. The operator then proceeds to convert the photographic imagery into a numerical "manuscript" by digitizing all relevant map features visible on the aerial photography. By using various feature identification codes (Figure 3) to enter the cultural and terrain features, the geographic data base is built so that later automated manipulation is possible for data analyses and presentation of selective graphics. The information is stored as it is digitized in a project file on a disk of a minicomputer system (Figure 4). Upon completion of digitizing all desired information visible on the aerial photography, the stereoplotter operator transmits the data from the minicomputer disk to the host IBM 370 computer for edit processing. During the computer edit routine, operator input errors such as closure blunders are detected and adjusted, and the digitized X-Y coordinate values are converted to lines and shapes for presentation graphically.

In the Texas Automated Mapping System a hard copy edit plot of this information can be produced for review by the stereoplotter operator for omissions and corrections. Production of this plot involves some delay even when produced on a high-speed digital plotter. Therefore, in order to provide the operator with this edit information without having to produce a hard copy edit plot, the Department purchased an Interactive Graphics Drafting System (IGDS). The Interactive Graphics Drafting System is composed of a processing unit (Figure 5), an Edit Station (Figure 6), and an Applications Station (Figure 7).

The Edit Station is used by all of the stereoplotter operators



- |                                      |                                    |
|--------------------------------------|------------------------------------|
| 1. X-Y Coordinate Arm Assembly       | 4. Electronic Data Display Console |
| 2. Tracing Table Recording Interface | 5. Recording Interface             |
| 3. Remote Data Control Switch System |                                    |

FIGURE 2. STEREOPLOTTER UNIT CONVERTED FOR AUTOMATED DATA COLLECTION

AUTOMATED MAPPING SYSTEM CODES  
FOR DESIGN MAPPING

01	PRINCIPLE POINTS & CONTROL	SYM	26	MANHOLES (on inlets), etc.	SYM
02	BUILDINGS (square)	PP	27	GUARD POSTS, etc.	SYM
03	CURBS I	SC	28	ORCHARD (interior trees)	SYM
04	PAVED ROADS, DRIVEWAYS, etc.	SC	29	SMALL TREE, ORCHARD (outline trees)	SYM
05	SIDEWALKS	PC	30	TREES	SC
06	STEPS, STAIRS, FIRE ESCAPES (square)	PP	31	PALM TREES	SYM
07	FENCES & GATES	PP	32	TREE FARM	SC
08	SLABS, etc.	PC	33	CURB II	PC
09	WATER	SC	34	MARSH & PIT	SC
10	POLES & TFP	SYM	35	RR & WORKCAR SIDINGS	SC
11	LIGHT POLES & TRAFFIC LIGHTS	SYM	36	RR SWITCH	SYM
12	BUILDINGS (not square), etc.	PC	37	RR SIGNAL	SYM
13	WALLS	PC	38	RR STANDARD	SYM
14	GUARD RAILS	SC	39	CURB III	SC
15	GUARD FENCES	SC	40	CEMETERY	PC
16	DIRT ROADS, etc.	SC	41	PAVED SHOULDER	SC
17	RUINS, etc.	PC	42	CONTOUR INDEX	SC
18	EARTHEN DAMS & LEVEES	SC	43	CONTOUR INTERMEDIATE	SC
19	CULVERTS, INLETS, etc.	PC	44	SPOT ELEVATION	SC
20	TRANSMISSION LINE TOWER	PP	45	GUARD RAIL II	PC
21	TANKS	SYM	46	GUARD FENCE II	PC
22	GENERAL	PC	47	RAILROADS II	PC
23	ROW MARKERS	SYM	48	SINGLE LINE RAILROADS II	PC
24	MANHOLES (not on inlets)	SYM	49	COUNTY LINE	SC
25	SIGN POSTS, FLAG POLES, POSTS	SYM	50	MATCH LINE	PP

PC - Plotted Curve      SYM - Symbol  
PP - Point to Point      SC - Smooth Curve

FIGURE 3. FEATURE IDENTIFICATION CODES

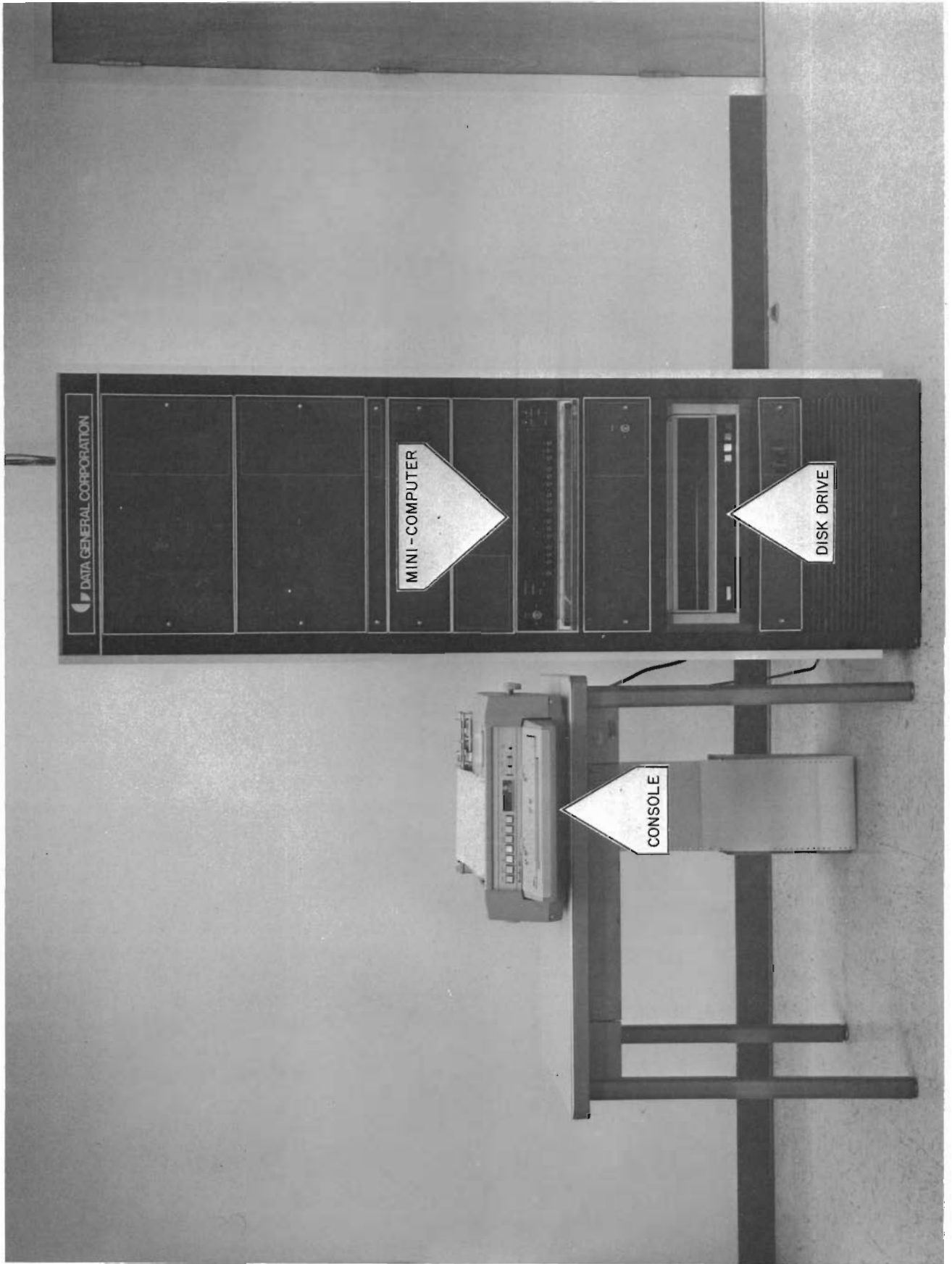


FIGURE 4. DATA ACQUISITION SYSTEM

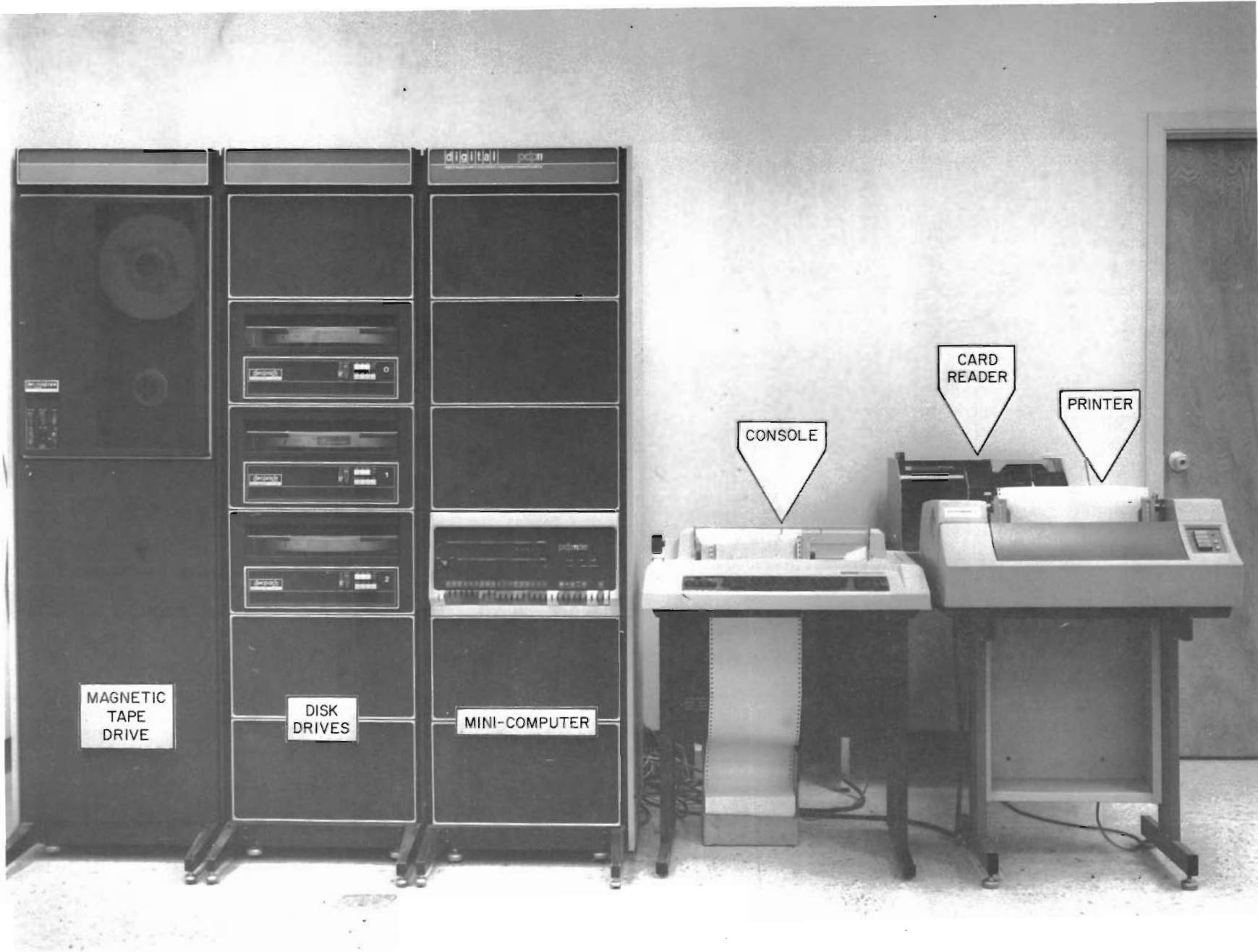


FIGURE 5. INTERACTIVE GRAPHICS DRAFTING SYSTEM PROCESSING UNIT



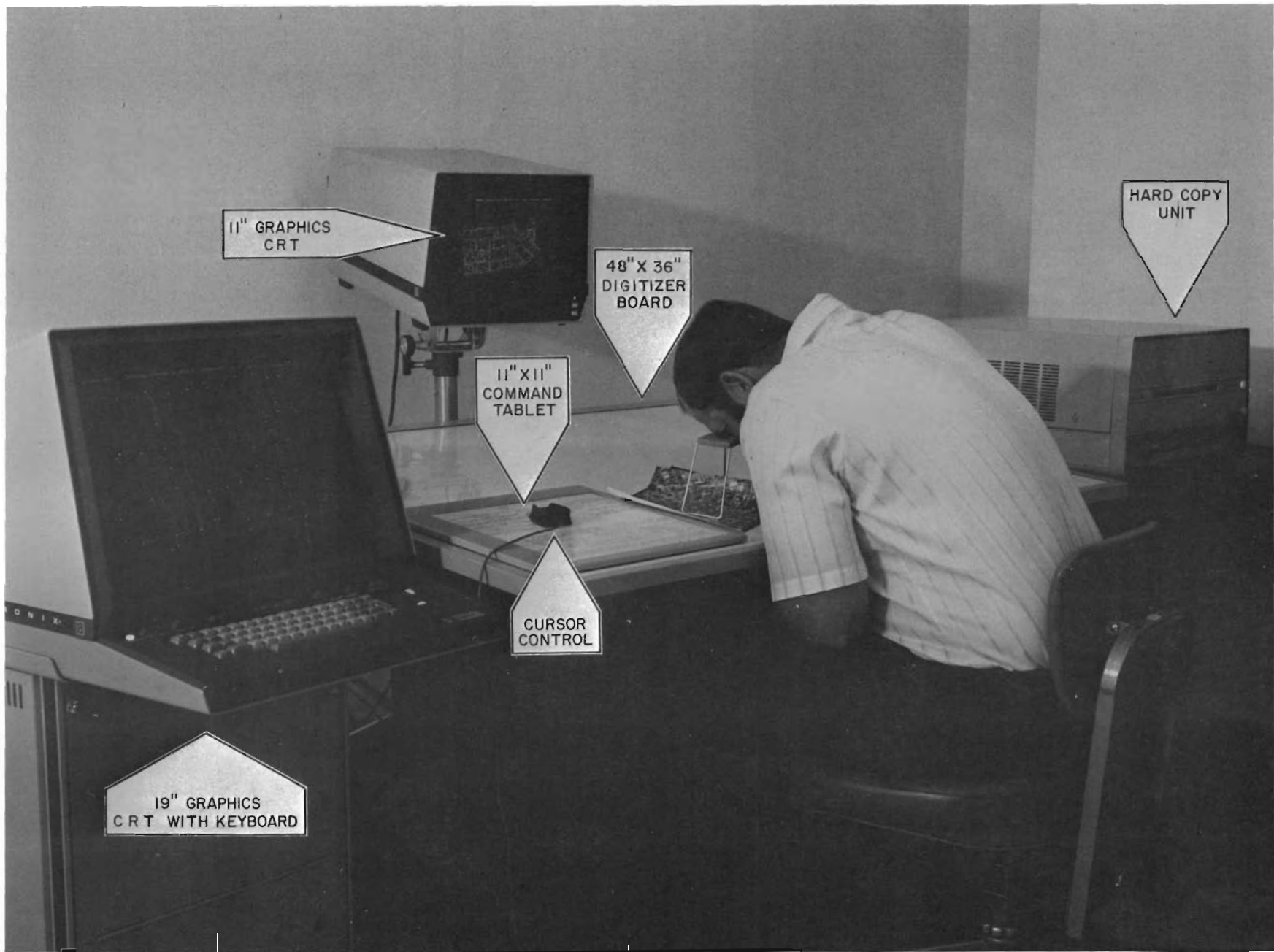


FIGURE 6. INTERACTIVE GRAPHICS DRAFTING SYSTEM EDIT STATION

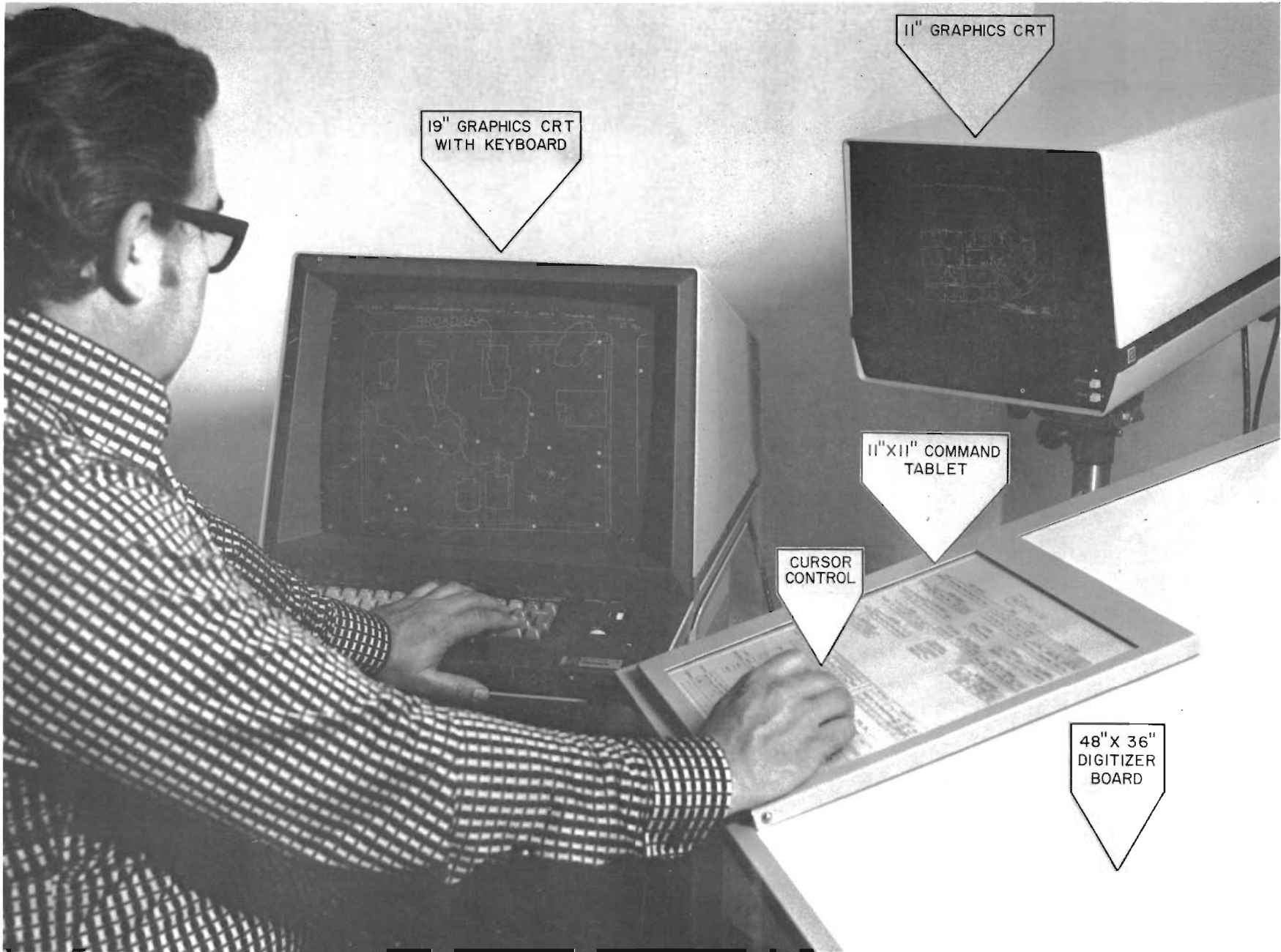


FIGURE 7. INTERACTIVE GRAPHICS DRAFTING SYSTEM APPLICATIONS STATION

for validating data, annotating features, and making necessary corrections or additions (not requiring the stereoplotter) to the map file (geographic data base). Having two CRT screens available permits the operator to observe the total file on one of the screens and selectively view any part of the file on the other screen for detailed study and editing. The stereoplotter operator has the option to obtain a quick copy of the data displayed on either screen using the attached hard copy printer. This copy can be taken back to the stereoplotter digitizer station and used for data validation in lieu of the screen display graphics. This option is especially advantageous when editing a dense data file and when other operators are waiting to edit their data.

Upon completion of the edit process by the stereoplotter operator, the revised map data is then transmitted back to the host computer for data base corrections. When sufficient models or units of a project have been edited and stored, this data is recalled from the host computer for finalization by a cartographic technician using the Applications Station of the Interactive Graphics Drafting System. Finalization of the map data by the cartographic technician primarily involves interaction with the data for subsequent generation of map sheets. This finalization includes adding the remaining annotations such as street names and grid numbers, bordering, and adding appropriate title blocks. After the map data has been finalized, it is then transmitted back to the host computer for storage as the geographic data base file.

This stored data may be manipulated and presented as follows:

1. Total Map Graphics - A photogrammetric map (Figure 8) can be obtained containing all cultural and terrain features extracted from the aerial photography similar to maps heretofore obtained using manual photogrammetric techniques.



2. Selective Map Graphics - Different levels of management information can be extracted from the geographic data base project file as shown in Figure 9. These selective graphics might include separate maps showing only the transportation networks, recreation areas, buildings, utilities, various information classifications of land use, or any combination of management information.
3. Selective Area Graphics - Specific areas can be extracted from the geographic data base and plotted without requiring a plot of the entire area. This "windowing" feature is very useful to the traffic engineer for extracting selective interchanges for signalization studies and design, and to the safety engineer for accident site evaluations. Windowed areas can also present only selective features, if desired.
4. Additions and Deletions - The geographic data base file can be accessed to update land use applications as new subdivisions, parks, transportation routes, and industrial changes occur. Obsolete information can also be deleted or modified as these changes occur.
5. Differential Scales - The system offers the flexibility of selecting the scale of the graphic presentations. The accuracies are determined from the photographic scale at the time of data entry. Several areas from the same geographic data base can be obtained at various scales to accommodate a multiplicity of data utilization.

Graphics from the geographic data base are produced on a precision flatbed plotter and/or drum plotter. These graphics are available at different scales, line weights and line types, and covering different areas with selective formats in a time frame much faster than an identical map manuscript can be scribed using standard cartographic techniques.

#### Use of Photogrammetric Design Maps

In DHT, the aerial photogrammetric maps used for design (Figure 10) are produced with the physical features located to third order survey accuracy. Right-of-way and alignment determination are performed by scaling the dimensions directly from the map or by scaling coordinates and computing distances. Reconstructing tangent lines on existing roadways are accomplished by scaling a series of points along the roadway and producing a "mean line" through the points.

# AUTOMATED MAPPING SYSTEM ENGINEERING INFORMATION MANAGEMENT

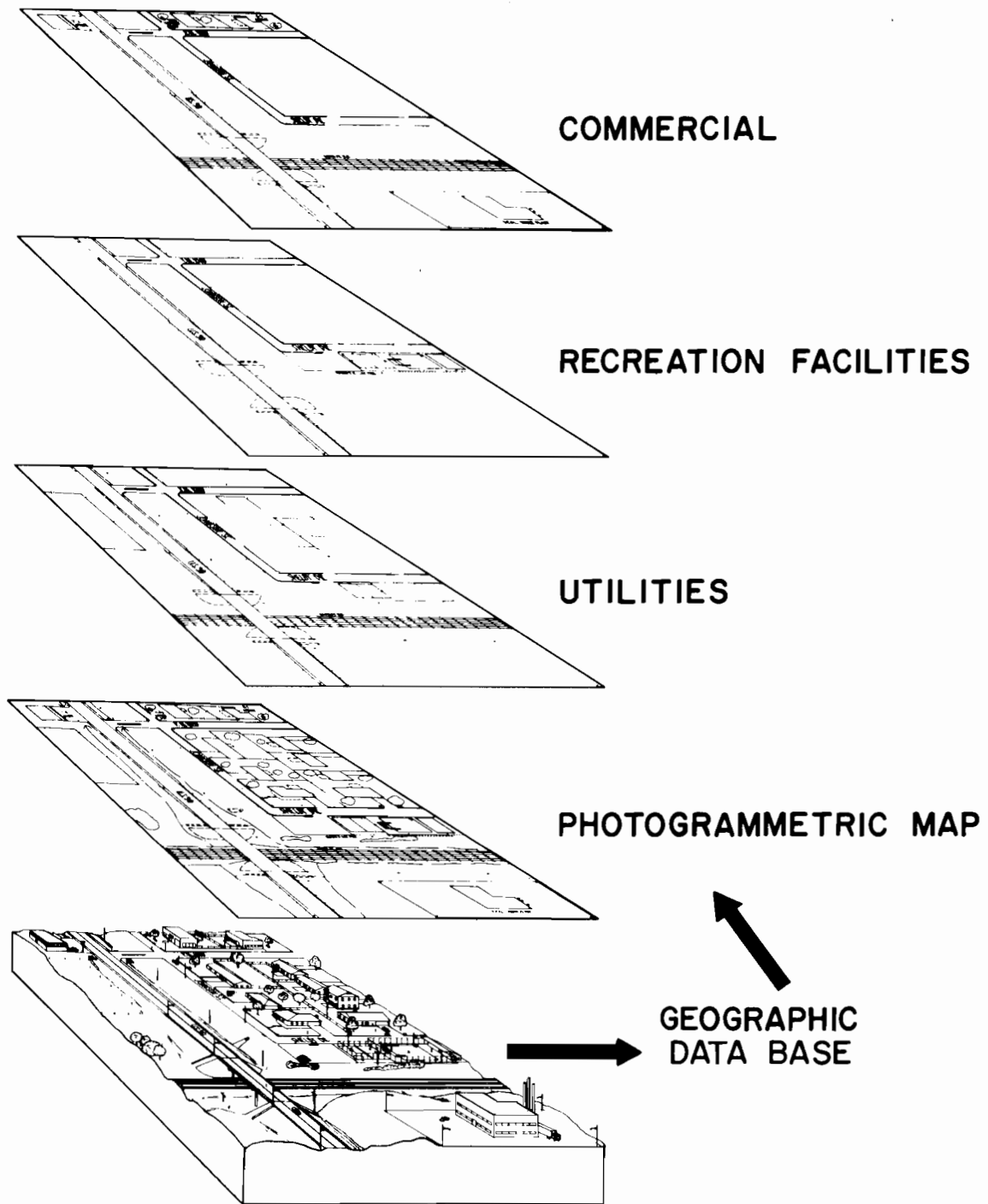


FIGURE 9. SELECTIVE MAP GRAPHICS

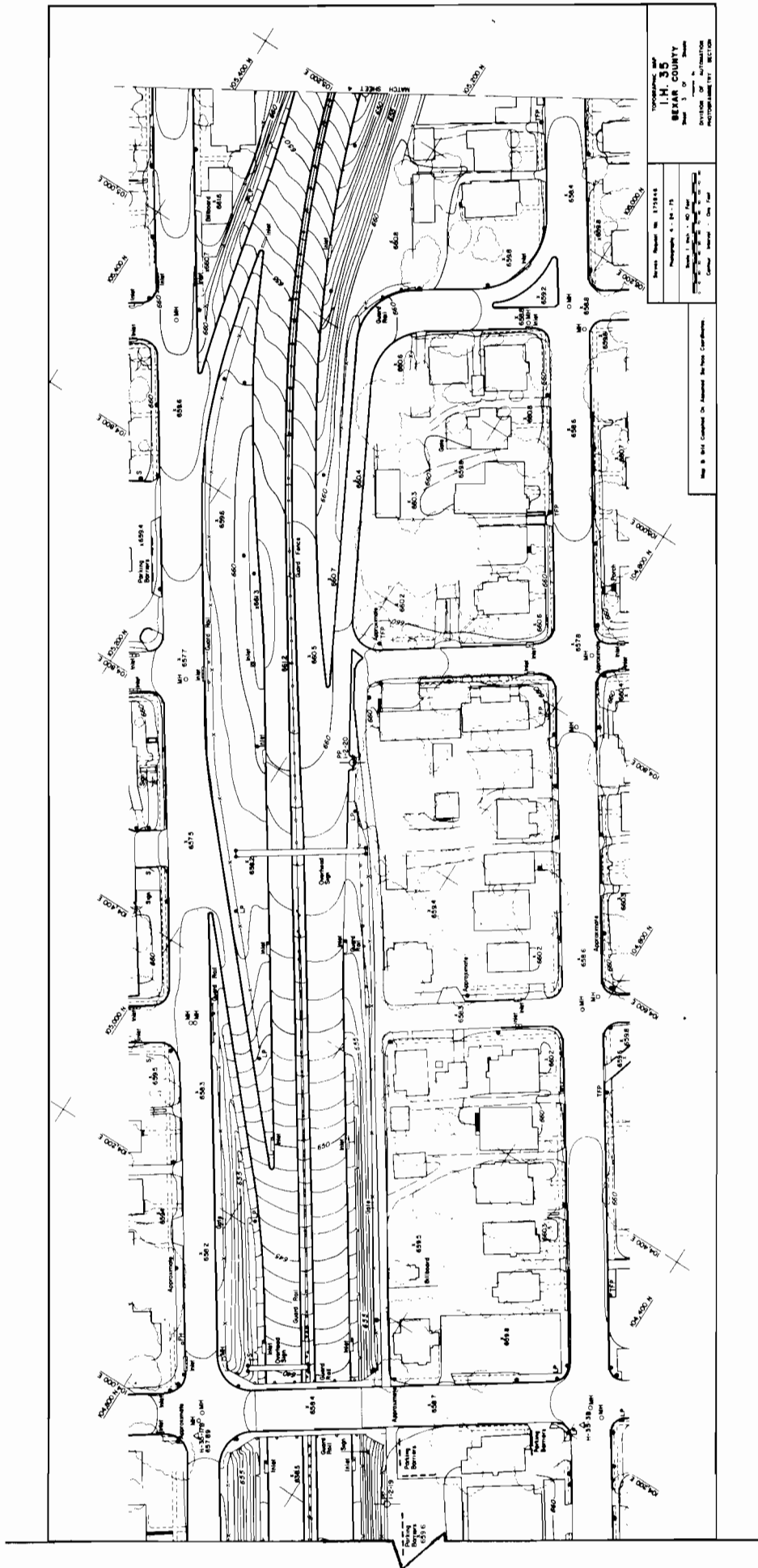


FIGURE 10. PHOTOGRAMMETRIC DESIGN MAP

Property lines which are visible on the maps, such as fence lines, are determined in a similar fashion. In DHT geometric calculations are performed with the scaled and supplemental survey information using the Roadway Design System. Calculations of right-of-way and alignments using these procedures have been shown to be more accurate than the use of information obtained from a conventional topographic survey where terrain relief and vegetation cause sight problems. To the transportation engineer, the imagery on the graphics display tube will serve the same purpose as the hard copy map he is currently scaling coordinates from. However, he will now use an electronic scale rather than a mechanical scale. To obtain the necessary accuracy he will utilize the software available to expand the viewed image to a size sufficient to extract coordinates with the accuracy equivalent to his previous methods.

#### Terrain Data

In addition to the geographic position of the topographic features, the transportation designer also needs information defining the vertical relief of the terrain. This is obtained by a reconnaissance survey or through photogrammetric methods. Currently in DHT the terrain contours are digitized as planimetric features and stored in the geographic data base for graphic display. The contours provide the designer with a visual display of the relief but the cross-sections required for design must be obtained separately using the same aerial photography.

The Numerical Ground Image system (NGI) (Figure 11) developed by the Texas Highway Department under HPR Research Study 1-19-71-186 (3) provides the ability to obtain a numerical terrain model from photogrammetric imagery and to generate terrain cross-sections



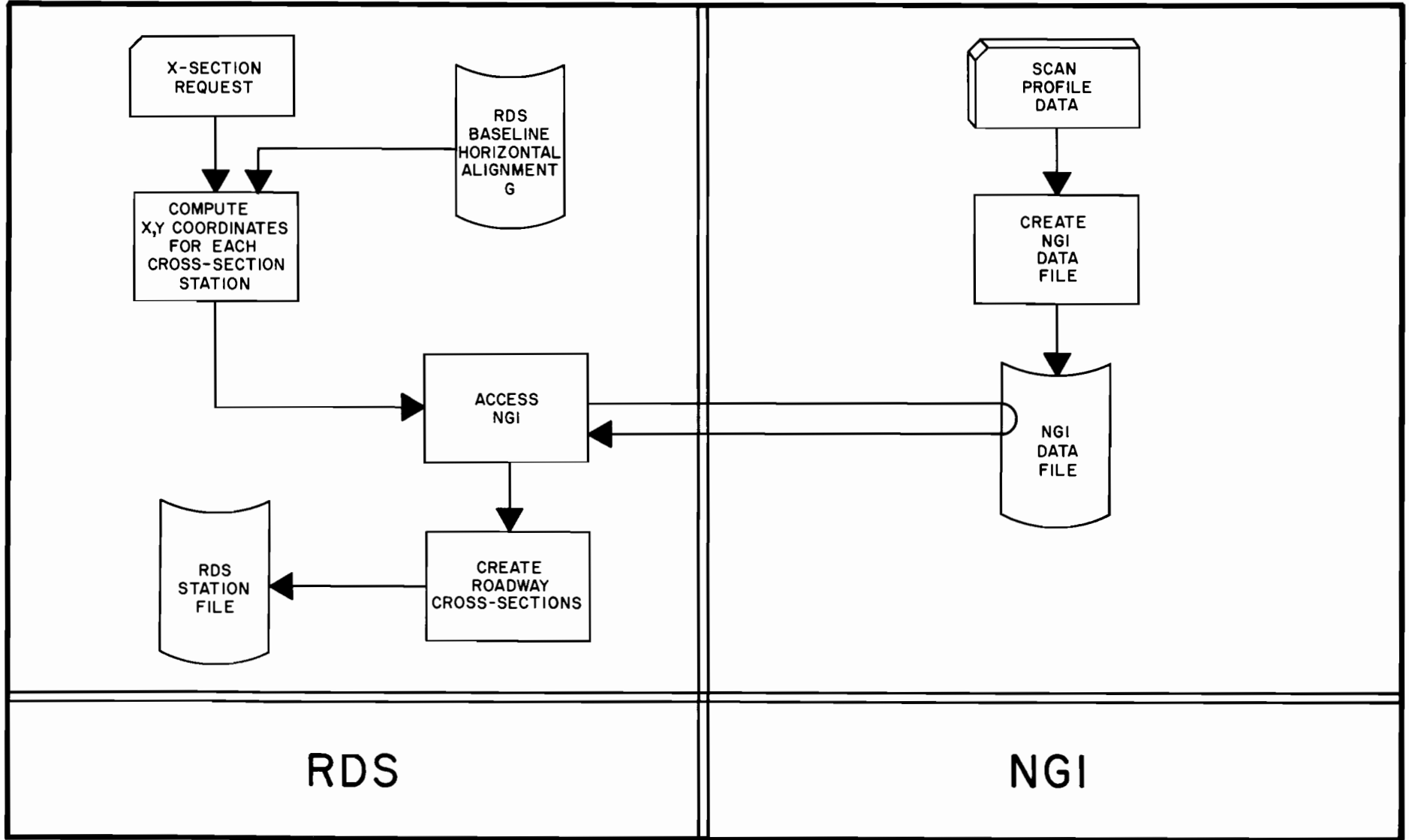


FIGURE 11. SCHEMATIC OF RDS/NGI INTERFACE

(Figure 12) for design. These terrain cross-sections are referenced to a horizontal alignment defined in the Roadway Design System. Terrain cross-sections may also be obtained either by a conventional survey and key punching the information or by photogrammetric cross-sections.

The terrain cross-sections are utilized in one of the most laborious and time consuming tasks of highway design - earthwork. Earthwork in this context is meant to be the process of defining the proposed shape of the roadway after the construction is completed, calculating the location and elevations of all control points, and calculating estimated quantities of earth to be moved in reshaping the terrain. The terrain cross-sections are also used in calculating the final pay quantities for the project.

#### Design Calculations

The planimetric features and terrain cross-sections obtained in the reconnaissance survey provide the basic information for the design of the highway. The traditional method used to compute the estimated quantities is to plot the original cross-sections to scale on grid paper, compute the elevations of the design cross-sections, superimpose them on the original cross-sections, and compute the quantity of earth to be moved by the end-area method. Obviously any revision to the proposed design necessitated the recalculation of the design elevations, plotting of the revised design cross-sections, and recalculation of the quantities. Therefore, changes were kept to a minimum because of this inflexible process. Since it was expensive and time consuming to make changes, fewer alternate design analyses were performed. With the advent of computer systems such as the Roadway Design System (RDS) much of the time required for earthwork

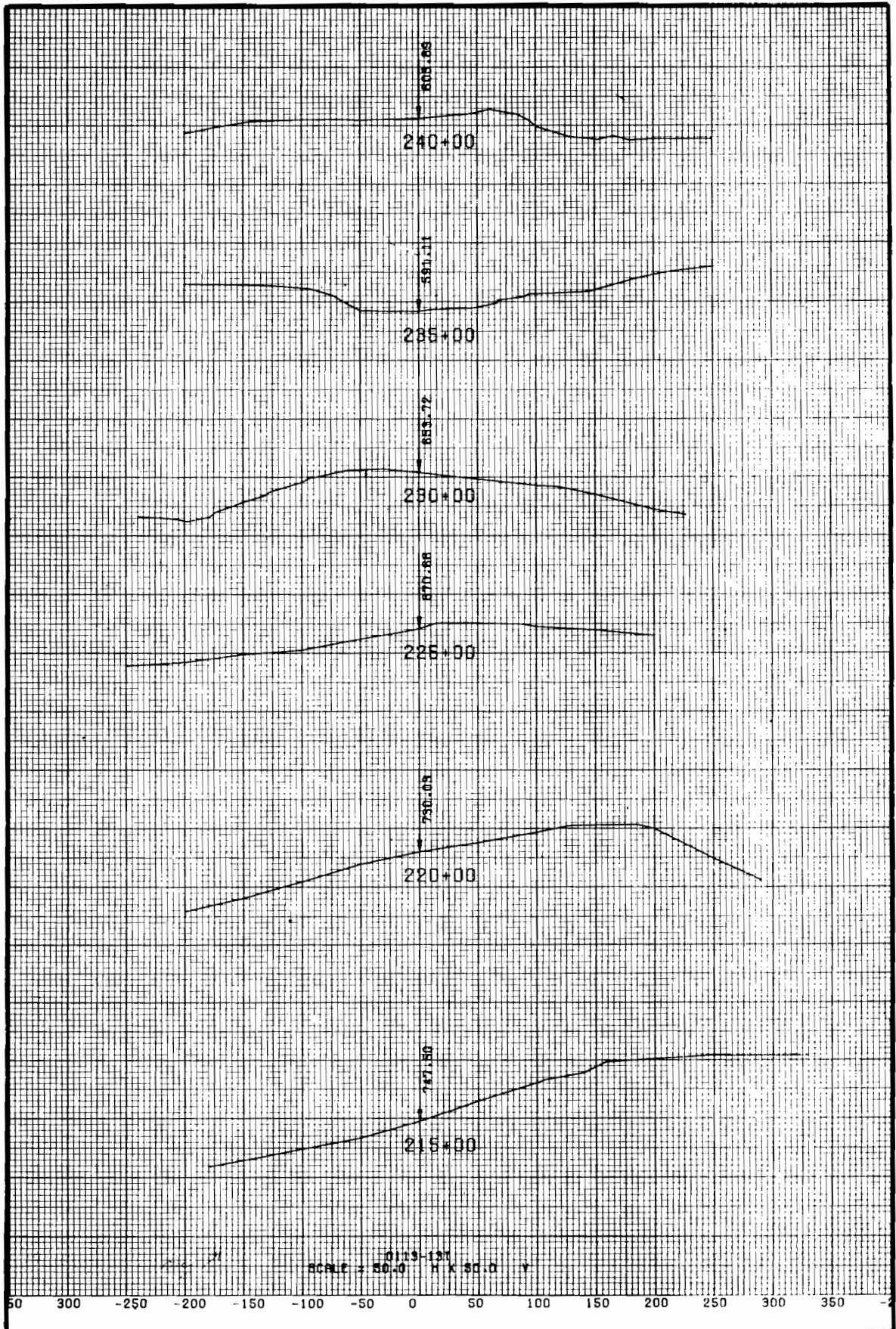


FIGURE 12. ORIGINAL TERRAIN CROSS-SECTIONS

calculations was reduced. The ability to easily perform alternate designs was enhanced resulting in better and more economical roadway design. To provide sufficient information for the design to be computed, parameters such as the station, elevation, and length of vertical curves are entered for each change in vertical alignment. Also the cross-slopes and super-elevation of each roadway are defined, and the parameters for slope, ditch, and median are entered. Even with this apparent large amount of input, use of computer programs for earthwork design is more economical than calculating the information by hand.

The results of the computer calculations are a tabular listing of all elevations and distances and quantities; and the familiar (to the highway designer) original and design cross-section plot (Figure 13) which provides the engineer with the graphic representation of his design he has always reviewed. This graphic representation allows him to visualize the finished construction; and, if revisions are required, the necessary computer cards are revised and the program rerun, resulting in a new design. This process is repeated until a satisfactory product is obtained within the time and economic restrictions imposed by project scheduling.

The proceeding discussion of the reconnaissance surveys required to provide the base information for highway design, DHT's development of automated procedures to obtain this information and the brief descriptions of current automated design procedures using this base survey data provide background information to those not familiar with automated design as practiced in DHT. The following discussion will provide the reader with background information on the capabilities of some of the engineering design systems used by DHT, which may be

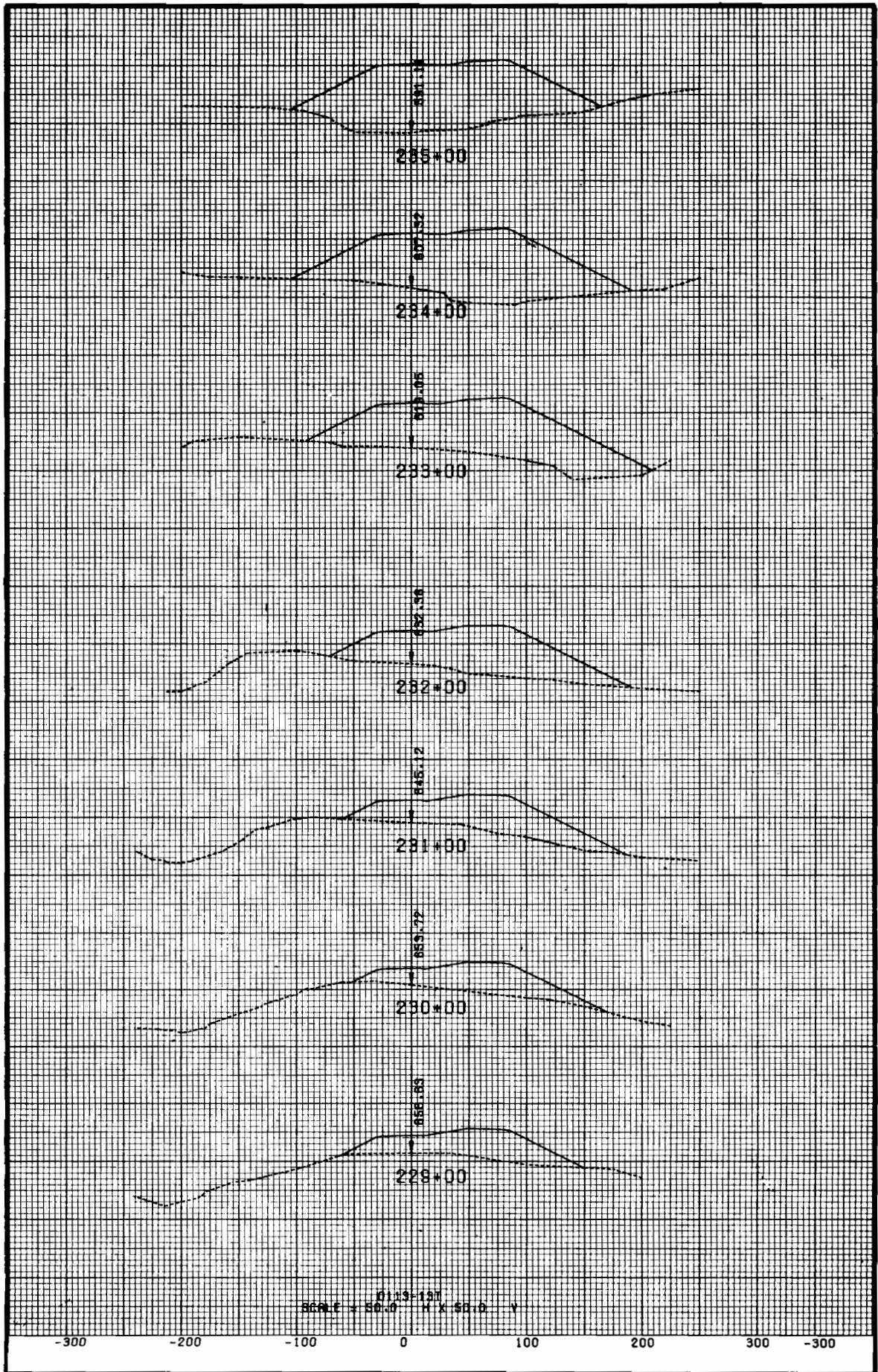


FIGURE 13. ORIGINAL AND DESIGN TERRAIN CROSS-SECTIONS

integrated into the Interactive Graphics Aided Design System.

Roadway Design System (RDS)

The Roadway Design System which will be the base design system of the Interactive Graphics Aided Design System is an integrated program of over 350 computer processes developed to aid engineers in the design of highways and bridges. It has broad applications within the entire spectrum of highway design, structures, and construction. An integrated data file is the link between all of the capabilities of the system. The following is a list of some of its capabilities:

1. Electronic Survey Data Reduction
2. Traverse Adjustment
3. Analytical Aerotriangulation Processes
4. Computation of

- General Geometry
- Horizontal Alignment Data
- Horizontal Alignment Offset
- Geometry
- Horizontal Alignment Relationships
- Coordinate Bounded Areas
- Roadway Elevations

5. Cross-Section Data

The system edits, reduces and stores original or final cross-section data. Previously stored cross-sections may be corrected, extended or adjusted.

6. Roadway Cross-Section Design

The system compiles complete design cross-sections for up to six roadways with independent horizontal and vertical alignments, stationing, roadway templates and superelevation and widening criteria. Medians, cut and fill slope selection, special ditch grades, benching, bridge exceptions, and right-of-way and slope intercepts are used to complete the design cross-sections.

7. Design or Final Earthwork Volumes and Haul Quantities

Volume parameters (compaction factors, added quantities, forced balance stations and bridge exceptions) are used in the volume computation process. Design volumes may be based on single roadways and/or any combination of road-

ways.

8. Construction Staking, Hub Elevations and Blue Top Data

9. Bridge Geometry

Complete frame layout for simple span and continuous span structures including dimensions, elevations, and plots. Computation facilities include:

- a. Bent, diaphragm and splice locations.
- b. Automatic beam layout for various options for simple span structures.
- c. Automatic layout for groups of parallel or concentric beams for simple span and continuous span structures.
- d. Slab geometry for slabs defined by various combinations of straight or circular elements.
- e. Locations and elevations of bearing seats.
- f. Lengths of beams and diaphragms.
- g. Surface elevations and bottom of slab elevations for various locations on the bridge.
- h. Vertical clearances between roadways.
- i. Extensive construction grade information.

10. Graphic Representation Including Plots of

Adjusted Traverse  
General Geometry  
Annotated Horizontal Alignments  
Cross-Sections (any combination)  
Original, Design and Ditch Profiles  
Haul Diagram  
Coordinate Areas  
Perspective Views  
Bridge Frame Layout  
Bridge Slab Layout  
Contouring of Bridge or Roadway Surfaces

The Roadway Design System has extensive applications in such areas as right-of-way parcel geometry, highway alignment geometry, ramp intersection layout, quantity calculations, earthwork design, construction grade calculations, specialized drafting calculations, calculation of earthwork quantities, overhaul quantities, and



bridges.

In addition to the Roadway Design System, the Department has structural design and analysis, hydraulics, and environmental programs available for integration into the Interactive Graphics Aided Design System if found justifiable.

#### Structural Design Programs

Two existing structure design/analysis programs were linked with the Roadway Design System during its development to demonstrate the feasibility of utilizing the bridge geometric capabilities of the Roadway Design System to compute bridge frame information as input to structural design/analysis programs. These two widely used programs are:

1. Continuous Beam Analysis

This program is a modified version of the original Georgia program and provides a line-member analysis that computes moments, shears, deflections and reactions for continuous beam or girder units loaded with standard highway loadings. It also produces plots of moment or stress and deflection.

2. Prestressed Concrete Girder Design

This program performs the calculations for the design of simple span I-shaped beams of pretensioned, prestressed concrete for use in highway and railroad bridges. It determines the composite and non-composite section properties, moments, shears, stresses, dead load deflections, web reinforcement, ultimate moments and the location of prestressing strands. Standard and non-standard beam cross-sections may be used.

Other structural design/analysis programs are available for integration into the Interactive Graphics Aided Design System including two-dimensional finite element programs developed for DHT by the University of Texas.



## Other Design Programs

Other programs are available for integration into the Interactive Graphics Aided Design System if found justifiable. One example is the Texas Hydraulic System (THYSYS). This is an integrated system of computer programs for highway hydraulic design and analysis. It has five major subsystems which are as follows:

HYDRO (abbreviation of hydrologic) - computes peak flow for surface runoff. This peak flow is available for use in subsequent HYDRA, CULBRG or PUMP subsystems.

HYDRA (abbreviation of hydraulic) - computes channel flow characteristics from given channel cross-sections and computed peak flow from HYDRO. Peak flow may be entered directly into the HYDRA subsystem.

CULBRG (abbreviation of culvert/bridge) - designs or analyzes hydraulic structures (bridges and/or culverts) from input parameters, the peak flow from HYDRO and the tailwater from HYDRA. This data may be entered directly into the CULBRG subsystem. Cost analysis of alternate culvert designs is provided.

SEWER designs or analyzes storm sewer networks. This subsystem is independent of the other subsystems.

PUMP designs or analyzes PUMP stations. Peak flow from HYDRO may be used if desired.

THYSYS is designed so that each subsystem can be used independently or computed data from one subsystem may be automatically passed on to other subsystems and used as input. The printed output for each subsystem contains both the input and output. The HYDRA, SEWER, and PUMP subsystems feature optional graphical output.

### III. Proposed Development

Development of the Interactive Graphics Aided Design System is being performed in implementable phases corresponding to specific areas of design. While detailed design of the two initial phases is complete or nearing completion, the detailed design will not be included in this first report. Reports detailing the design of each phase will be published as the design of each phase is completed. Therefore, only the conceptual design of the Interactive Graphics Aided Design System will be outlined. The finished system, as conceived at this time, will be described in this section of the report and the current status of the development work in the next section.

As described in the previous section, the Texas Automated Mapping System produces a geographic data base (Figure 14) from aerial photography. The information in this geographic data base is captured in digital form at the time of acquisition and will provide the required base map for design using the Interactive Graphics Aided Design System. Although the Texas Automated Mapping System is not the only method which could be used by an agency to produce the geographic data base, it will be the method utilized by DHT since it requires a minimum manpower commitment to build and maintain a file of Departmental survey data. The development of the Texas Automated Mapping System is not considered a part of the development effort for the Interactive Graphics Aided Design System; however, parts of the development work for displaying and modifying graphics output will be conducted jointly and shared by both systems.

Development work on the Texas Automated Mapping System has been underway for some time and the description of the system in the previous section provides an overview of its design. Additional capa-

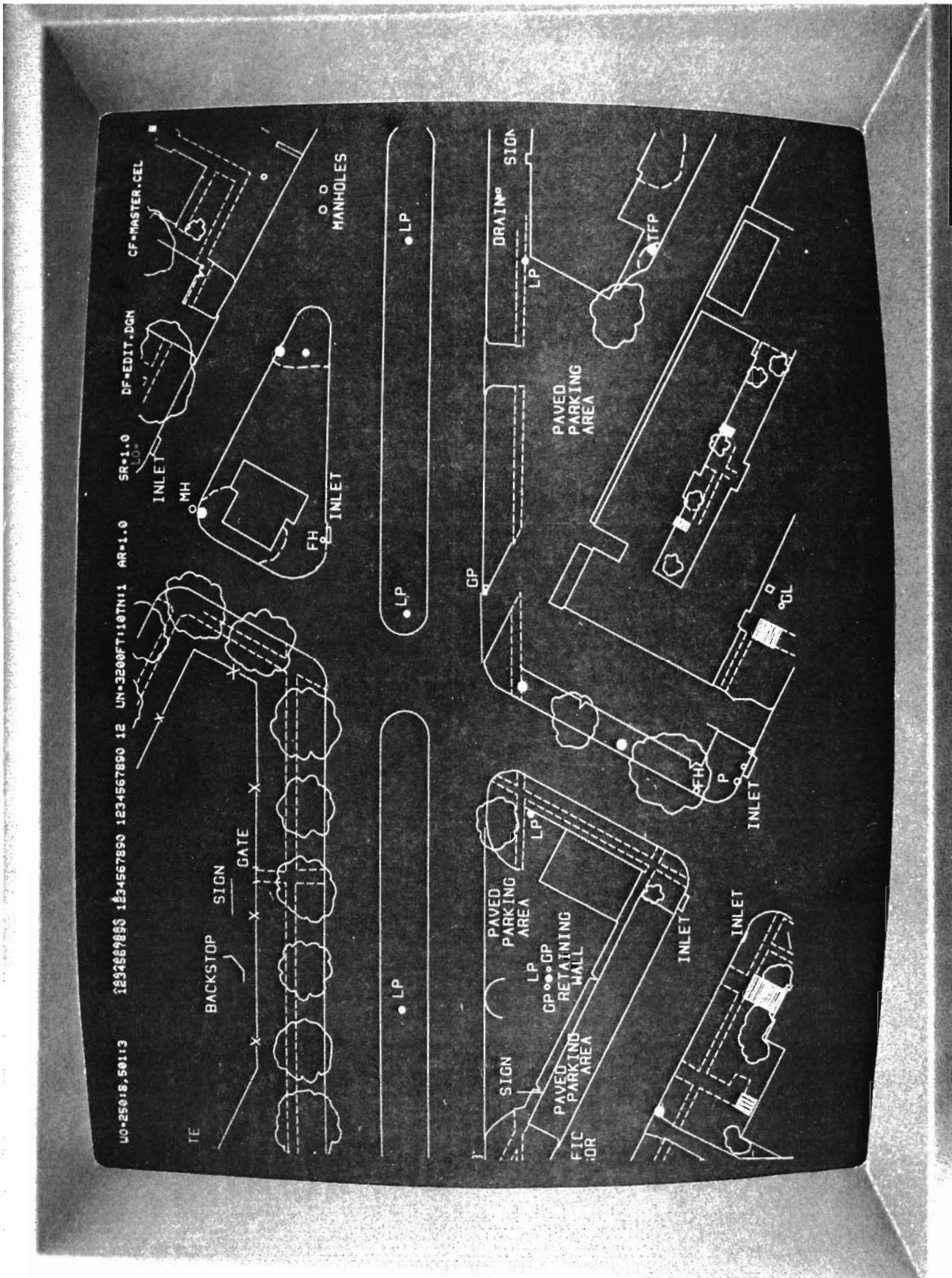


FIGURE 14. DISPLAY OF DESIGN MAP FROM GEOGRAPHIC DATA BASE

bilities which were not specifically mentioned include the use of the system for the production of large area maps such as counties and urban area maps (Figure 15). The proposed development work will primarily be devoted to a redesign of the geographic data base and the development of a General Plotting System which will provide capabilities to plot any data such as design drawings and maps. To provide other agencies with the same capabilities for developing a geographic data base for interactive graphics design, DHT agreed to make the Texas Automated Mapping System available under the development contract.

#### First Phase of Development

The first phase of development of the Interactive Graphics Aided Design System is designed to take advantage of the extensive digital graphics output of the existing Roadway Design System (RDS). Figure 16 provides a simplified schematic of this first phase of development. As shown on the schematic, in the upper left side, the Roadway Design System will maintain its present card input, printed output, and use of the project file. The plot generation routines were modified to output graphic element records instead of the digital plotter instructions. These records are output to a Graphics Interface File which is accessible by both the General Plotting System and the Interactive Graphics Drafting System. The Graphics Interface File developed by the Department provides a common format for all graphic data generated by the design systems, such as the Texas Automated Mapping System and the Roadway Design System. The data in the Graphics Interface File may be displayed using the Interactive Graphics Drafting System and/or converted to hard copy graphics

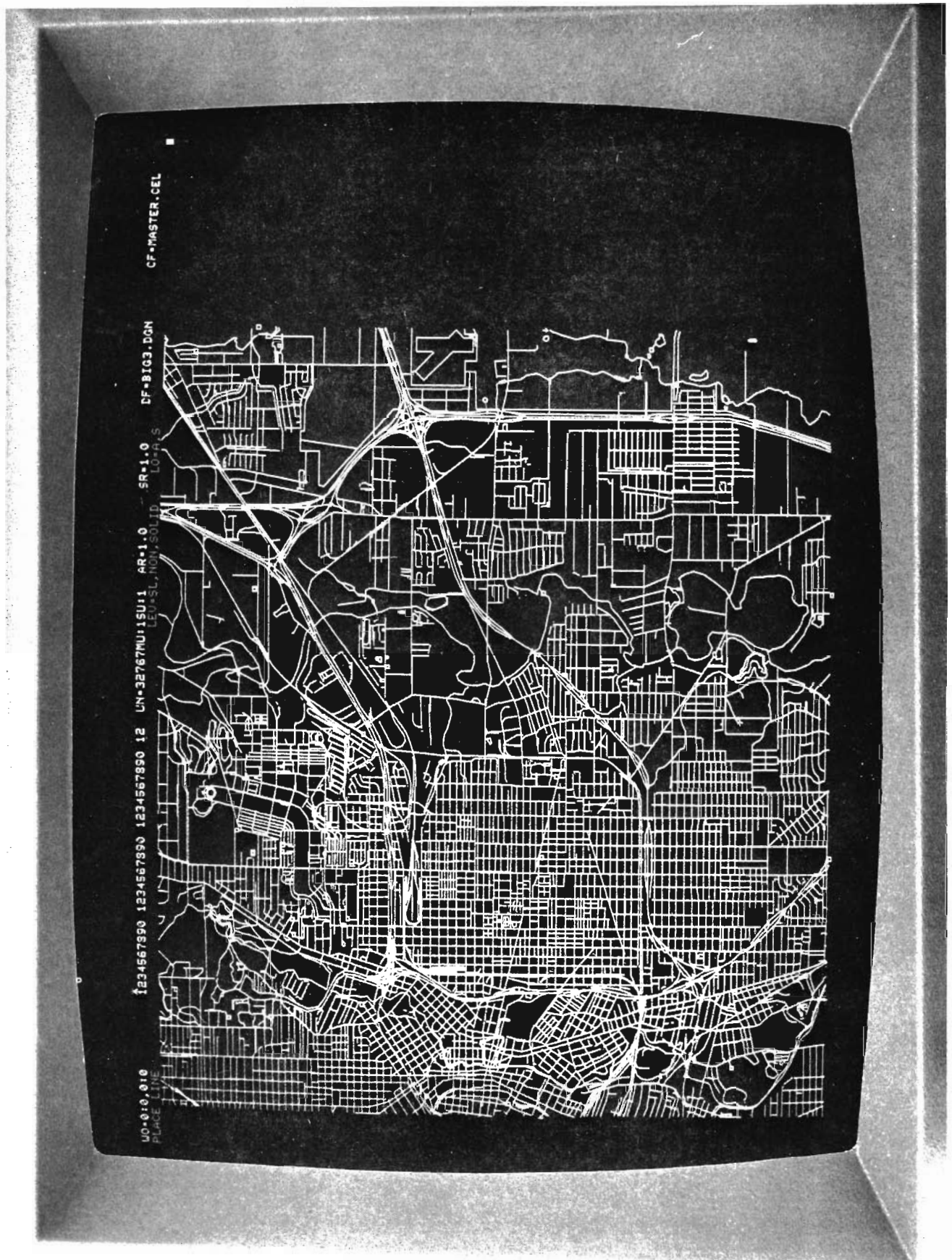


FIGURE 15. DISPLAY OF A PORTION OF A CITY MAP

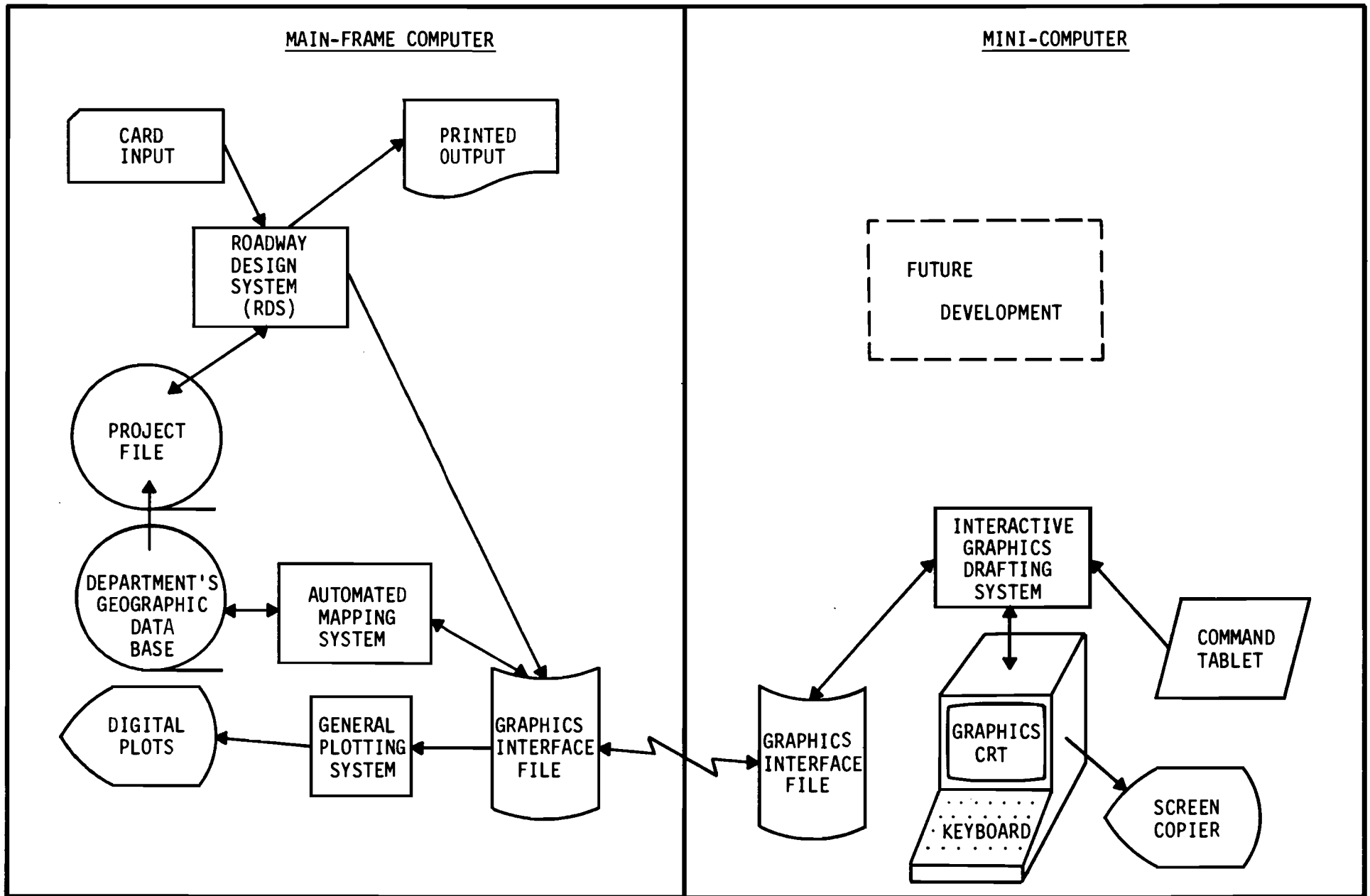


FIGURE 16. SCHEMATIC OF PHASE I OF THE INTERACTIVE GRAPHICS AIDED DESIGN SYSTEM

using the General Plotting System.

The Interactive Graphics Drafting System is controlled by a command tablet and keyboard and has the ability to perform such functions as modify the scale of the display, rotate or mirror the display, and add annotation or graphics elements. It provides extensive drafting capabilities and will allow the display of a combination of Roadway Design System graphics and Texas Automated Mapping System survey information. This will allow the user to perform such functions as draft complete plan profile or right of way plan sheets, review terrain cross-sections (Figure 17) or profiles (Figures 18 and 19), and draft structural detail sheets (Figures 20-22). All modifications to the graphics file will be transmitted back to the Graphics Interface File in the main frame computer for plotting through the General Plotting System. The Interactive Graphics Drafting System's capability of making a copy of any screen display will allow a designer to view information on the display screen and make a copy for more detailed review at his desk if required.

The geographic data base developed using the Texas Automated Mapping System will contain more information than will be needed on any one design project; therefore, the information needed for a specific project will be copied to a Roadway Design System project file for use in the design process.

This phase of development provides the user the ability to:

1. Process a design using the Roadway Design System
2. Review the graphic results on the CRT
3. Determine corrections or revisions
4. Make the necessary changes to the original Roadway Design System input and reprocess the data.

Hard copy graphics can be produced at any time during the above se-



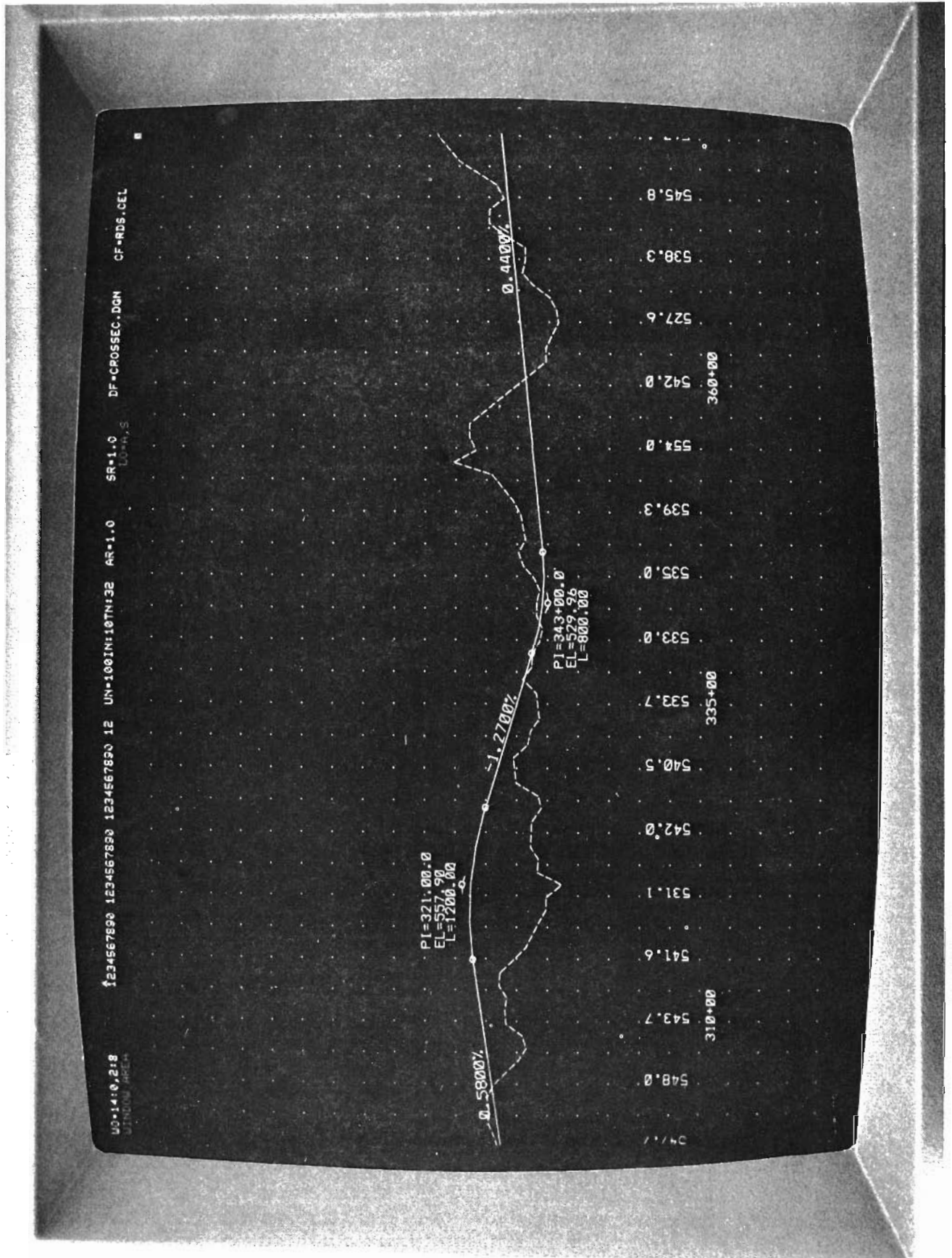


FIGURE 18. DISPLAY OF A PORTION OF AN ORIGINAL AND DESIGN PROFILE PLOT



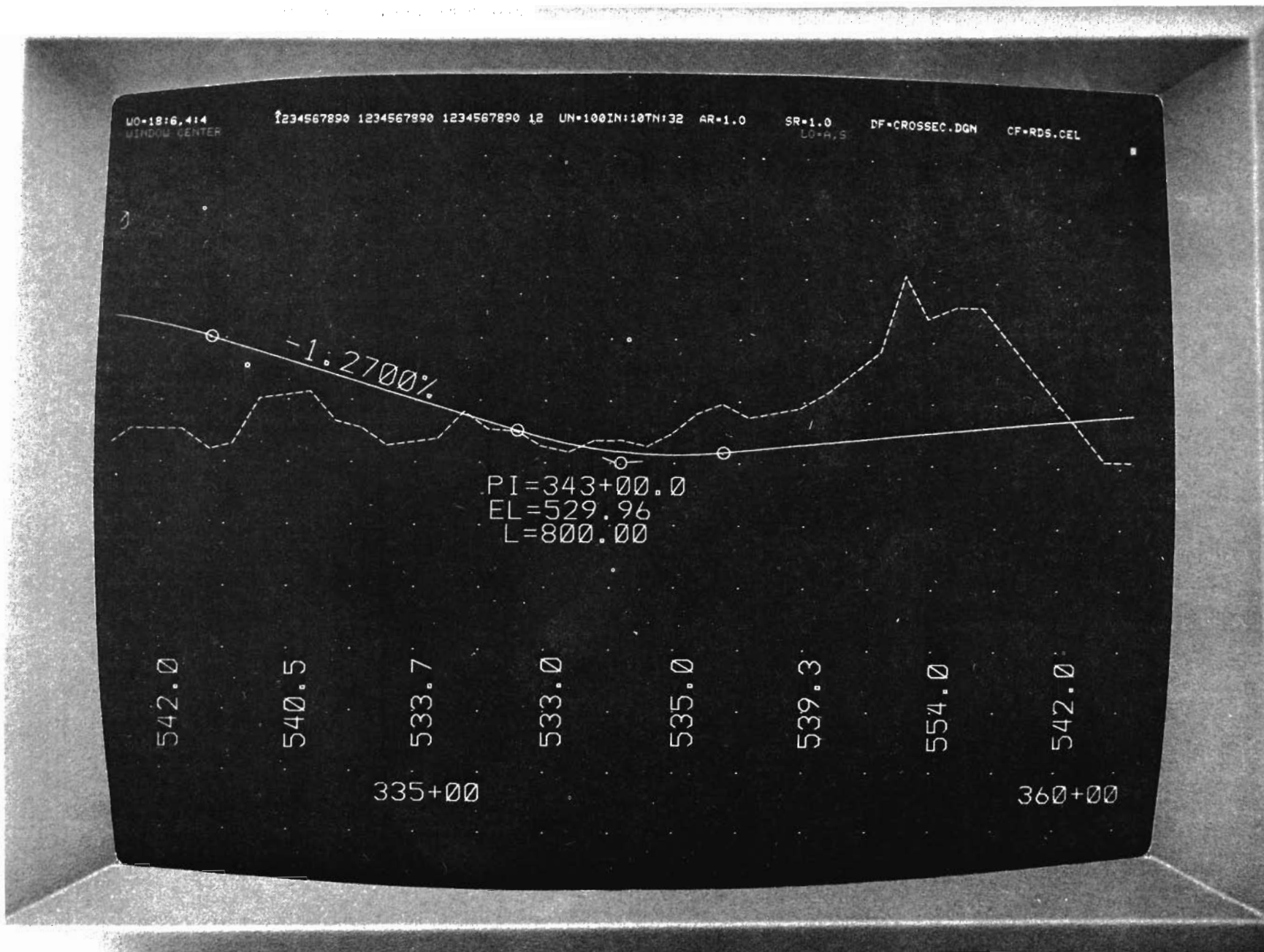


FIGURE 19. ENLARGEMENT OF PORTION OF FIGURE 18 (PROFILE PLOT)

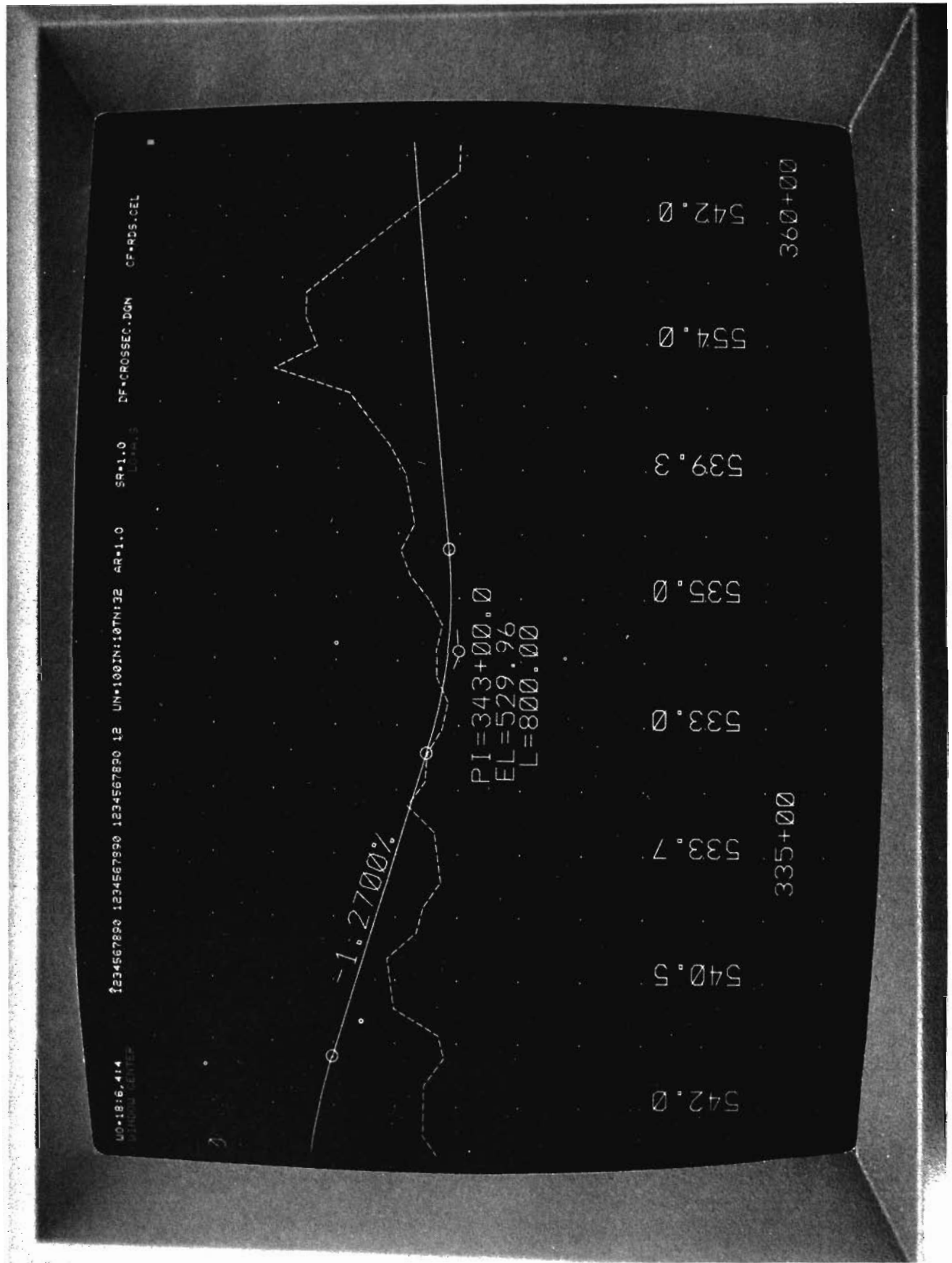


FIGURE 19. ENLARGEMENT OF PORTION OF FIGURE 18 (PROFILE PLOT)



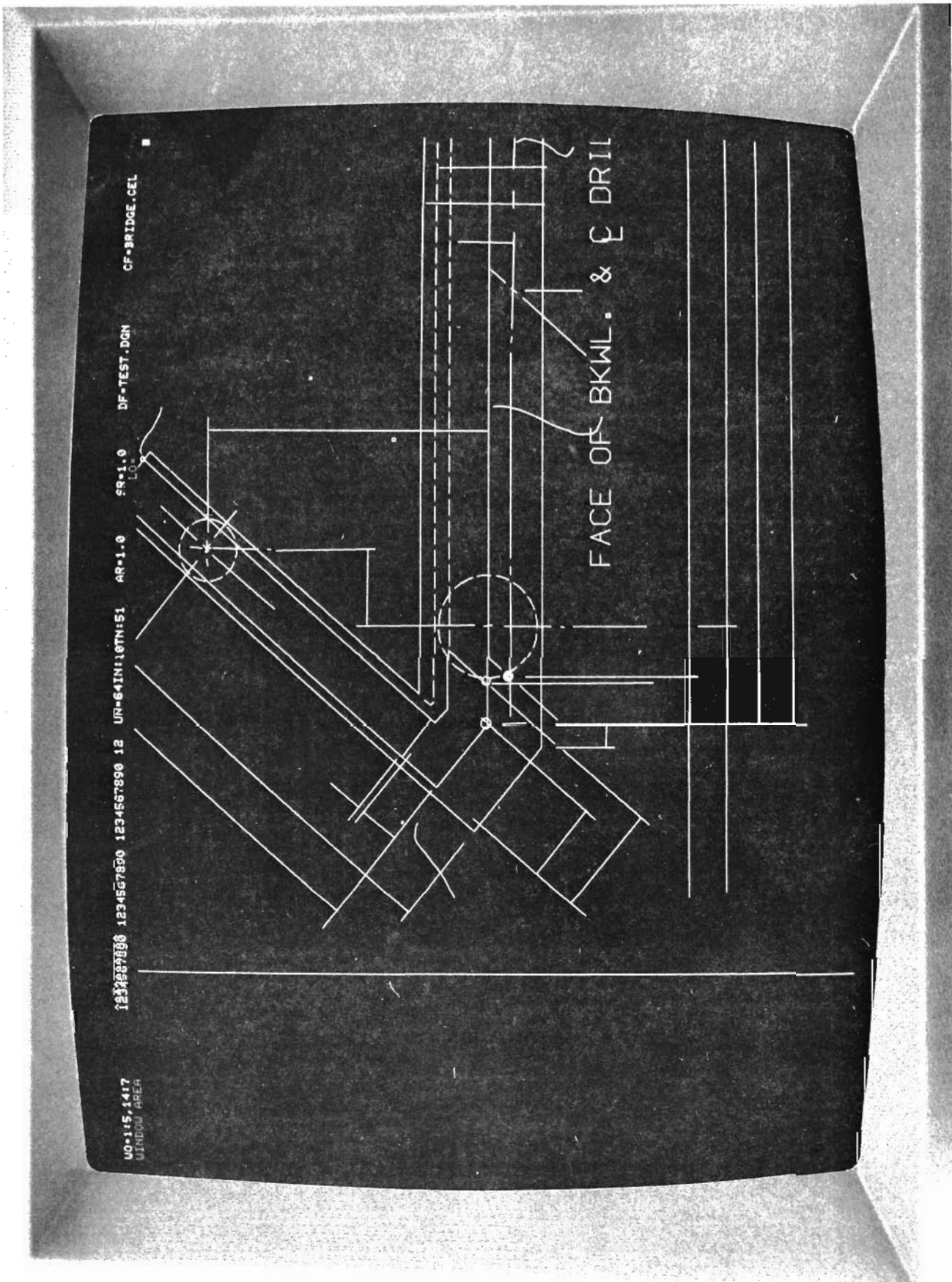


FIGURE 21. ENLARGEMENT OF PORTION OF FIGURE 20 (STRUCTURAL DETAIL SHEET)





quence using the General Plotting System. A user not having access to the Interactive Graphics Drafting System will process his Roadway Design System calculations as he has in the past but any requested plots will be produced by the General Plotting System. In addition, since the plotting will be through the General Plotting System, he will be able to superimpose Roadway Design System plots over the Texas Automated Mapping System design maps for the production of worksheets (or rolls), plan profile and/or right-of-way sheets.

#### Interactive Graphics Command Geometry Subsystem

The remaining phases of the project are specifically aimed at developing interactive graphics input/output capabilities for the Roadway Design System and other design systems. The existing card input capabilities of the systems will be retained. The first area of the Roadway Design System to be provided interactive graphics input capability will be command geometry which includes the bridge command geometry routines. Figure 23 provides a simplified schematic of the Interactive Graphics Aided Design System. Comparison of this schematic with the schematic of Phase I (Figure 16) indicates how the remaining development will interface and expand the development work on interactive graphics capabilities for the Texas Automated Mapping System and Phase I.

An input process will be developed for the minicomputer which will guide the user through his geometric calculations and prompt him (question him) to supply the required information. As the user inputs a geometric command, the resultant graphic representation will be displayed on the screen for immediate review and a data record will be stored for later transfer to the main frame computer. These data records will substitute for the card input currently used with

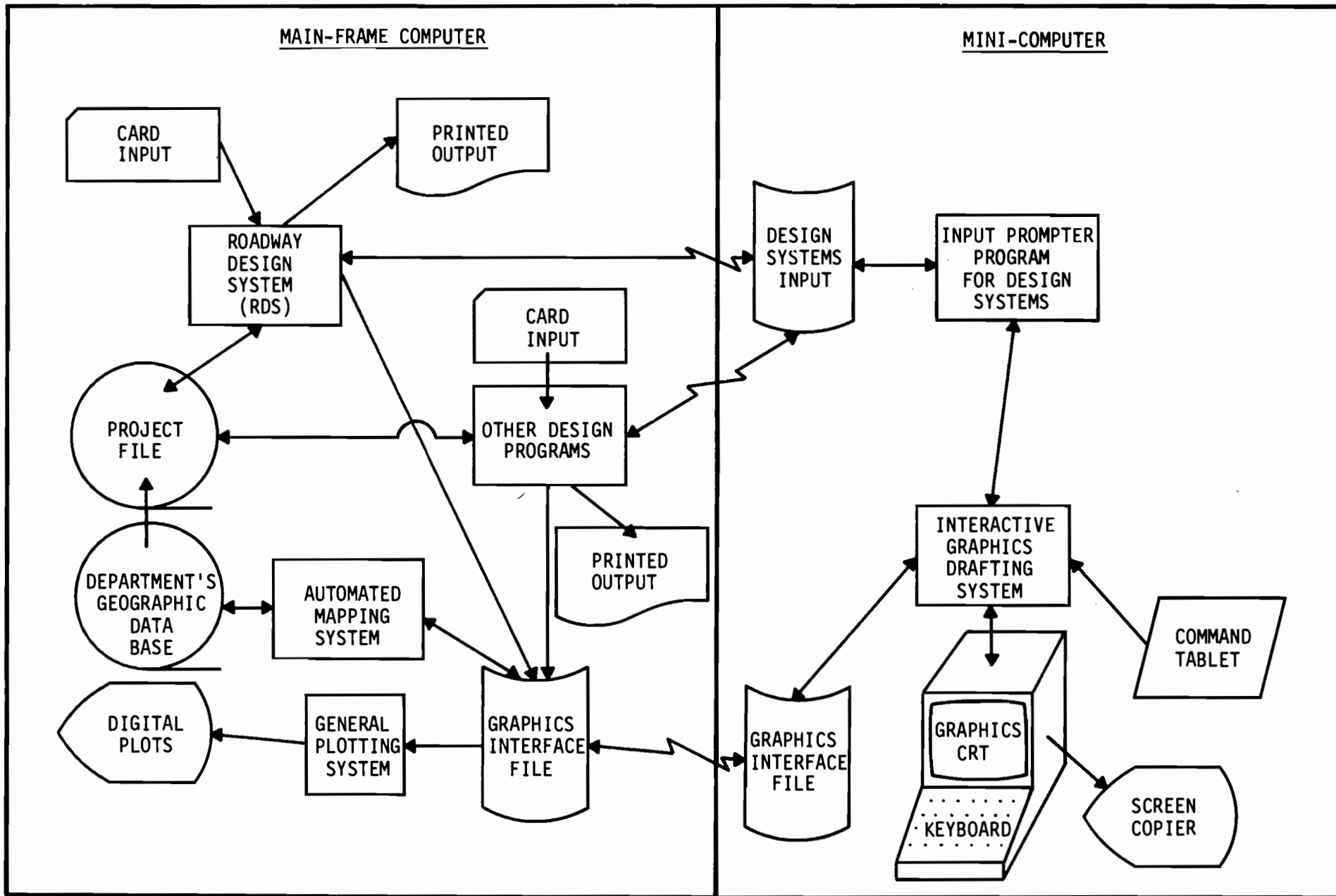
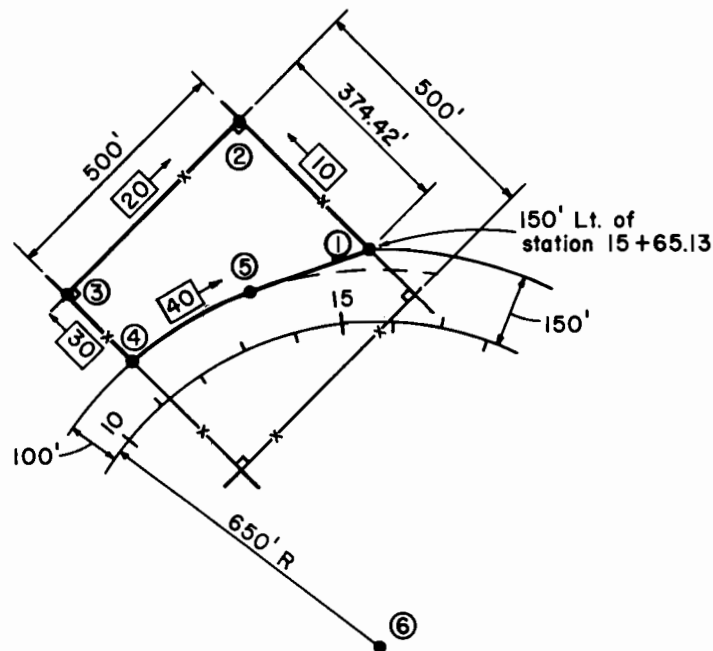


FIGURE 23. SCHEMATIC OF THE INTERACTIVE GRAPHICS AIDED DESIGN SYSTEM

the Roadway Design System. The graphics output resulting from the Roadway Design System processing will be available for transfer through the Graphics Interface File to the mini-computer system for review by the designer on the CRT.

For those not familiar with the Roadway Design System command geometry, the pages shown in the Appendix illustrate the card input and resulting output for a simple right-of-way calculation. These pages (2-6 through 2-16) were extracted from the "Roadway Design System Self Instructional Course Training Text". Although the example is not complex, it does provide an indication of the capabilities of the system. The sketch below from this example will be used to describe, in general, how the proposed Interactive Graphics Aided Design System would be used to perform command geometry calculations.



With a survey map from the geographic data base displayed as background, the physical features will be used by the designer in the



definition of needed geometric elements. For example, the property line (fence indicated with 10) could be defined by selecting two points on the fence line with the screen cursor. This line would be displayed and stored as line 10. Lines 20 and 30 could be similarly stored. Input using interactive graphics is further simplified by using graphic elements previously defined to define other elements. For example, point 3 could be defined by intersecting lines 20 and 30 which were previously defined. The user would have the option to select the two lines with the cursor. The resulting intersection point would be indicated as point 3 and stored. Another feature which can simplify the input is to use the cursor control to select each command from the command tablet. With each command represented on this tablet by a sketch, the user will be able to quickly identify the command needed for his next calculation. For example, the ISCT (intersect) command for two lines would be represented by two intersecting lines. As each command is selected, a unique response will appear on the screen indicating what data is required (prompting the user). Much of the input prompting will give the user a choice of selecting features from the screen or inputting the appropriate data from the keyboard. After the data for each command has been entered correctly, the resulting element will be displayed. The identification numbers will be assigned and displayed. The user will continue selecting the necessary commands to perform the desired geometric calculations for problems such as the example right-of-way. Development of input for geometric calculations in this manner will provide the user immediate visual edit of his input data. One benefit quickly identifiable by those users of command geometry is in the calculation of the intersection of a line and a curve. This partic-

ular geometric calculation results in two possible answers. By developing the input using the Interactive Graphics Aided Design System, the user will have the ability to immediately indicate the correct intersection on the screen.

The same process used in general command geometry calculations will be followed in the development of the specialized bridge geometry commands with similiar benefits. Figures 24 and 25 are example bridge frames designed using the Roadway Design System and displayed on the graphics CRT using the capabilities developed in Phase I. Additional Roadway Design System commands will be developed to more completely define the three dimensional aspects of a structure. This will allow more complete structural detailing (drafting) of both the horizontal and vertical geometrics of a structure.

#### Interactive Graphics Structural Design Subsystem

Another phase of development directly related to the bridge command geometry is the development of an Interactive Graphics Structural Design Subsystem. In this phase, the current interface between the Roadway Design System and the structural design systems for simple span prestressed concrete girder design and preliminary continuous beam design will be enhanced by the addition of selected structural design/analysis programs. The specific programs to be included have not been defined at this time; however, there are several programs available for use. It is not intended to develop interactive graphics structural design capabilities for all types of structures; only commonly used structures which justify their inclusion will be considered. The basic concept of the design will be similar to that described under the command geometry development. That is the substituting of interactive graphics input for the exist-

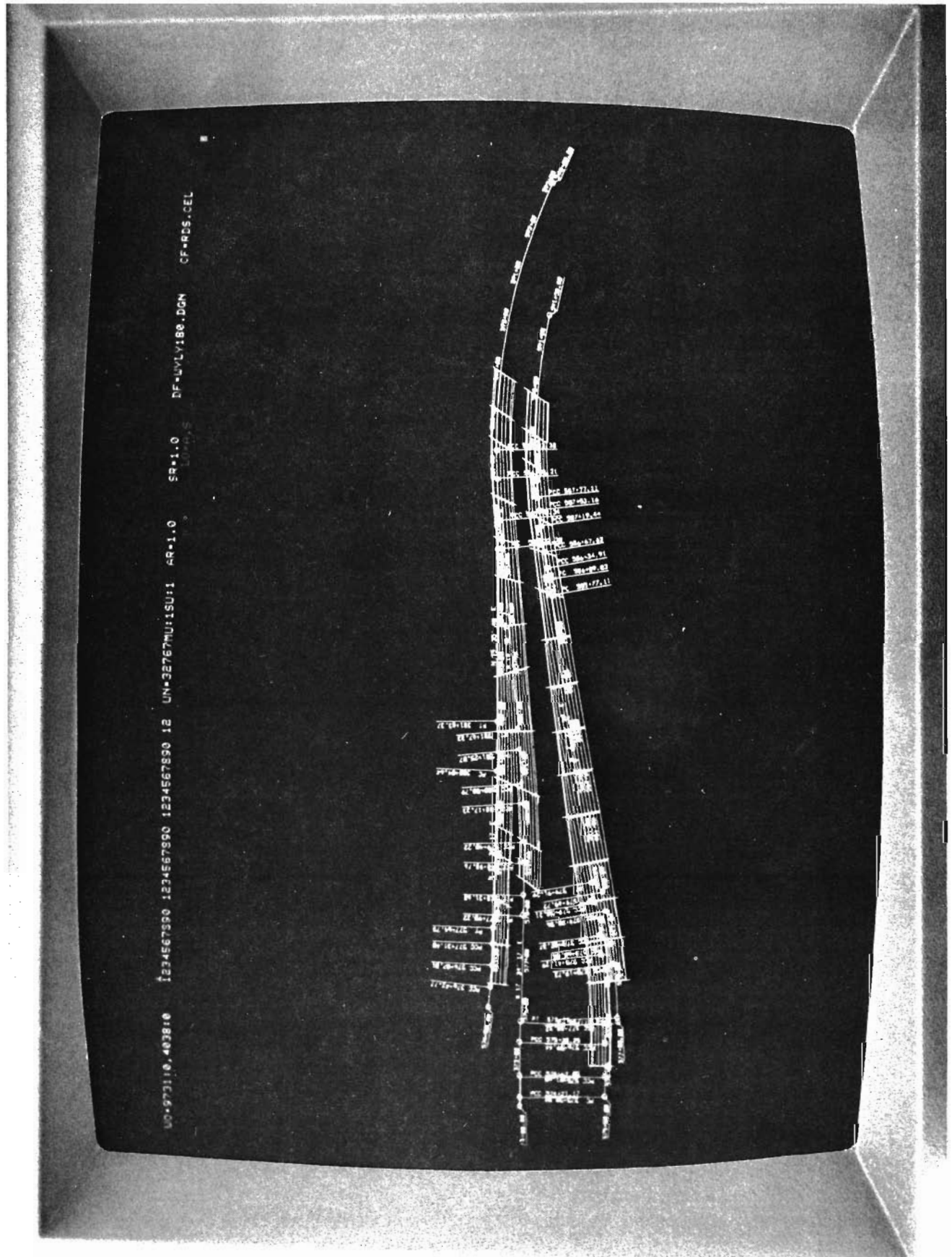


FIGURE 24. DISPLAY OF BRIDGE FRAMING PLOT

UO=230110,747810    1234567890 1234567890 1234567890 12    UN=32767MU:1SU:1    AR=1.0    SR=1.0    DF=UPLY180.DGN    CF=RDS.CEL  
 WINDOW CENTER    LU=H,S

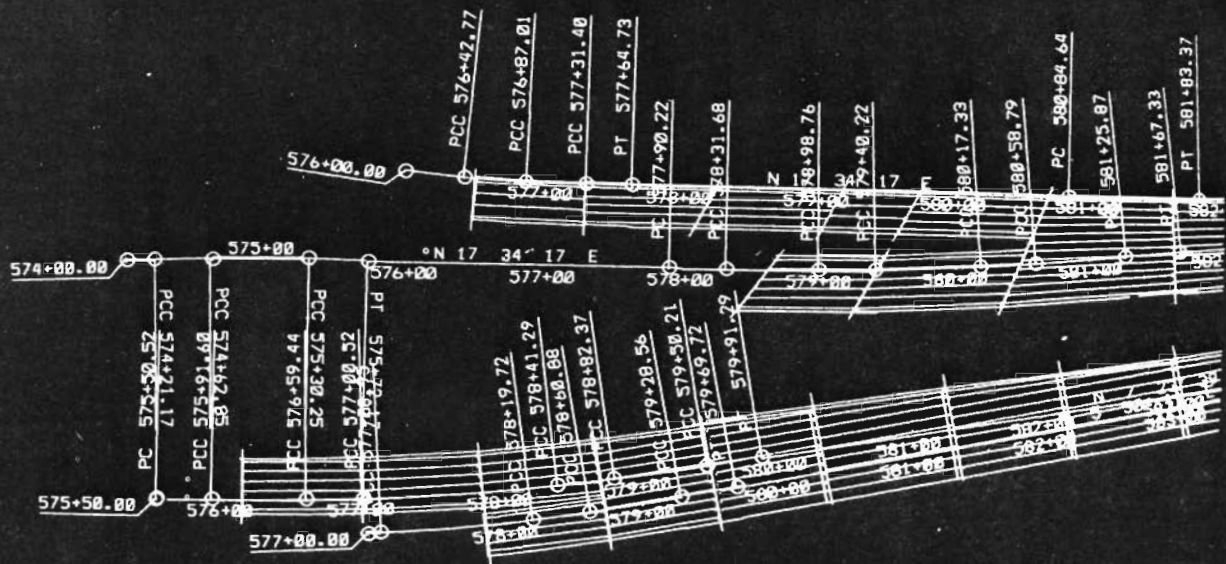


FIGURE 25. ENLARGEMENT OF PORTION OF FIGURE 24 (BRIDGE FRAMES)

ing card input. In the case of structural design programs, the input may be prompted text type rather than graphics oriented with emphasis on prompting the user and editing the input prior to performing the calculations on the main frame computer. Where beneficial, graphics representation of the input will be utilized. Emphasis will be placed upon transfer of information from one design function to another and the addition of interactive graphics drafting capabilities.

Development effort in this phase will be coordinated with the proposed NCHRP Project Number 12-18 entitled, "Development of an Integrated Bridge Design System", if at all possible. The elimination of duplication of effort between these two projects is essential and discussions with NCHRP indicating the potential duplication have been held.

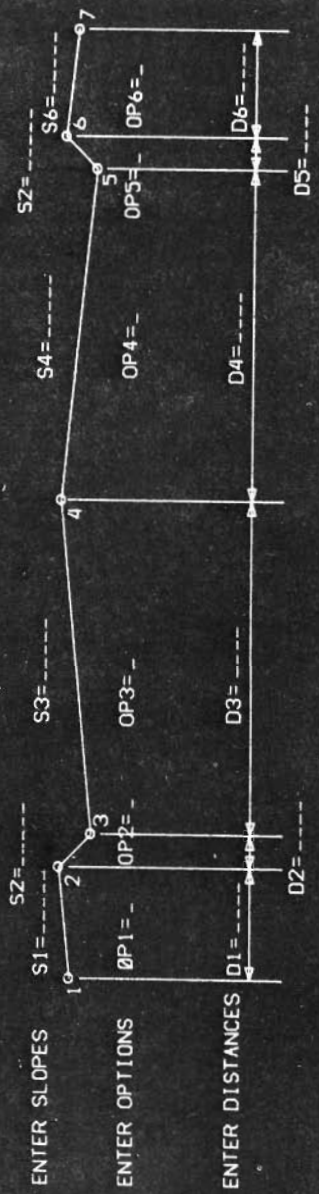
#### Interactive Graphics Earthwork Subsystem

Another area of the Roadway Design System capability which will benefit from interactive graphics is earthwork. Development in this phase of the project will include the replacement of the card input with a prompted input from the CRT terminal. The design effort in this phase has not begun; however, Figure 26 illustrates one possible method of inputting roadway template information. Since the roadway shape used in a specific geographic area is generally very similar for corresponding types of highways, the system should allow a user to predefine a master file of roadway, ditch, and median shapes and to recall them for modification and use for a particular project. The original ground profile from the Roadway Design System could be displayed as background for defining the design profile. The resultant design profile would be displayed superimposed over the original



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 LEU\*SL\*NON,SOLID

MASTER TEMPLATE A  
 STORE/RECALL NO. = --



ENTER 'S' OR 'F'  
 ENTER SUGRADE DEPTH  
 ENTER PROFILE GRADE POINT NO.  
 ENTER CENTERLINE POINT NO.  
 ENTER LEFT PIVOT POINT NO.  
 ENTER RIGHT PIVOT POINT NO.

FIGURE 26. DISPLAY OF ROADWAY TEMPLATE INPUT

ground profile (Figure 18). The user could make any necessary adjustments from a visual examination.

After all the design parameters are input, the resultant calculations will be performed on the main frame computer using the Roadway Design System. The resulting original and design cross-sections, mass haul diagram and earthwork quantities can then be reviewed on the CRT terminal and/or plotted on a digital plotter. Any necessary revisions to the design parameters required to adjust the quantity of material to be moved or to remove objectional design features would be defined using the graphics terminal. The revised input would be reprocessed on the main frame computer with subsequent review on the terminal. Also available for the user will be perspective views of the roadway. The designer will have the ability to modify and recompute his design as required and to try alternate designs in order to optimize construction costs. Needed digital plots of the calculations will be available at any time in the process using the General Plotting System.

#### Other Design Systems

Included in the work plan of the project is a phase of development which is contingent upon the time involved in completing the phases previously defined. If time is available, other design systems will be reviewed for inclusion into the Interactive Graphics Aided Design System. One possible system that will be considered is the Texas Hydraulics System (THYSYS). Inclusion of this system in the development effort will result in its interface with the project file and geometric calculation capabilities of the Roadway Design System. Three dimensional layout of a storm sewer would be possible

through the use of the geometrics from the Roadway Design System and the terrain defined in a numerical terrain model.



#### IV. Status

##### Current Status

The following will provide a brief statement of the current status of each phase of the development.

Automated Mapping System. This system is in full production use by the photogrammetric section of this Department with most of DHT's design maps being produced by it. The current production version could be implemented by any agency. Interactive graphics capabilities are not a requirement. Without an Interactive Graphics Drafting System, editing of the maps would be through hard copy edit plots as were used by this Department during the system's development. Annotation would be by manual drafting on the plotted map. This is the method used currently by this Department. The current version of the Texas Automated Mapping System has all required plotting capabilities internally in the system. Presently under design is a revision to the design file and development of the General Plotting System. Currently available is the ability to transfer graphic elements to the Interactive Graphics Drafting System for visual editing. Remaining to be developed is the reverse process and the updating of the design file with the edited and annotated map information.

Documentation of the system is complete with typing and finalization nearing completion. An implementable package of the system will be made available to the Federal Highway Administration by mid 1977. Any agency with a requirement to develop a geographic data base in preparation for implementation of the Interactive Graphics Aided Design System could obtain the necessary digitizing equipment and implement the existing package.

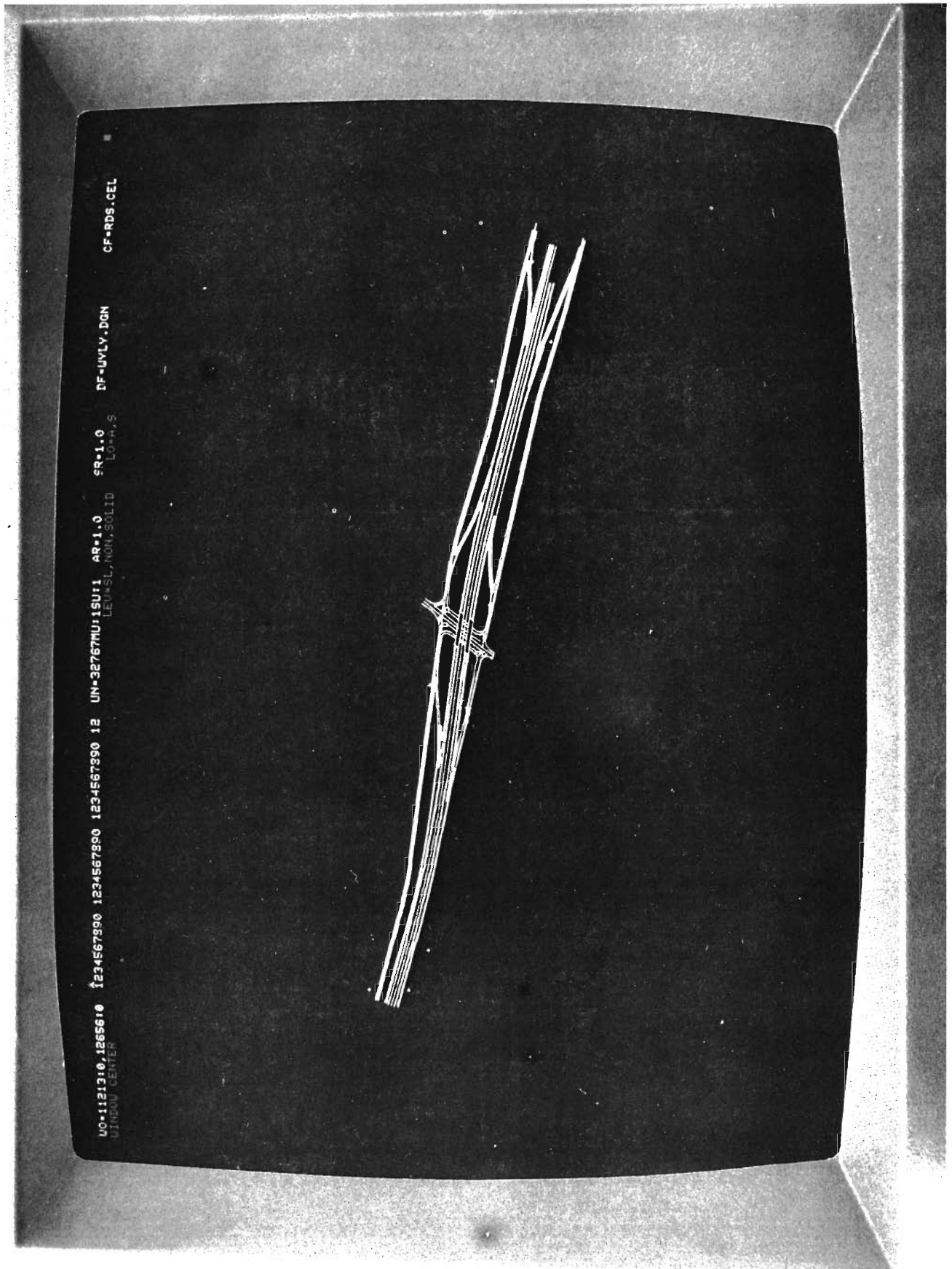
Roadway Design System. The Roadway Design System is in full production use by this Department and production runs average approximately 900 per month. It is utilized over the Department's RJE network from remote terminals by designers in its 25 Districts. Recent enhancements have been in the area of bridge construction elevation and layout calculations. In addition to use in this Department, the system has been furnished to over 50 other agencies by the Federal Highway Administration. Seven other transportation agencies and DHT have formed a user group and applied for sponsorship of technical support by the American Association of State Highway and Transportation Officials. This request has been approved and the contractual details are being prepared.

#### Phase I Development

The necessary modifications to the Roadway Design System have been completed or are currently being completed to generate graphic data in the Graphics Interface File format for display of all Roadway Design System plots on the CRT. Figures 27 through 29 provide additional examples of displays which have been processed through the Roadway Design System. Remaining to be developed is the reverse process to transmit data from the Interactive Graphics Drafting System to the Graphics Interface File and the General Plotting System. Development of the General Plotting System will take advantage of available capabilities of both the Roadway Design System and Texas Automated Mapping System, therefore reducing the total effort required.

#### Interactive Graphics Command Geometry Subsystem

The design of the user interface requirements for the command geometry portion of the Interactive Graphics Aided Design System is



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WINDOW CENTER LEV=SL, NON, SOLID LOW, S

FIGURE 27. DISPLAY OF PLOT OF AN INTERCHANGE

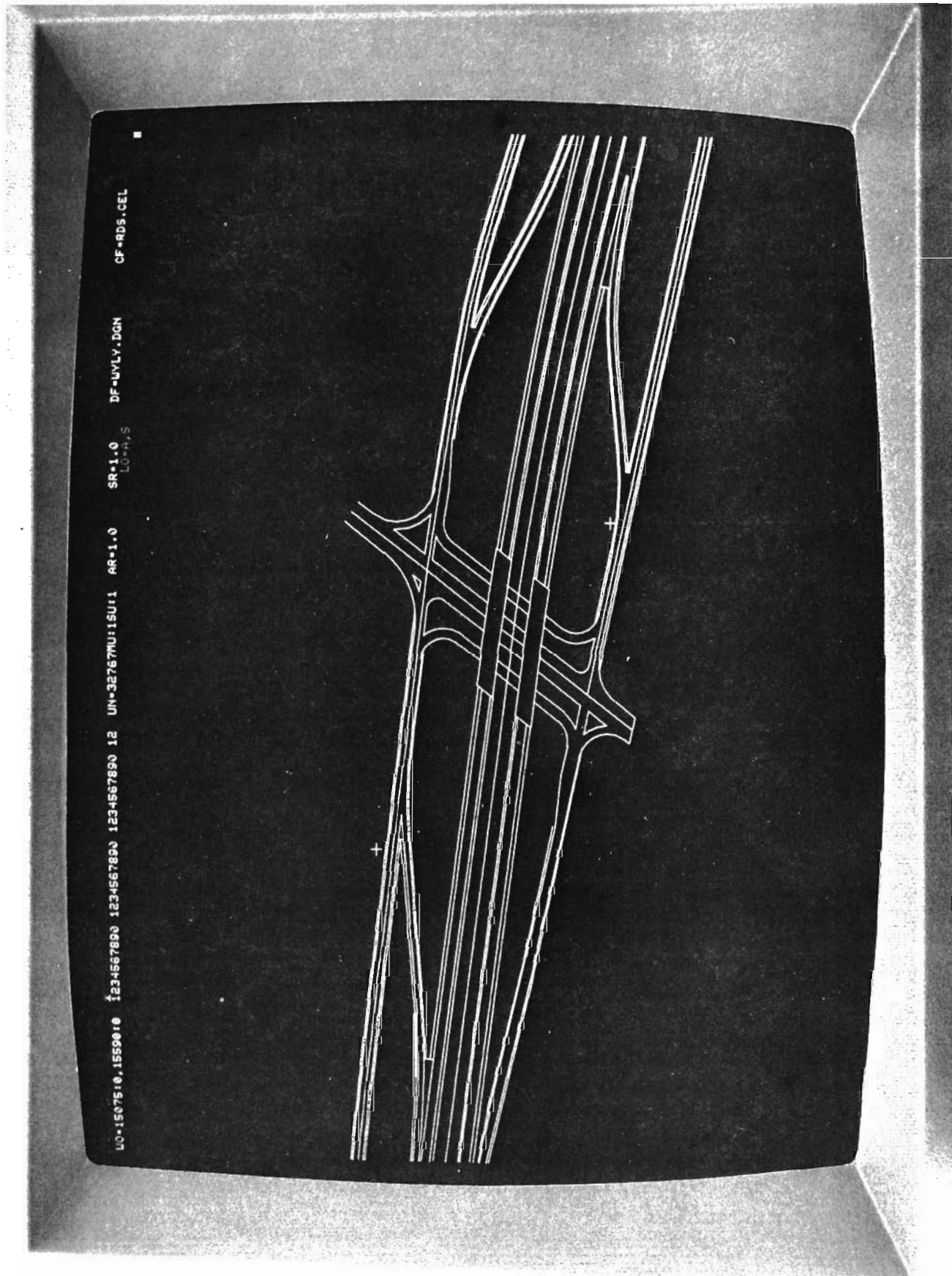


FIGURE 28. ENLARGEMENT OF PORTION OF FIGURE 26 (INTERCHANGE PLOT)

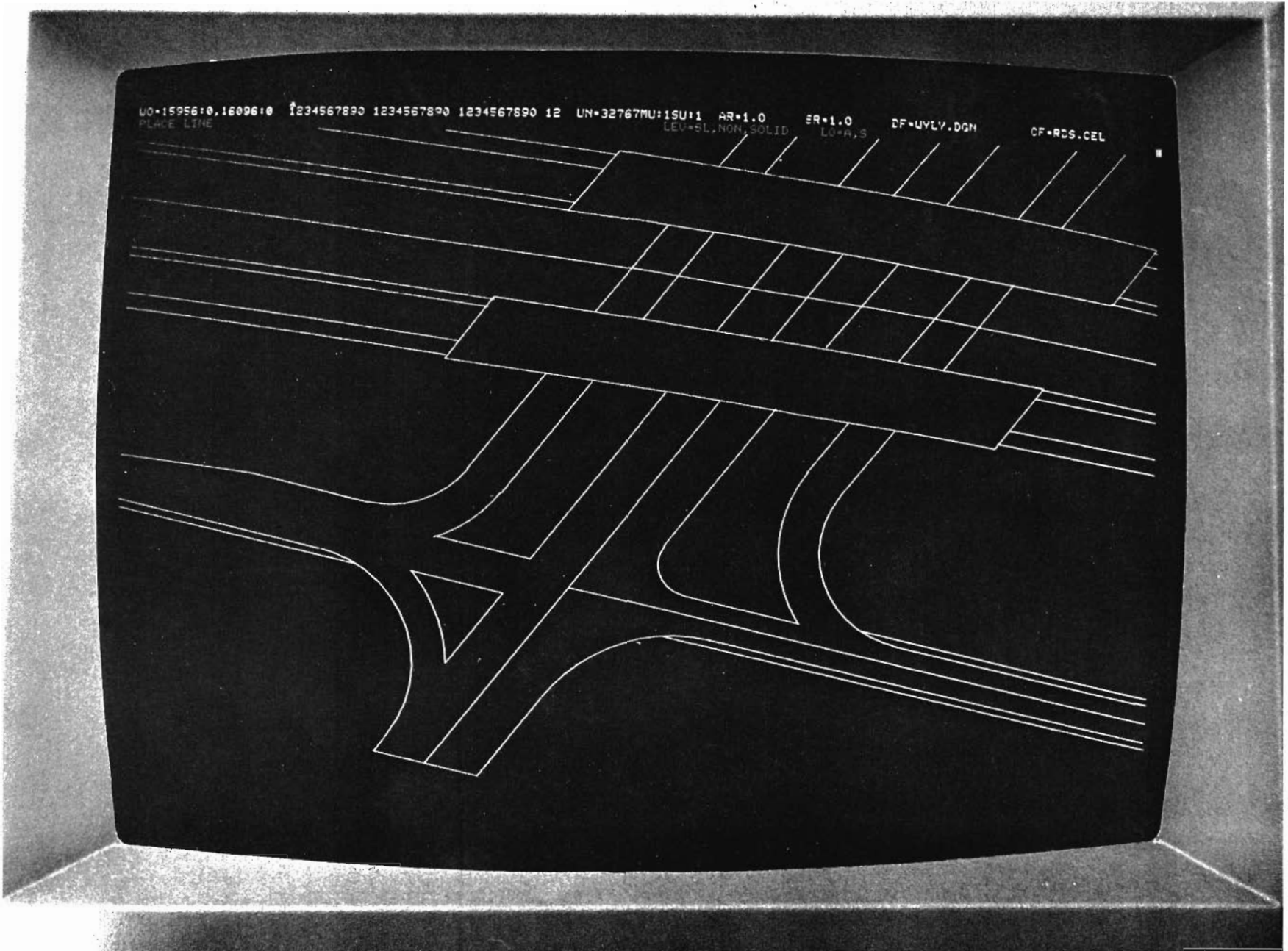


FIGURE 29. FURTHER ENLARGEMENT OF PORTION OF FIGURE 27 (INTERCHANGE PLOT)

being finalized with the detailed systems design of the Interactive Graphics Command Geometry Subsystem to be started in the near future.

Interactive Graphics Structural Design Subsystem

Analysis of the available structural design systems in preparation for detailed design of the Interactive Graphics Structural Design Subsystem is well underway. The project staff has assembled most of the systems used by the Department for detailed review. Completion of this analysis will allow the design of the necessary interfaces and input requirements. Coordination with the Contractor for NCHRP Project 12-18 will enhance this effort.

Interactive Graphics Earthwork Subsystem

Detail design on this phase of the system has not started; however the display of the graphics from the earthwork subsystem of the Roadway Design System being developed in Phase I will be utilized for this phase.



## V. Implementation

A full implementation package of the Roadway Design System (RDS) is available through FHWA Region 15 Demonstration Projects Office. Prior experience with the Roadway Design System by an agency interested in implementing the Interactive Graphics Aided Design System would be beneficial. The Roadway Design System Technical Support Capability should be functional in the near future, and help with implementation of the system from a qualified technical support staff should be forthcoming.

As outlined in the status of the Texas Automated Mapping System, an implementation package of the current version of the system will be available to FHWA sometime in the first half of 1977 for distribution to interested agencies. Implementation of the system will provide the ability to develop a geographic data base for design map preparation and the production of larger area maps such as county and city maps. The geographic data base will allow the user to produce maps at varying scales with varying details through input parameters.

Specifying a completion date of development which would be of benefit to other agencies is not possible at this time. However, the work is being performed in implementable phases; and, at the completion of each phase, the merit of making that phase available for implementation will be evaluated and recommended to the contract officer.

## VI. Potential Benefits

The potential cost savings of an Interactive Graphics Aided Design System are difficult to assess. However, it is certain that, as the current computerized systems provide cost and time savings over the manual process, the interactive graphics process with its more timely response and prompting of the user will provide additional savings through even more timely response. Perhaps the most cost savings in use of the Interactive Graphics Aided Design System can be realized by focusing an agency's calculation capabilities. Experience has shown that a specialist in the use of computer systems such as the Roadway Design System can perform design calculations in much less time than the infrequent user. To effect a balance between a computational specialist and a designer would appear to offer substantial savings in the design process. The design engineer could concentrate on the design requirements and supply the design to a specialist in the use of the computer programs with access to an interactive graphics terminal. This computer specialist would perform the required calculations for review by the design engineer. Any necessary revisions in the design would be defined and returned to the technician for reprocessing. Experience has shown that a very small number of specialists could perform the calculations for numerous design engineers; and, since the specialist would be adept at using automated techniques for production of plan sheets, the required number of technicians for plan preparation could be minimized.

One of the major benefits of the Interactive Graphics Aided Design System to the user will be the apparent man-computer interface. Since the user will input a command and the computer will



respond with an acknowledgement of completion of the requested function or request additional information, the delay experienced in the current card oriented process will be eliminated. This process is, of course, not new since systems developed under the time sharing system concept function in this manner. These systems do not have the graphics display capabilities of an interactive graphics system, however. The proposed system will provide this man-computer relationship but will not necessitate making the large main-frame computer with its high overhead costs directly available to the user as is the case with time sharing systems. The minicomputer will provide the necessary man-computer interface with the main-frame computer performing the calculations requiring its capabilities.

## VII. Recommendations

It is recommended that both the Roadway Design System and the Texas Automated Mapping System be made available to those agencies which would benefit from their implementation and use. It is also recommended that the project be continued with emphasis on completing the conversion of all Roadway Design System graphics to be displayable on the Interactive Graphics Drafting System and on completion of the development of the General Plotting System so that Phase I can be implemented. This will provide the potential users of an Interactive Graphics Aided Design System the ability to review graphics on the cathode ray tube and to provide input into the development effort. In addition, since design of the interactive graphics command geometry capability is nearing completion, it is recommended that this phase be pursued so that experience may be gained in the use of an interactive graphics design capability.

It is also recommended that as soon as the conversion of all Roadway Design System graphics has been completed that DHT place a demonstration terminal in selected DHT District offices for production use and input into the development effort.

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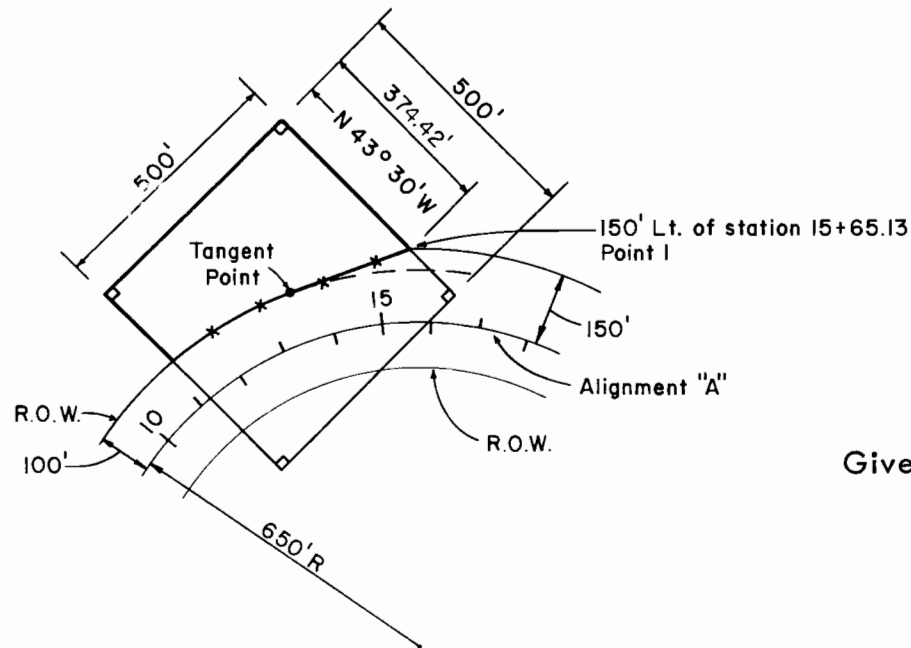
Appendix: Roadway Design System Command Geometry

## ROADWAY DESIGN SYSTEM COMMAND GEOMETRY

The following pages (2-6 through 2-16) are reprinted from the "Roadway Design System Self-Instructional Training Text". The complete training course which is made up of three separate books is available from the FHWA Region 15 Demonstration Projects Office. The pages supplied here give a portion of the command geometry example instructions.

Working with Commands

Try using commands to compute and plot the remainder on the left of the centerline for the right of way parcel shown below. Also compute the length of fencing required to fence the left right of way line along this parcel.



- Given:**
- + Alignment "A" previously stored.
  - + The total parcel is 500' square.
  - + Point 1 is 150' left of station 15+65.13.
  - + Bearing of northeast boundary is N43°30'W
  - + R.O.W. limits as shown.
- Find:** The remaining area on the left and the length of new fencing required.

This problem will give you a basic introduction to the use of Commands. A more detailed look at Commands will be given later in this chapter and in Run 5.






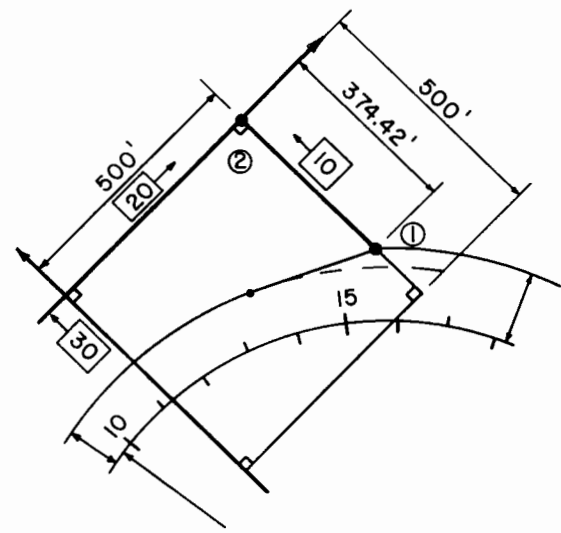




PERL and PARL

Step  Construct and store curve 20 through point 2 perpendicular to curve 10. Use the PERL command, input option II. Refer to table VI. Also construct and store curve 30. Use the PARL command.

CARD NO.	COMMAND	A	B	C	D	E	F	X-COORDINATE OR CORRECTION	Y-COORDINATE OR STATION	RADIUS, OFFSET, DISTANCE, ETC.	BEAR, AZ, OR SKEW									
											N	S	DEG	MIN	SEC	E	W			
10	1	CMNT						STORE POINT	1											
11	2	PONT	/				A		1565.13	-150.										
12	3	CMNT						STORE CURVE	10											
13	4	CURV	/	10																
14	5	CMNT						STORE POINT	2											
15	6	TRVS	/	10	2		A			+374.42										



Check your input on the next page.



5

ISCT curves 20 and 30 to get point 3.

6

OSCT curve 30 with an offset 100' to the left of alignment A to get point 4.

7

Store curve 40 concentric to the centerline offset 100' to the left.

8

Use the TANG command to locate and store point 5.

9

Store point 6 as the radius point of the alignment.

10

Compute the length of the new fence. Use the ANGL command to compute the arc length from point 4 to point 5 and use the BRDS command to compute the distance from point 5 to point 1.

11

Now compute and plot the area of the remainder to the left of the centerline.

12

Finally compute the station and offset of point 5.



Here is the correct input.

CARD NO.	COMMAND	A	B	C	D	E	F	X-COORDINATE OR CORRECTION	Y-COORDINATE OR STATION	RADIUS, OFFSET, DISTANCE, ETC.	BEAR, AZ, OR SKEW									
											N	S	DEG	MIN	SEC	E	W			
1	CMNT							STORE POINT 1												
2	PONT	1					A		1565.13	-150.										
3	CMNT							STORE CURVE 10												
4	CURV	1	10																	
5	CMNT							STORE POINT 2												
6	TRVS	1	10	2			A			+374.42										
7	CMNT							STORE CURVES 20 AND 30												
8	PERL	10		2	20															
9	PARL	10			30															
10	CMNT							STORE POINTS 3 & 4												
11	ISCT	20	30	3			A													
12	OSCT	30	4				A		1100.	-100.										
13	CMNT							STORE CURVE 40												
14	CURV	40					A		1200.	-100.										
15	CMNT							STORE POINT 5 (TANGENT POINT)												
16	TANG	40	1	5			0													
17	CMNT							STORE POINT 6 (RADIUS POINT FOR ALIGNMENT A)												
18	PONT	6					A		1200.	+650.										
19	CMNT							COMPUTE LENGTH OF FENCE												
20	ANGL	4	6	5						750.										
21	BRDS	5	1																	
22	CMNT							NOW COMPUTE AND PLOT AREA OF REMAINDER												
23	EJCT																			
24	CMNT							REMAINDER ON LEFT												
25	AREA	4	3	2	1	1														
26	AREA	5	4							-750.										
27	CMNT							COMPUTE STATION AND OFFSET OF POINT 5												
28	YPNT	5					A													

Did you get it right? Good. If not, go back and review. The output is on the next two pages. The plot is not included, but there will be an example of an AREA plot in Run 5.



GENERAL GEOMETRY LIST													
CD NO	COMMAND	A	B	C	D	E	F	X-COORDINATE OR CORRECTION	Y-COORDINATE OR STATION	RADIUS, OFFSET DISTANCE, ETC.	ELEV.	BEAR, AZ, SKEW D M S	STORE
****STORE POINT 1													
2	PONT	1	0	0	0	A	0	0.0 100437.6465	1565.1300 500327.8459	-150.0000 0.0	0.0	0 0 0.0 0 0 0.0	SP 1
****STORE CURVE 10													
4	CURV	1	10	0	0	0	0	0.0 100437.6465	0.0 500327.8459	0.0 0.0	0.0	N 43 30 0.0 W N 43 30 0.0 W	SC 10
****STORE POINT 2													
6	TRVS	1	10	2	0	0	0	0.0 <u>100179.9128</u>	0.0 <u>500599.4406</u>	374.4200 0.0	0.0	0 0 0.0 0 0 0.0	SP 2
****STORE CURVES 20 AND 30													
Computed coordinates of Point 2													
8	PERL	10	2	20	0	0	0	0.0 100179.9128	0.0 500599.4406	0.0 0.0000	0.0	R 0 0 0.0 F N 46 30 0.0 E	SC 20
Computed bearing of Curve (line) 20													
9	PARL	10	0	30	0	0	0	0.0 100074.9593	0.0 499983.6686	-500.0000 0.0	0.0	0 0 0.0 N 43 30 0.0 W	SC 30
****STORE POINTS 3 & 4													
11	ISCT	20	30	3	0	A	0	0.0 99817.2256	0.0 500255.2633	0.0 0.0	0.0	0 0 0.0 0 0 0.0	SP 3
Computed station and offset of Point 3													
12	OSCT	30	4	0	0	A	0	0.0 99963.4651	1100.0000 500101.1590	-100.0000 0.0	0.0	0 0 0.0 0 0 0.0	SP 4
Computed station of Point 4													
14	CURV	40	0	0	0	A	0	0.0 100447.0721	1200.0000 499527.9014	-100.0000 <u>750.0000</u>	0.0	0 0 0.0 0 0 0.0	SC 40
Computed radius of Curve 40													

GENERAL GEOMETRY LIST

CD NO	COMMAND	A	B	C	D	E	F	X-COORDINATE OR CORRECTION	Y-COORDINATE OR STATION	RADIUS, OFFSET DISTANCE, ETC.	ELEV.	BEAR, AZ, SKEW D M S	STORE
****STORE POINT 5 (TANGENT POINT)													
16	TANG	40	1	5	0	0		0.0	0.0	0.0		0 0 0.0	
								100177.8170	500227.9027	0.0	0.0	0 0 0.0	SP 5
								100699.7587	500234.0526	0.0	0.0	0 0 0.0	NS 0
****STORE POINT 6 (RADIUS POINT FOR ALIGNMENT A)													
18	PONT	6	0	0	0	A	0	0.0	1200.0000	650.0000		0 0 0.0	
								100447.0721	499527.9014	0.0	0.0	0 0 0.0	SP 6
****COMPUTE LENGTH OF FENCE													
20	ANGL	4	6	5	0	0		0.0	0.0	750.0000		0 0 0.0	
								<u>250.1778</u>	126.2618	750.0000	0.0	<u>19 6 43.83</u>	NS 0
Computed Arc Length from Point 4 to Point 5													
21	BRDS	5	1	0	0	0		0.0	0.0	0.0		0 0 0.0	
								100177.8170	500227.9027	<u>278.3882</u>	0.0	<u>N 68 57 38.86 E</u>	NS 0
****NOW COMPUTE AND PLOT AREA OF REMAINDER													
Computed bearing and distance from Point 5 to Point 1													
****REMAINDER ON LEFT													
AREAS TABULATION													
INIT. PT	FINAL PT	DISTANCE (FT)	BEARING (DMS)	ARC LENGTH	DEPARTURE (FT)	LATITUDE (FT)	X-COORDINATE (FT)	Y-COORDINATE (FT)	RADIUS				
4	3	212.4479	N 43 30	0.0	W	0.0	-146.2395	154.1042	99817.2256	500255.2633	0.0		
3	2	500.0000	N 46 30	0.0	E	0.0	362.6872	344.1773	100179.9128	500599.4406	0.0		
2	1	374.4200	S 43 30	0.0	E	0.0	257.7337	-271.5947	100437.6465	500327.8459	0.0		
1	5	278.3882	S 68 57 38.86	0.0	W	0.0	-259.8295	-99.9432	100177.8170	500227.9027	0.0		
5	4	249.0195	S 59 24 16.95	W	250.18	-214.3520	-126.7436	99963.4651	500101.1590	-750.0000			
TOTAL AREA = 139232.4546 SQ FT <u>3.1963 ACRES</u> TOTAL LATITUDE = 0.0 TOTAL DEPARTURE = 0.0													
****COMPUTE STATION AND OFFSET OF POINT 5													
28	YPNT	5	0	0	0	A	0	0.0	0.0	0.0		0 0 0.0	
								100177.8170	500227.9027	0.0	0.0	0 0 0.0	NS 0
								0.0	1334.1062	-100.0000	0.0	0 0 0.0	NS 0