COMPUTER AIDED DESIGN PARAMETERS FOR FORWARD BASING

A Special Research Problem

Presented to

The Faculty of the School of Civil Engineering
Georgia Institute of Technology

by

Gerardo M. Salsano

In Partial Fulfillment
of the Requirements of the Degree of
Master of Science of Civil Engineering

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DEDICATION

This work is dedicated to the memory of Lieutenant Colonel James G. Novakoski (USAF, Ret) who taught me more about hard work, discipline, and determination in the short two years I new him than any other person I've known. Jim taught me the meaning of family. He showed me how to work hard, how to play hard, and how to decide the proper time for each. His guidance has led me to this point in my life and I feel honored to have come so far. Thank you, Jim. I think of you often.

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LIST OF ABBREVIATIONS AND ACRONYMS

2-D	two dimension
3-D	three Dimension
ABDR	air base damage repair
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
ATDC	Advanced Technology Development Center at Georgia Tech
BPI	bits per inch
CAD	computer aided drafting
CCT	computer compatible tapes
CNES	Centre National d'Etudes Spatiales
GOGO	coordinate geometry
DEG	degrees
DEM	digital elevation model (USGS term)
DFAD	digital feature analysis data (DMA term)
DLG	digital line graph
DMA	Defense Mapping Agency
DOS	disk operating system
DTED	digital terrain elevation data (DMA term)
DXB	AutoCAD drawing file interchange format
DXF	AutoCAD drawing file interchange format
EGA	enhanced graphics adaptor or array
EOSAT	Earth Observation Satellite Company
ERTS	Earth Resources Technology Satellite
ERS	ESA Resources Satellite
ESA	European Space Agency
FOR-TRAN	Formula Translation programming language
GCP	ground control points
GIS	Geo-based Information System
GRS	Grid Reference System (SPOT term)
GTRI	Georgia Tech Research Institute
GWN-DTM	GWN System's Digital Terrain Model software

HCMM heat capacity mapping mission

IBM International Business Machines

KM kilometer

MEF minimum essential facility (USAF term)

MOS marine observation satellite

MSC multi-spectral camera

MSL mean sea level

MSS multi-spectral scanner

NDCDB National Digital Cartographic Data Base

NHAP National High Altitude Program

OS-2 IBM's new micro-channel architecture operating system

PS/2 IBM's Personal System/2

RAM Random Access Memory

RBV three-camera return beam vidicon

RMSE root mean square error

SAR synthetic aperture radar

SPOT Satellite Pour l'Observation de la Terre

TA2 standard ASCII format for 3-D data (X, Y, Z)

TM thematic mapper

TTM Triangulated Terrain Model

USAF United States Air Force

USGS United States Geological Survey

UTM universal transverse Mercator

VGA video graphics adaptor or array

WDB World Data Bank

WGS World Geodetic System

SUMMARY

Problem

Forward bases are those military installations strategically located around the world equipped with the minimum facilities necessary to conduct war-fighting operations if necessary. Construction of these facilities in remote locations offers many challenges to the architect, engineer, and builder. Beginning with site selection and ending with the completion of construction, a myriad of problems face the responsible group. Site surveys may be difficult to acquire because the site is inaccessible due to geographical remoteness, armed conflict, host nation tension, or simply because the proposal must remain classified information. Not being able to "walk" the site is a major obstacle for all concerned.

Computer aided design (CAD) packages coupled with digital topographical data, collected by satellite, may offer a solution to these problems. The overall objective is to develop a system capable of retrieving satellite imagery into a CAD environment and using that data to site, engineer, and construct the required facilities.

The total system should be able to retrieve, import, and manipulate the site data and combine it with proposed

construction data. The user should then be able to make siting decisions, accomplish the layout work, and produce all the necessary construction drawings. Ideally, the system should automate some or all of the process and should also generate manpower, material, and equipment estimates.

Solution

This paper is one of the first steps in developing such a system. It focuses on the background of the systems and software which must be brought together for the proposal to work. Specifically the following goals were pursued:

1. Determine software and hardware availability and capabilities.
2. Determine data availability
3. Acquire a data set
4. Choose a software-hardware combination and perform some elementary data importation.
5. Create a simple construction entity and overlay it on the data set.
6. Manipulate and do a graphical output of the combination data set.
7. Do a preliminary evaluation and make recommendations.

Conclusions

There are a number of software and hardware packages, currently available, which will perform the basic functions required by this project. Of those reviewed, however, no single package in its present form seems capable of doing all the required work. Of the available satellite data, a major portion is of insufficient resolution to be of use to the designer or engineer. There are avenues, though, to acquire the data in sufficient resolution for the prescribed needs.

The test system demonstrated that the required elementary operations are possible. These included conversion, importation, and 3-dimensional (3-D) display from various viewpoints. It also included creation and insertion into the data set of a 3-D construction entity. Computational times were excessive on the test system, with screen regenerations requiring as much as 4 or 5 hours when coupled with hidden line representation.

This type of work requires hugh amounts of mass storage and RAM. The ideal system should provide extremely fast processing speed (for both computations and graphics) to make it functional.

In general, this project revealed that the technology exists today to field a system capable of the proposed functions. While that technology exists, for the most part, in commercially available systems, it does not come together in any one system. Consideration should be given to eschewing the use of existing systems and designing a task-specific system around a graphics kernel. Doing so, the developer could eliminate the overhead associated with maintaining a general application system and design an efficient system capable of only the tasks necessary. Resident memory requirements could be minimized and more efficient storage methods for data sets could be developed.

CHAPTER 1

INTRODUCTION

It must be noted at the start this is not ground-breaking work. It represents a compilation of existing technology, data, software, and hardware brought together to perform a certain unique task. Second, it must be noted that this volume is not all-inclusive. It is intended as a starting place for subsequent work in the same area by students to follow. The primary focus is to bring together, in one document, the background data necessary to facilitate and expedite further investigation.

Project Goals

The larger research and development project, of which this problem is a subset, is as follows: The objective of the overall project is to develop a system, presumably ideally microcomputer-based, capable of using existing digital terrain data inside a computer aided design package to graphically portray, in three dimensions, proposed sites for military bare bases. Additionally, the system should be capable of performing normal CAD functions and further computations resulting in a variety of outputs ranging from construction drawings to estimates. The main goal is to better manage the siting and constructability problems associated with working in remote locations. A bare base is a preselected site which either already possesses, or will have constructed, minimum essential facilities (MEFs). Minimum essential facilities are those minimum features which cannot be quickly or easily constructed but which are required to support a war fighting effort. As an example, for United States Air Force (USAF) use, they include airfield pavement, hardstand parking facilities, a water supply, and a fuel storage facility.

Upon acquiring the digital terrain data and graphically portraying it, construction entities for the individual minimum essential features (runway, parking ramps, fuel storage, etc.) are then overlaid on the digital data, initially spaced using appropriate USAF criteria. Additionally, any subsequent construction features, (control towers, ammunition storage, perimeter fencing, utilities, etc.) could also be overlaid using the same spacing guidelines. This combined data could then be used for several purposes.

First, it would give the user, who may not have access to the bare base locations (because of cost or other considerations), the opportunity to view the site as more than just a map or photographic plan view. The ability to visualize the sites in three dimensions gives the user a much better perspective and has the potential to make them more productive once they arrive at the site for actual work.

Second, by combining existing construction features and terrain data with proposed construction, the user can evaluate the site for suitability of the proposed work. Decisions can be made regarding optimal locations of individual features relative to a specific purpose or as dictated by terrain considerations and whether the site itself is suitable for the proposed use.

Third, once a site has been selected for construction and the layout has been determined, the available data could be used to produce computer generated plans, sections, and elevations for construction purposes. Also, the same data could be used to produce cut-and-fill information, a bill of materials, proposed manpower and equipment requirements and a schedule, potentially all generated by computer.

The system should be capable of capturing terrain data from a variety of sources and manipulating that data into meaningful display and hard-copy outputs. Further, it should be capable of combining that data with construction templates and performing the necessary calculations to derive required construction drawings. Ideally, the system should be capable of doing material and manpower takeoffs and estimates.

As stated above, this work will not bring all these goals to fruition. Specifically, the following sub-goals will be pursued:

1. Determine software and hardware availability and capabilities.
2. Determine data availability
3. Acquire a data set
4. Choose a software-hardware combination and perform some elementary data importation.
5. Create a simple construction entity and overlay it on the data set.
6. Manipulate and do a graphical output of the combination data set.
7. Do a preliminary evaluation and make recommendations.

The subsequent chapters will step through this project, beginning with a review of the current state-of-the-art of the various elements brought together by this work. In the following background review we will take a brief look at the development of those elements as they relate to this work.

CHAPTER 2

BACKGROUND - STATE-OF-THE-ART

In this chapter we will look at the development and current state of the data collectors, the data available, sources of the data, various software and hardware systems available for manipulating the data, and the capabilities of those systems.

Remote Sensing

Platforms

One can divide the history of remote sensing into two distinct periods in history[1], prior to 1960 and post 1960. Prior to 1960 the sole source for remote sensing data was aerial photography. Subsequent to the development of the space programs of various countries, remote sensing moved to orbiting platforms, and the quantity and quality of data increased significantly.

With the first photographs from the Mercury program, the pace of technological development for remote sensing accelerated.[2] While not specifically designed for remote sensing duty, the Mercury spaceflights revealed the limitless potential of space-based systems for gathering earth data.

The first satellite designed specifically for remote sensing of the earth's surface and resources was the Earth Resources Technology Satellite (ERTS-1). Later renamed Landsat 1, ERTS-1 was launched in July 1972 and carried a 4-band multi-spectral scanner (MSS) and a three-camera return beam vidicon (RBV). Both systems viewed a ground scene approximately 185 km by 185 km, with a ground resolution of about 80 meters.[a] With the launch of Landsat 2 in January 1975, the name of the series was officially changed from ERTS to Landsat. Landsat 3 was launched in March 1978 and added a fifth band (thermal infrared). Also, it carried two RBVs, delivering a resolution of 40 meters. The first three Landsat satellites have been retired from operation, but have been succeeded by two additional Landsats, 4 and 5. Both Landsat 4 (Launched July 1982) and Landsat 5 (launched March 1984) have all the capabilities of the previous three and have added the capabilities of a 7-band thematic mapper.

Other remote sensing satellites or platforms have included Skylab, launched May 1973; the HCMM (Heat Capacity Mapping Mission), launched April 1978; the Seasat-1, launched June 1978; the Space Shuttle missions, first launched April 1981; and SPOT, launched February 1986. SPOT (the acronym is for the French System Pour l'Observation de la Terre) is owned by the Centre National d'Etudes Spatiales (CNES), the French Space Agency. It warrants special mention here because it is the first satellite launched specifically to provide commercial remote sensing capabilities. It is also the first satellite to provide 10 meter resolution data to the general public.[8] A compilation of the most prominent platforms from which data is widely available and pertinent data about each is presented in Appendix A.

There are many other satellites producing usable imagery, including those of foreign countries and those specialized satellites, such as Japan's MOS 1 (Marine Observation Satellite) and the European Space Agency's (ESA's) ESA Resources Satellite-1 (ERS-1).

Additionally, and perhaps most important for this work, there are a number of satellites launched and maintained by the military and intelligence communities which are providing some of the most detailed and comprehensive data available.

Data Sources

Various agencies, and now corporations, provide remote sensing data in a variety of formats and media. Among them are: the Defense Mapping Agency, the World Data Bank, the United States Geological Survey, Earth Observation Satellite Corporation, and the SPOT Corporation. Appendix B lists the agencies, addresses, and telephone numbers, and Telex and FAX numbers, where available.

Data Attributes

The true effectiveness of remote sensing inputs to information systems can be measured by the appropriateness, temporal resolution, spacial resolution, and accuracy of data provided to the system.

Appropriateness

For the data to be appropriate it must be available for the desired location and in the required format. In this problem we are faced with the potential requirement, operationally, for data relating to a significant portion of the free world's land mass. While surface data for a majority of the earth's surface (most notably in the northern hemisphere and equatorially) is recorded, the format becomes critical.

The various sources offer different data formats. Those range from basic quantitative elevation data to selected natural and man-made planimetric features (roads, buildings, rail beds, etc.) to ground-cover data (vegetation, timber, agriculture) to geologic information (soil type, subsoil characteristics). Digital terrain data is required for the work in this project. Of note here is the fact that the Landsat 4 and 5 satellites by themselves do not have the capability to take the overlapping photographs necessary for stereo imagery. They can, at higher latitudes (decreasing to 0 percent at the equator), operate together to capture offset images of the same scene, thereby producing the pairs required for stereo viewing and data extraction. SPOT, on the other hand, has the pointing capability required to capture these image pairs.

Remote sensing is gathered by several methods, most notably: visible light photography, radar of various types, and infrared. The data is typically captured by two methods: fixed-frame photography (less common as of this writing) and magnetic tape recording. The resultant data is typically stored and analyzed in the analog format (either actual photographs or synthetic color photographs. The data is now more frequently stored in a digital format. However, that storage format is designed specifically to provide graphical imagery, not CAD capability. This poses a retrieval and manipulation problem which will be discussed later and in the recommendations.

This CAD-based project requires digital terrain data in an X-Y-Z format. Only a very small portion of the available data is now currently in this digital (X,Y,Z) format, commonly referred to as the TA2 format. When the data is available only in the photographic format (either multi-spectral or panchromatic) some form of machine processing must be applied to digitize the data.[a] Typically the process is a semi-automatic one, involving a trained operator and a stereoplotter. A stereoplotter is a device which, using lens pairs, prisms, or electronics, allows the user to view stereo pairs of photographs (taken of the same area but from different angles) in 3 dimensions. This allows a trained operator to discern changes in relative elevations and thereby assemble digital topographical data sets. This data can then be readily stored in any of several digital terrain data formats. Increasingly the analytical stereoplotter is becoming more automated, with systems capable of accomplishing the transformation from start to finish and providing the output in formats directly usable by virtually all the fully capable engineering design packages.

The problem of data transformation from the graphic format to a suitable digital format will be considered outside the scope of this project, more a problem of photogrammetry than of construction management or engineering. Suffice to say that prior to processing, the data must be digitized into a format suitable for the system.

Temporal Resolution

Temporal resolution, or the timeliness of image gathering, is another factor. For preliminary topographical work, data sets that are several months to several years old may afford sufficient temporal resolution. However, when the accuracy of construction drawings and costs estimates hinges on the currentness of the data set, a more timely image may be required. A decision must be made, relative to cost versus benefit, based on the application, whether the existing available data is sufficiently current or whether addition data must be gathered.

Spatial Resolution

Spatial resolution of the data is another important factor. The spatial resolution of the data varies widely from source to source. One must choose a system with resolution appropriate to the task at hand. The phenomenon of interest can vary from cultural to natural and coexist within the environment at macro-, meso-, or micro-scales. Each scale reduction requires progressively finer spatial resolution.[2] Thus resolution must remain "germane to the task"[3]. Resolution can vary from 150 meters spacing from the older platforms to as fine as 10 meters for the SPOT panchromatic data.

Data Accuracy

Data accuracy is a function of the platform's orbit height; the obliqueness of the observation; the acuity of the data collection devices, recorders, and transmitters; and the level of processing applied to the data. Elevation data accuracy is expressed in terms of absolute and relative error.

USGS Data

As an example, data accuracy of USGS digital elevation models (DEM's) is categorized at 3 levels, designated levels 1, 2, and 3. The following descriptions are quoted:

> Level 1 DEM's are considered to be elevation data sets in a standardized format. The intent for DEM data at this level is that no point will have an absolute error over 50 meters when compared to the true height from mean sea level (MSL) or that an array of points not encompass more than 49 contiguous elevations (an effective 7 by 7 array) wherein the relative integrity is not in error by more than 21 meters. Systematic errors within limits stated for absolute accuracy are tolerated at this level. DEM data acquired photogrammetrically using manual profiling or the Gestalt Photo Mapper are restricted to the level 1 category. For National High-Altitude-Program (NHAP) source data, an elevation root mean square error (RMSE) of 7 meters is considered to be a reasonable desired accuracy standard, attainable under a variety of terrain and instrument conditions. A RMSE of 15 meters in elevation is the maximum permitted in the National Digital Cartographic Data Base (NDCDB).
>
> Level 2 DEM's are elevation data sets that have been processed or smoothed for consistency and edited to remove identifiable systematic errors. DEM data acquired by contour digitizing, either photogrammetrically or from existing maps, are entered into the level 2 category after review on a DEM Editing System. A RMSE of one-half contour interval is the maximum permitted. There are no errors greater than two contour intervals in magnitude.
>
> Level 3 DEM's are data sets that have been vertically integrated to insure positional hypsographic* consistency with planimetric data categories such as hydrography and transportation. DEM data in the level 3 category are derived from digital line graph (DLG) data using selected elements from both hypsography (contours, spot elevations) and

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* A hypsograph is an instrument of the slide-rule type used to compute elevations from vertical and horizontal distances.

hydrography (lakes, shorelines, drainage). If necessary, ridge lines and hypsographic effects of major transportation features are also included in the derivation. A RMSE of one-third of the contour interval is the maximum permitted. There are no errors greater than one contour interval in magnitude.[4]

Virtually all the data available to the general public at this time is level 1 data. Only a very small percentage of level 1 data has been converted to level 2 and an even smaller percentage to level 3.

DMA Data

As a further example, data accuracy of the Defense Mapping Agency (DMA) Digital Terrain Elevation Data sets (DTED) and Digital Feature Analysis Data (DFAD) sets is also categorized at 3 levels, designated levels 1, 2, and 3. Those levels connote different meanings than those of the USGS. The following descriptions are quoted:

> Accuracy statements are individually calculated for every product and provided in the Accuracy Header Record. Using our best sources the accuracy evaluations typically are in the following ranges:

Absolute Horizontal	25 - 35 M at 90% circ' error
Point to Point Horiz'	15 - 30 M at 90% circ' error
Absolute Vertical	+/-25 - 30 M at 90% linear error
Point to Point Vert	+/-20 - 25 M at 90% linear error

> DMA Product Specification accuracy objectives for DTED level 1 are:

Absolute Horizontal	130 M at 90% circular error
Absolute Vertical	+/-30 M at 90% linear error

> DMA Product Specification accuracy objectives for DFAD level 1 are:

Absolute Horizontal	80 - 90 M at 90% circ' error
Point to Point Horiz'	50 - 60 M at 90% circ' error

DMA Product Specification accuracy objectives for DFAD level 1C are:

Absolute Horizontal	110 - 120 M at 90% circ' error
Point to Point Horiz'	155 - 165 M at 90% circ' error

DMA Product Specification accuracy objectives for DFAD level 2 are:

Absolute Horizontal	80 - 90 M at 90% circ' error
Point to Point Horiz'	50 - 60 M at 90% circ' error[8]

Virtually all the data available to the general public at this time is level 1 data. Only a very small percentage of level 1 data has been converted to level 2 and there is no level 3 data available.

SPOT Data

SPOT Data is available in a variety of processed formats of varying accuracy. Note that SPOT resolution is 10 meter for panchromatic data and 20 meter for multispectral data. Though a great deal more detailed, the following quoted processing level information is provided for SPOT data. It provides some further insight into the types of processing that imagery can undergo:

> Image data are available after having been processed to one of four levels which range from radiometric and geometric corrections to precision processing. Ancillary data used for basic radiometric and geometric corrections are supplied with all digital data items. The following sections describe the four standard processing options.
>
> Level 1A - Images processed to Level 1A are essentially raw data which have undergone radiometric correction to normalize detector response within each of the spectral bands. The number of pixels per line, the number of scan lines per scene and the orientation of the image scan lines are the same as that in which

the image was recorded by the satellite's sensors. Images processed to this level are available as photographic prints or transparencies, or in digital form on computer compatible tapes (CCT). No geometric corrections have been applied to the data. Ancillary data supplied with this imagery include absolute detector calibration coefficients, detector response histograms, all parameters used to process to Level 1A and acquisition information such as angle of incidence, acquisition time and date, sun angle, SPOT Grid Reference System (GRS) coordinates, scene center coordinates and scene orientation.

Level 1B - Images processed to Level 1B have undergone radiometric correction similar to Level 1A. In addition, these images have also been geometrically corrected to reduce distortion from systematic and orbital effects. These effects include variations in satellite attitude, rotation and curvature of the Earth, and viewing angle effects. Geometric corrections accomplished through resampling of the image data can increase in number of pixels per line from 6,000 to 10,200 for panchromatic images acquired with a maximum angle of incidence (31 degrees). For Level 1B data items the orientation of the image scan lines is the same as that in which the image was recorded.

Imagery processed to this level is available on CCT, or as photographic prints or transparencies. Ancillary data accompanying the imagery are identical to that described for Level 1A.

Level 1B images have a location accuracy of approximately 830 meters (rms error) and internal distortion of .00413. Radiometric accuracy is the same as that for Level 1A.

Level 2 - This is a *precision* processing level in which SPOT scenes are rectified to a specific map projection. In addition to Level 1B radiometric and geometric corrections, Level 2 processing includes bi-directional corrections based on ground control points (GCP). The resultant imagery is oriented to true north and presented in one of the following cartographic projections: Lambert conformal, universal transverse Mercator (UTM), oblique equatorial, polar stereographic, or polyconic. The production of Level 2 data items is dependent upon maps with scales of 1:100,000 or larger for GCP extraction. Note: Parallactic displacement due to terrain relief and angle of incidence remains in the data.

Level 2 data items are available on CCT, or as photographic prints or transparencies. Ancillary data include those described for Level 1A, plus GCP coordinates and Level 2 model and map projection identification.

Level 2 data have a location accuracy of approximately 30 meters (rms error) provided the image was recorded at a vertical viewing angle, and the range of terrain relief in the scene does not exceed 1250 meters. Imagery with a maximum angle of incidence of 31 degrees can be processed to this same level of accuracy if the range of terrain relief on the corresponding ground area does not exceed 170 meters. Radiometric accuracy is the same as that for Level 1A.

Level S - Level S precision processing involves registering one SPOT scene to another SPOT scene, referred to as the "reference scene." The type of scene processing is used primarily for multidate and change detection studies in which scene registration accuracy is essential. Level S precision processing requires that both scenes have identical angles of incidence and be processed to the same level, either 1B or 2. This option is available on CCT, or as photographic prints or transparencies, and can be presented at any map projection listed for Level 2 processing. Ancillary data include those described for Level 1A, plus coordinates of the registration control points, the registration model and reference scene identification, including the map projection, if applicable. Accuracy specifications for the individual scenes are determined by the levels to which those scenes have been processed (Level 1B or 2). Registration accuracy between scenes is 0.5 pixels or better.

Note that the descriptions center on a more cartographic line and are more raster oriented than vector oriented. SPOT data is available in all the described levels.

Data Formats

Different formats are available for DTED sets and DEMs. An excerpt from a USGS DEM is included at Appendix C. A description of the data fields is included at Appendix D. This format varies greatly from that used by the DMA. Characteristics and data field descriptions for DMA DTED are included at Appendices E and F. No data examples or field descriptions were available for SPOT data sets.

Media

Data are basically available on two media. The most familiar is hard-copy photography and imagery from multispectral scanners and return-beam vidicons. These include both single-image and stereo pairs. The other media is CCT.

The most useful medium for the purposes of this problem is that which already has the topographical data distilled out. This is typically done on half-inch magnetic tape in an ASCII format. Data is stored in 9 tracks at either 1600 or 6250 bits per inch (BPI).

Geographic Information Systems

Geographic information system (GIS) is a term used to describe systems capable of efficient data storage, processing, and retrieval of geographic data. GIS's have evolved as a means of assembling and analyzing diverse data pertaining to specific geographic areas, using the spatial location of the data on the earth's surface as the basis for the information system.[7] In the simplest terms, GIS's must be capable of accepting and using user-defined criteria and data and channeling output to the intelligence level at which decision making takes place. Remote sensing provides a source of data for such systems, and has demonstrated the potential to improve the quality and quantity of such data.

It is most interesting to note that even today, after nearly 30 years of satellite remote sensing, conservative estimates are that nearly 95 percent of all digital terrain data and digital elevation models in the United States are generated from existing ground survey-based maps from the USGS. This is primarily a result of both the relative ease and reduced costs associated with converting existing topographic maps into digital terrain elevation data versus extracting the same data from orbiting platform imagery.

CAD Systems

A less extensive treatment will be offered of this topic in the background. In general, a partial list of the most widely known systems will be presented along with some general comments on those systems. Because each system was not available to the researcher, no recommendations can or will be made about relative merit of the systems. However, general capabilities will be presented.

While there are many CAD packages available on the market today, a handful have risen to the forefront in the professional arena. The most familiar program is AutoCAD, by AutoDesk. This is a professional drawing package, capable of the manipulation required for this project. With the AutoLISP programming language (a variation on the LISP programming language) developed by AutoDesk, AutoCAD offers extreme flexibility and an open architecture that has prompted many third party vendors to offer a variety of software that enhances the capabilities of AutoCAD. These range from programs which tailor AutoCAD to land surveying, to those that allow material estimates to be generated, to those capable of producing digital terrain models derived from several sources within AutoCAD.

Several other major firms have developed proprietary software-hardware systems which can also be classified as professional systems. Most notable among those are Intergraph and McDonnell Douglas. Both firms offer software and software-hardware combinations which surpass AutoCAD in capabilities when compared to AutoCAD without third party support. Intergraph offers a variety of subsystems capable of structural design and modeling, raster to vector conversion, mapping and geodesy, mechanical engineering, and a host of other special applications. McDonnell Douglas has similar programs available. Both systems are primarily designed to operate in a 32-bit minicomputer. Intergraph recently purchased the highly-rated MicroStation CAD software from Bentley Systems. They now offer the full capabilities of their mini-based system in that micro-based package. Several other vendors offer similar systems, but exploring the features and capabilities of the various systems is beyond the scope of this paper.

What is important is that while researching this problem, the author discovered that a multitude of vendors, both software and hardware, have software or total systems which can accomplish virtually every phase of the overall project envisioned by this work. None, however, has been specifically designed to do this particular work from start to finish. A partial listing of the various software and hardware developers is provided in Appendix H on page 116. This leads us to a discussion of the system used for this work.

CHAPTER 3

EQUIPMENT

This section deals with both the hardware and software used by this researcher and that which the researcher recommends for optimal efficiency of the system.

Utilized System

Hardware

Central Processing Unit

An IBM Personal System (PS)/2, Model 50 was used. This machine is driven by an 80286 processor operating at 10 megahertz with 1 wait state. The standard RAM is 1 megabyte, of which 640 kilobytes is addressable under DOS. The additional 360 kilobytes is extended memory which is usable as a disk cache, for print spooling, as a RAM disk, and for various other configurations. Also, an 80287 math coprocessor was installed to increase computational speed and because the more recent versions of AutoCAD require a math coprocessor to operate.

Monitor

An IBM PS 2, Model 8513, 12 inch video graphics array (VGA) color monitor was used for all data display.

Storage Devices

The PS 2, Model 50 comes standard with an internal 20 megabyte hard disk operating with a 65 millisecond access time. Also a 1.44 megabyte 3 1/2 inch internal floppy drive comes standard with this model. The researcher added a 360 kilobyte 5 1/4 inch external floppy drive to afford compatibility with machines which have not yet adopted the 3 1/2 inch standard.

Hard Copy Output

All output for both the text and graphics in this project was done on a Toshiba P341SL, 24-pin, wide carriage dot matrix printer.

Software

Operating System

IBM DOS 3.3 was used as the operating environment for this project.

Computer-Aided-Design Package

AutoCAD Version 9.0 was used, equipped with the Advanced Drafting Extension 3.

Data Conversion Package I

Because the terrain data extracted from satellite imagery is rarely provided in a form which is usable by most CAD and conversion packages, a transformation must be done on the data before it can be used. For this project an ANSI FORTRAN 77 program was written by Mr. Nickolas L. Faust, of

```
      dimension iz(10),ixv(17),ixv1(45),iv(62)
      open(20,file='test.dat')
      do ll=1,13

      read(20,99)ia
99    format(a1)
c  write(5,101)ll
      end do
      do j=1,99
c  write(*,102)j
102   format(2x,'lrec = ',i7)
      read(20,99)ia
      read(20,100)ixv
      read(20,103)ixv1
100   format(918x,17i6)
103   format(45i6)
      do (ll=1,17)iv(ll)=ixv(ll)
      do (ll=1,45)iv(17+ll)=ixv1(ll)
        xx=625680.+(j-1)*30
      do jj=1,62
        yy=3868882.+(jj-1)*30
        write(5,101)xx,yy,iv(jj)
        end do
101   format(2x,2f10.0,i7)
      end do
      end
```

Table 1 - FORTRAN TRANSFORMATION by Mr. Nickolas Faust

GTRI. That program is shown in Table 1. Also, a second, similar, transformation was performed with ANSI FORTRAN 77 by Mr. J. G. Jay, of ERDAS Inc. That transformation program is proprietary for ERDAS, however, and was not available for publication in this report. Basically, the algorithms were applied to the data to transform it from the existing format (a USGS digital elevation model) into a standard X, Y, Z coordinate format which most conversion packages can use.

625680.	3868942.	474
625680.	3868972.	469
625680.	3869002.	466
625680.	3869032.	469
625680.	3869062.	474
625680.	3869092.	472
625680.	3869122.	474
625680.	3869152.	470
625680.	3869182.	474
625680.	3869212.	479
625680.	3869242.	482
625680.	3869272.	478
625680.	3869302.	476
625680.	3869332.	479
625680.	3869362.	478
625680.	3869392.	482
625680.	3869422.	482
625680.	3869452.	479
625680.	3869482.	477
625680.	3869512.	475
625680.	3869542.	476
625680.	3869572.	485
625680.	3869602.	482
625680.	3869632.	477
625680.	3869662.	478
625680.	3869692.	483
625680.	3869722.	487
625680.	3869752.	492
625680.	3869782.	493
625680.	3869812.	488
625680.	3869842.	483
625680.	3869872.	484
625680.	3869902.	483
625680.	3869932.	486
625680.	3869962.	490

Table 2 - Example of the ASCII TA2 Format

The resultant ASCII file is simply a line-by-line listing of the coordinates of each point in the data set. The format is called the TA2 format (See Table 2).

Data Conversion Package II

GWN System's Digital Terrain Modeling (DTM) package was used. This AutoLISP-based third party software is specifically designed as an overlay for AutoCAD. It is designed to import digital elevation data from analytical stereo plotters, total stations, and other devices which provide a standard TA2 format output. It can manipulate the data into appropriate contours, profiles, sections, and triangulated terrain models. Additionally, it can do cut-and-fill calculations based on user-input templates and existing terrain data. This package was not directly available to the researcher. GWN Systems, and specifically Mr. Wayne T. McLachlan, one of the principals of GWN, were gracious enough to process the data with their software, at no cost to the researcher.

Recommended System

Hardware

Central Processing Unit

Because of the computational intensity of both the CAD environment and the third party software packages that manipulate the data, and because the data sets are extremely large, the system should be based around an 80386 processor, with the fastest processing speed that the budget will allow. Certainly a 25 megahertz machine would perform faster than a 16 megahertz machine. Screen regenerations and data manipulation are markedly faster with the 32-bit architecture of the 80386 processor. Also, again because of the typical size of data sets (see Appendix G), an absolute minimum of 4 megabytes of expanded memory is recommended. This will allow the opening of much larger drawings without the requirement for the software to page through small sections of the drawing. This improves the speed with which the operator can pan through a given drawing without the necessity to continually access storage devices for the data. Again, a math coprocessor (ideally an 80387 operating at the same speed as the central processing unit) is a must. It is required to operate most CAD systems and significantly improves both computations and drawing regenerations.

Monitor

A large-screen VGA or EGA color monitor is essential for the work performed in this project. While the 12-inch unit used for this problem was adequate, a minimum size of 19-inch for the fielded system is recommended.

Storage Devices

Again a function of the size of the data sets and drawing files, adequate mass storage is essential to an efficient system. The 20 megabyte hard disk used for this problem was seriously inadequate for this work. As an absolute bare minimum the system should have a 40 megabyte hard disk with 100 to 300 megabytes being the recommended range. Also, the access time of 65 milliseconds afforded by this researcher's system's hard disk is unacceptable. Many of the newer hard disks now available offer access times of 28 milliseconds and less, with quite a few performing at 15 to 18 milliseconds.

Hard Copy Output

While any wide carriage printer will suffice for text output, it will not satisfactorily perform the plotting necessary for this problem. High quality output of construction drawings, sections, profiles, templates, and perspective views of the site and facilities will require a pen plotter. A D-size plotter (33" x 21" max plotting area) is recommended as a minimum, with an E-size plotter (43" x 33" plotting area) as an optimum. The choice between a single- and multiple-pen plotter is strictly a function of cost versus convenience.

Software

Operating System

Presently DOS seems to be the operating system of choice for most personal computer-based CAD system manufacturers. DOS presently does not support multi-tasking, which could be of benefit when working in expedient situations. Also, the 640 kilobyte limitation on DOS-addressable memory will require that an expanded memory driver be installed to handle the additional random access memory the machine will need. The introduction of IBM's OS-2 micro-channel operating system opens up the ability to multi-task. It also eliminates the 640 kilobyte restriction, allowing the use (without additional drivers) of up to 16 megabytes of random access memory. At this time, however, few developers in the CAD arena have reworked their products to function in the OS-2 environment. Several of the integrated systems (Example: Intergraph's Microstation) are designed to operate in the 32-bit environment. If a system is chosen that does not have it's own proprietary operating system, then DOS should be the operating system of choice. It is the most commonly available and most widely understood of the PC operating systems. In the event that software must be transferred to a backup machine at a remote location, a DOS machine would most certainly be the easiest to locate.

Computer-Aided-Design Package

AutoCAD was chosen by this researcher solely based on its availability within the Georgia Tech system. Any of a number of systems are capable of performing the data conversion, manipulation, display, and output required for this project. Several capabilities of the CAD system are essential. First, the system should be capable of supporting pen plotters of a sufficient size. Second, the system should be capable of 3-D rendering, both on screen and as output to the plotter. Also, the program should have the ability to do hidden line representation, solid surface representation, and shading. A full discussion of the other required capabilities is presented in the Data Conversion Package II section below.

Data Conversion Package I

Depending on the form of the data set, some form of transformation may be necessary in order to make it readable either by the conversion package designed to interface with your CAD system (such as the GWN - AutoCAD combination) or to make it readable by a total integrated system (such as Mcdonnell Douglas or Intergraph). Regardless, the transformation is usually fairly straightforward and can be handled by a competent programmer. It is conceivable that more than one algorithm must be maintained due to the fact that data may be acquired from various data sources with differing formats.

Data Conversion Package II

No recommendation shall be made for a specific package. The key issue is that the package chosen be capable of the data manipulation required by the user. Some of the elements which the researcher believes are key to an adequate system are listed below:

File Processing - A file of 30 meter data for a rectangular parcel of land 2 miles on a side (4 square miles) requires 11,664 data points. A 10 meter data set for the same area requires 110,224 points. Appendix G lists some representative data file sizes and their resultant drawing sizes in AutoCAD. It is obvious that the software must be capable of storing and processing significant quantities of data. Some developers have limited both the size of the primary data set and the size of the model that can be generated from that primary set. It is common for the systems to manipulate large data sets by paging in the data in some maximum increment of approximately 6000 to 9000 points. A compromise may have to be made regarding size capability of the system. A specification for purchase or development of such a system must certainly contain both minimum total file size and minimum model size capabilities. Additionally, the system must be capable of processing irregularly spaced data points.

Data Input - The software should permit data input by keyboard entry of coordinates, by graphical entry on screen, by using a digitizer, and by file processing.

Data Format - The system should be capable of input and output of data in some standard format which provides interchangeability with other systems.

Graphics Capabilities - The system should be capable of representing all of the displays required by the user, such as TTMs, contours, profiles, and sections, depicting them in

3-D where appropriate. The user must have the capability to view the 3-D models in 3 dimension from any orientation. Surface modeling and variable shading would also enhance the system.

Data Manipulation - The system must be capable of producing TTMs and contours (both indexed and non-indexed) and must be capable of smoothing contours. Manual entry of breaklines must be allowed. If the user selects any horizontally referenced point (graphically or by manual entry) the system should provide elevation data for that point.

Profile and Section Capability - The user must be able to identify an alignment through any of the files (2-D and 3-D) mentioned previously. Graphic and hard copy output of selected profiles and sections is required, in both 2-D and 3-D. Vertical exaggeration by a user-selected factor would aid in visually validating displayed sections.

Surface Volume Capability - The system should have the capability to perform volumetric calculations between two surface models, thus providing the capability to do cut-and-fill volume reports. Results should be available in both metric and english volumetrics.

Template Design Capability - The system must provide for creation of user-defined templates which can be applied to user-defined profiles. The system should provide volumetrics on these applications for cut-and-fill reports. It should also include a slope stake offset summary report including design profiles and original ground elevations by station.

Additional requirements include those associated with take-off work. Facility overlays in the form of templates should be capable of being used to provide material and manpower take-offs as an option to the system. This phase of the overall problem, however, is outside the scope of this paper. Given the requirements of the system, a discussion of the procedures of the overall project will follow.

CHAPTER 4

PROCEDURES

This section is subdivided into six categories, each dealing with a particular phase of the problem. They are: research, data gathering, data conversion, data manipulation, graphical representation, and system evaluation.

Research

The research for this problem began with a thorough computer literature search in the various systems at the Georgia Tech Library. The GTECH system yielded only a few sources of information on the areas of satellite imagery, photogrammetry, and CAD as it relates to mapping. The INSP system was more lucrative in all three areas, but many references were foreign and not available. The most recent texts available were published in 1986 and deal primarily with remote sensing and photogrammetry. The main sources of current information on CAD systems are periodicals, manufacturer's technical literature, and specifications. While manufacturer's literature provides a good overview of a system's capabilities, it is inadequate to make a determination of the system's relative merit. Consequently, it is not practical to make a recommendation regarding the best system of those mentioned in the text.

The greatest wealth of information was gleaned from those individuals who have published recent literature and/or are actively involved in use and design of systems similar to that which we are investigating here.

Data Gathering

Data Sets

The first step was to determine the sources of data. The literature search revealed four main sources available at the present time. They are USGS (limited to US), World Data Bank, DMA, EOSAT, and SPOT. Addresses and telephone numbers for each organization are listed in Appendix B.

As this problem unfolded, it appeared the chief source of data would be the DMA. In fact, the DMA is the central point of contact for the military and civilian government entities for acquisition of all forms of cartographic data. That is, they provide Landsat, SPOT, and "by-request" imagery and digitized data sets to all military and government services at reduced rates. Requests by civilian researchers may also be directed to the DMA but only for non-commercial data sets. The USGS data used for this report was chosen because it was 30 meter resolution and available at no cost. Data availability and resolution will be the key considerations in any effort to use a fielded system. When data for a particular site is unavailable, the user will need to consider the cost of gathering data of sufficient resolution.

Software/Hardware Combinations

Again, some preconceptions on the part of the researcher affected the manner in which this research was approached. Naivety led the researcher to believe that AutoCAD was the most sophisticated CAD system available. While AutoCAD's superiority may be debatable, it is certain there are other systems on the market that offer at least the same capabilities, and, in some cases, more. AutoCAD availability insured its use in this problem. However, the other CAD systems noted in Appendix H on page 116 appear, based on manufacturer's literature and specifications, to be perfectly capable of performing the same data importation and manipulation as done here with AutoCAD and GWN System's DTM Module.

Several vendors offer third party software designed to operate with AutoCAD in performing operations similar to those presented in this paper and those are presented also in Appendix H, page 116. Of special note is that three firms were discovered (TerraCADD, Intergraph, and McDonnell Douglas) which have single software packages designed to operate either on their proprietary hardware, or on user-supplied hardware that will perform the necessary work.

These systems are totally integrated packages that have the data importation, conversion, manipulation, display, and output capabilities operating as a single package. There are definite advantages to these systems in terms of flexibility, speed and ease of use. However, these advantages come at significant cost. The cost of such systems (software alone) can range from 3 to 5 times the cost of AutoCAD and GWN-DTM.

Data Conversion

As previously stated, data available is rarely in the proper form to be used by the system (USGS .DEM files and DMA DTED files must be converted into the TA2 format for use by packages that operate with AutoCAD). This problem may be done, as in this research, by some suitable algorithm outside the system. Ideally it should be added to the system as an integral part. This conversion assumes that the data is in a digital format but not in one suitable for the system. If, however the data is in a hard copy image format, than another preliminary transformation must be accomplished before the data can be used. This is typically done by an analytical stereo plotter. Though outside the scope of this problem, consideration should be given to inclusion of an automated analytical stereo plotter with the system.

Data Manipulation

The data used (USGS digital elevation model) required conversion to the TA2 format. Once in the ASCII format, it could be processed by the Base Module of GWN System's GWN-DTM software. A simple AutoLISP conversion program (TA2DXF, TA2DXB) within the software converts the TA2 format into an AutoCAD DXF and/or DXB drawing file interchange format. Preliminarily the data may be contoured, a triangulated terrain model may be generated, or other manipulation may be done. The resultant files may then be transformed into DXB or DXF interchange files for importation into AutoCAD.

PNTPLY extracts the data points within a user-specified polygon. This is offered because the total data set is often much larger than the triangulation and contour algorithms can handle (9000 points maximum). Once the polygon has been defined, display and manipulation alternatives can be chosen.

TTM generates the triangulated terrain model from a full set of data points, while TTMPLY generates the triangulated terrain model from the polygon created by PNTPLY. TTM3DF converts a triangulated terrain model into a 3-D surface representation for generation of any 3-D view.

Graphical Representation

Fairly straightforward, representation consisted of using the existing GWN-DTM programs and AutoCAD routines to orient the individual drawings (contour and TTM). The views were then sent to the printer using the AutoCAD printer plot routine.

System Evaluation

During the course of the project the researcher noted the ease or difficulty of performing individual operations. Though it was not possible to determine if speed, or lack of speed, was software or hardware dependent, some indication of processing time was given. These will be presented in the discussion.

Also, user friendliness is a key consideration in evaluating any system. This is dependent on hardware, the operating system, and the application software. These were also evaluated and will be discussed later.

CHAPTER 5

DISCUSSION

Overview

This project poses a number of problems which have existing solutions or for which solutions can be readily accomplished. The following outline details the major and minor steps involved. Not all steps may be required, depending, among other things, on the format of the data available, or the level of detail required. Each of these steps will then be discussed in detail.

1. Determine area(s) of interest
2. Acquire data sets for specific areas
3. Determine processing required to make data set usable
4. Process data
5. Import data into CAD program
6. Determine optimal site
7. Use existing data or gather finer resolution data to perform more detailed evaluation of selected site
    a. Gather data by overflight or ground survey
    b. Process data as in 3. through 5., above

8. Perform detailed manipulation of data and overlay with construction entities.

9. Generate working documents

    a. Sections and profiles

    b. Cut-and-fill calculations

    c. Working drawings

    d. Cost, material, equipment, and manpower estimates

Determine Areas of Interest

The actual sites selected for consideration as bare base candidates will be a function of several factors. First, the strategic and tactical value of a given location must be considered, given the current state of international politics at the time of decision. Second, once it has been determined that a given region requires a bare base and that the host nation is willing to consider such a facility in the region, feasibility calculations must be accomplished. Some determination must be made as to the maximum number of allowable sites to consider. Within a given region alternative sites must be chosen based on availability, military considerations, and economic considerations. Finally, a group of potential sites must be chosen.

Acquire Data Sets for Potential Sites

Data sets are available for much of the earth's surface. The primary data source for the military community for DTED is the Defense Mapping Agency. There are additional data sources and these, as well as the DMA, are listed in Appendix B. Also, a comprehensive summary of the DMA data available is provided at Appendices E and F. Here we encounter our first difficulty, that of data availability in sufficient resolution for the required purpose. As stated earlier, the largest percent of data is 30 meter resolution or coarser. This poses a problem for the user. Results of this work suggest 10 meter data is more appropriate for both preliminary evaluation and computation. Though 30 meter data may be adequate for preliminary evaluation, it appears too coarse for site drainage, earthwork, alignment, sectioning, and other detailed engineering work. A prime consideration will be the availability of data with fine enough resolution. It is plausible that 30 meter data may be used for preliminary site evaluation. However, assuming the appropriate data sets have been acquired, the process of manipulating the data begins.

Determine Data Processing Required

Herein lies our second principal difficulty. Actually the problem has two parts. Our project proposes the marriage of two distinctly different systems -- GIS and CAD. First, a great deal of the information is in photographic form of large areas of land. The principal problem is that of converting this photographic form of information into a usable format. Conversion centers around transforming two-dimensional images taken at oblique angles of a spherical surface into some suitable projection. The methods developed for this are subjects for cartographic works and involve geometric transformations of the data into differing standardized projections, each having its strengths and weaknesses. These projections take on more meaning and importance when dealing with depictions of large land areas (state, country, continent). Their importance diminishes somewhat when dealing with smaller land areas such as those of a small base. Spheroidal corrections are less important in the distances with which the designer would normally be working.

Also, GIS systems come in two types, raster-based and vector-based. In a raster-based system the data set locational references generally come from pixel position and platform movement information. With a pixel-oriented system, when you draw an object the appropriate dots are lit on the computers's screen. On the other hand, CAD systems, and some GIS systems, are NOT raster-based; they are vector-based. They operate on a coordinate system and are object-oriented. That is, entities are stored as mathematical definitions rather than pixel locations. This vector-based system is much more accurate for producing precise drawings.

This difference between the two systems in data storage and manipulation is the root of perhaps the most difficult problem facing this project. Figure 1, Figure 2, and Figure 3 illustrate the differences between a raster-based and a vector-based system. Observe the small circle with a cross in Figure 1. When drawing such an object in a pixel oriented system the program lights the appropriate dots on the screen and stores the drawing as that collection of dots. When you "zoom in" or magnify such a drawing the program doesn't remember that the dots represent a circle with a cross. The program can only duplicate the dots, producing a display like that in Figure 2. With a vector

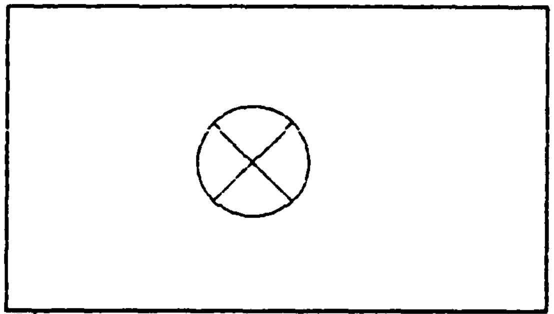

Figure 1 - Original Image

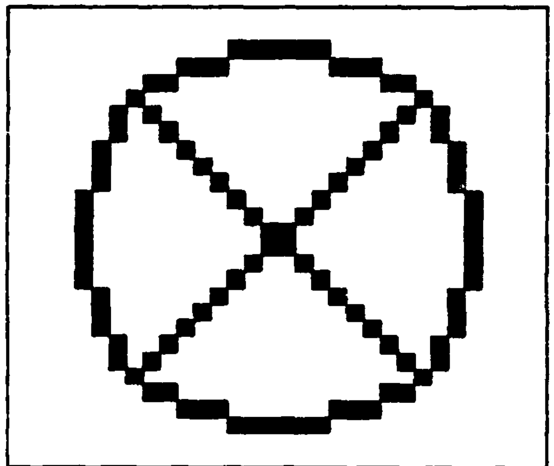

Figure 2 - Raster Enlargement

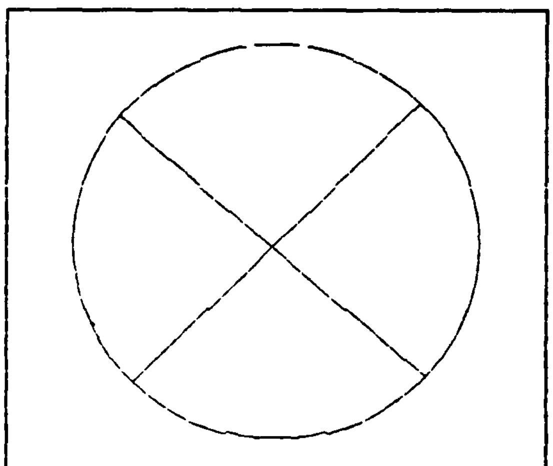

Figure 3 - Vector Enlargement

oriented system the program records the circle and cross as a mathematical representation of a circle with a given center and radius, and as lines with particular end points. When magnified, the new drawing remains true and results in an image with greater detail as in Figure 3. As can be seen, the vector-based system provides a more accurate means of storing and representing drawings, not necessarily images.

What must be noted is that when capturing images of existing terrain in a vector-based system the operation is performed at a given resolution (map scale). Extrapolation beyond that scale neither creates new information nor provides greater accuracy. At the same time, a raster set can always be made to represent data as accurately as any vector set IF the cell size is made small enough. Of course the problem then is the volume of data generated.

Process Data

The data set used is a subset of the USGS 7.5 minute quad sheet digital elevation model for Newhome, Georgia, near the Georgia-Alabama-Tennessee borders. The sample data set occupies a portion of the northwest corner of the quad sheet and consists of a rectangle approximately 2940 meters (1.83 miles) east-to-west and 1830 meters (1.14 miles) north-to-south. The UTM coordinates of the southwest corner of the data set are East 625,680 and North 3,868,882. The only processing required was to convert the data to the TA2 file format. That was accomplished using the FORTRAN algorithm previously described. So processed, the data was ready for importation into AutoCAD using the GWN-DTM software.

Import Data into CAD Program

There are several information options available to the user with the GWN-DTM package. The simplest of these is the TA2DXF[b] program which converts a TA2 file to an AutoCAD DXF drawing interchange file. The resultant drawing (obtained using the AutoCAD DXFIN command) is simply a point file. For this project, that procedure was observed but will not be presented in the results.

Outside AutoCAD, GWN-DTM offers a contouring utility called INDEX. The resultant contour file is then converted to a DXF file and imported into AutoCAD as above. Contour intervals are user-selectable and manual breakline entry is permitted. The contour feature is demonstrated in the results section.

A third option germane to this work is the generation of triangulated terrain models. GWN-DTM handles this in a three-step process also. First, the TA2 file is converted

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[b]. Throughout this section XXXDXF programs are referred to. Note that for each there is a companion XXXDXB program which creates a DXB file, also an AutoCAD drawing interchange file. DXB files are more compact but less flexible.

to a TTM file use the TA2TTM program. Second, the TTM file is converted to a DXF file using the TTM3DF (3-D face) program. Finally, the DXF file is imported into AutoCAD as above and a drawing file is created.

An important item must be noted here regarding the importation of data into AutoCAD when using geo-referenced coordinates. The sample data has X coordinates (eastings) in the 10^5 to 10^6 range and Y coordinates (northings) in the 10^6 to 10^7 range. For northings Y = 0.0 at the equator in UTM. The normal drawing limits put the southwest corner of the total drawing at coordinates 0,0. Upon importation and generation the data set is difficult to locate. Because of its area (approximately 2 square miles) relative to that of the total drawing (approximately 7 million square miles) the image occupies less than 3 x 10^{-5} percent of the display and can be virtually invisible.

Several methods can be used to bring the data set into view. The first is to do a ZOOM WINDOW command and manually enter the southwest and northeast corner coordinates of the data set. This will bring the full data set on screen. The second method is simpler and consists of issuing the ZOOM EXTENTS command. However, it only works if you have no entities in the drawing other than those within the confines of the data set coordinates. Default borders, title blocks or any other entity that is outside the extents of the data set will diminish or eliminate the usefulness of this command sequence.

The third method though more complicated and time consuming will gain the user more speed in manipulating the drawing later on. There are four steps involved.

1. Do a reorigin. That is, by windowing the data set on a MOVE command and selecting the southwest corner as the base point, the entire data set can be moved so that its southwest corner resides at coordinates X=0 and Y=0. This does not, however, change the size of the total drawing which was established at the time the data was imported.

2. Create a block of the entire data set using the BLOCK command and windowing the set.

3. Save the block as a drawing using the WBLOCK command. The block is then saved as a drawing file.

4. Exit your existing drawing and open the file you just created using the WBLOCK command. Your new drawing will have much smaller extents then the original and will be easier to manage.

One thing that must be noted with the third method above is that enormous amounts of hard disk storage space are required. While creating the block, the 1.2 megabyte drawing file expands to over 2.9 megabytes. Because AutoCAD also creates a backup file of the drawing as you are working and because there must be sufficient space on the hard disk to store the new drawing, you must start with at least 7 to 8 megabytes available on the disk before attempting the third method. However, the speed advantage it offers during subsequent manipulation and computation is well worth the effort if one intends to use the data frequently.

You will notice that the drawings come up in a 2-D (plan) view. Contour drawings are 2-D drawings so no 3-D viewpoint changes are necessary. By zooming and panning the user can acquire whatever view is necessary in whatever scale desired.

The TTM files, though actually 3-D files, also come up initially in plan view but can be changed to a 3-D view using the viewpoint (VPOINT) command and specifying the point in 3-D space from which the drawing is viewed. This combined with panning and zooming will net the desired views and scales.

The following topics are outside the scope of this project but are included for completeness in coverage of the full problem.

Determine Optimal Site

Once the data are available and stored, the user is ready to compare the sites. Individual sites can be evaluated based on site-specific differences. While cost may not likely be the key consideration in setting up a bare base, expediency may, and a site requiring less preparatory work may prove the best candidate for selection. Inasmuch as host nation approval is a requirement, the plan must be presented to the local and national governments for consideration. This type of system could be used to graphically present the concepts to government representatives at the national and local level. This could be done for the several sites under consideration. A possible outcome could be that the site selected is not the optimal one, but the one approved by the host nation based on the graphical presentations.

Detailed Evaluation of Selected Site

If a site selection has been based on data too coarse for detailed engineering work, or if more detailed information is required for selection, then additional data gathering may be necessary.

The actual criteria for evaluating a site will not be addressed in this work.

Detailed Data Gathering

Depending on the requirement, site availability, and cost, several alternatives are available for detailed site surveys. One method is to acquire by-request satellite imagery of the site that is of sufficient spatial resolution to meet the precise engineering needs. If that method is too costly or otherwise unavailable, there is a second alternative. The data can be acquired by either high or low altitude overflight of surveillance aircraft. A third method is also available which falls at several extremes when compared with the first methods. Ground surveying the site is the most accurate of all methods of acquiring the data. At the same time it is also the slowest method. It can be the least or most costly depending on the location, accessibility, and costs of manpower and transportation to perform the survey. All factors such as time, money, accuracy, and accessibility to the site(s) must be taken into consideration when deciding among the three methods. Often when considering prospective sites for military installations some caution must be exercised regarding placing a visible military presence in the region prior to actually acquiring rights to the site. Similarly, the deliberations might be of a sensitive or classified nature and actual military presence may be impossible. In such situations surreptitious data gathering may be the only alternative and costs may no longer be a consideration.

Process and Import Data

Once the new data is acquired, it too must be processed into the system as described above.

Perform Detailed Data Manipulation

At this point the engineer, designer, and/or site planner must establish a working plan for improvements to the site. Airfield criteria, clear zones, environmental impact, on-site and off-site drainage, required facilities, required demolition (if any), roads, utilities, and military and host nation siting criteria are but a few of the things that must be considered. The topographical data can be used to determine slopes and elevations so the designers can determine proper orientation and placement of facilities.

Overlay with Construction Entities

Once a plan is developed, the user can construct CAD models of the various facilities and insert them into the drawing, gradually building the bare base to the established standards. As the plan develops the entities can be relocated as necessary with little effort by simply using the move command. Note that these entities can and should be rendered in 3-D. By doing this the designer can "move around" the graphical mockup of the bare base and see an accurate representation of how the base will appear upon completion. Similarly the aircrews, base maintenance personnel, and even those who will do the construction can use the information.

Ultimately, given the proper spacing and siting criteria, the system may be capable of automating the process of optimally siting the facilities.

Generate Working Documents

A multitude of information can be derived from the data. These range from earthwork-related items such as cut-and-fill calculations and sections and profiles based on design templates to working drawings for all construction. As sub-routines are added to the system, it may become capable of additional derivations as complicated as cost, material, manpower, and equipment estimates.

Beyond this, the data can form the basis of the comprehensive plan for the base. Once the base construction is completed, the data can be updated and become a part of the records kept by the organization responsible for maintaining and repairing the installation. As-built drawings can be used to update the data base as facilities are added or removed.

Additionally, the data can become invaluable during conflict. As part of an integrated system the data could be used to compare airfield and facilities before and after attack and could become the basis for an automated air base damage recovery planning effort. Optimization techniques can be applied to determine the most needed repairs to airfield pavement and critical facilities. In fact, given manpower and equipment estimates and productivity figures, the system could be configured to determine repair times and provide schedules.

CHAPTER 6

RESULTS

This chapter contains output drawings of two of the forms provided by the GWN-DTM AutoCAD combination: contour drawings and triangulated terrain models.

The first set of drawings (Figure 4 through Figure 9) consists of the various views of the two drawing types. Figure 4 and Figure 5 are 2-D (plan view) contour drawings. Figure 6 through Figure 9 are 2-D and 3-D TTMs.

The second set of drawings (Figure 10 and Figure 11) depict the overlay facility alone, viewed facing north. Figure 10 shows the wire frame representation and Figure 11 shows the same view with hidden lines.

The third set of drawings (Figure 12 through Figure 17) consist of views similar to those of the first set with the addition of the facility and represented with hidden lines. Note that there is no full view 3-D TTM facing northeast. While printing only took 2 to 3 minutes, generating the full view hidden line drawings required nearly 5 hours of computational time to hide the lines and produce the drawing vectors prior to printing. Several attempts were made to generate the northeast view, but internal read errors in the program made it impossible with the test system. The cause of the error could not be determined.

The final set of drawings (Figure 18 through Figure 20) presents several 3-D TTM views with the facility depicted in wire frame. These figures show the difficulty in interpretation when lines are not hidden.

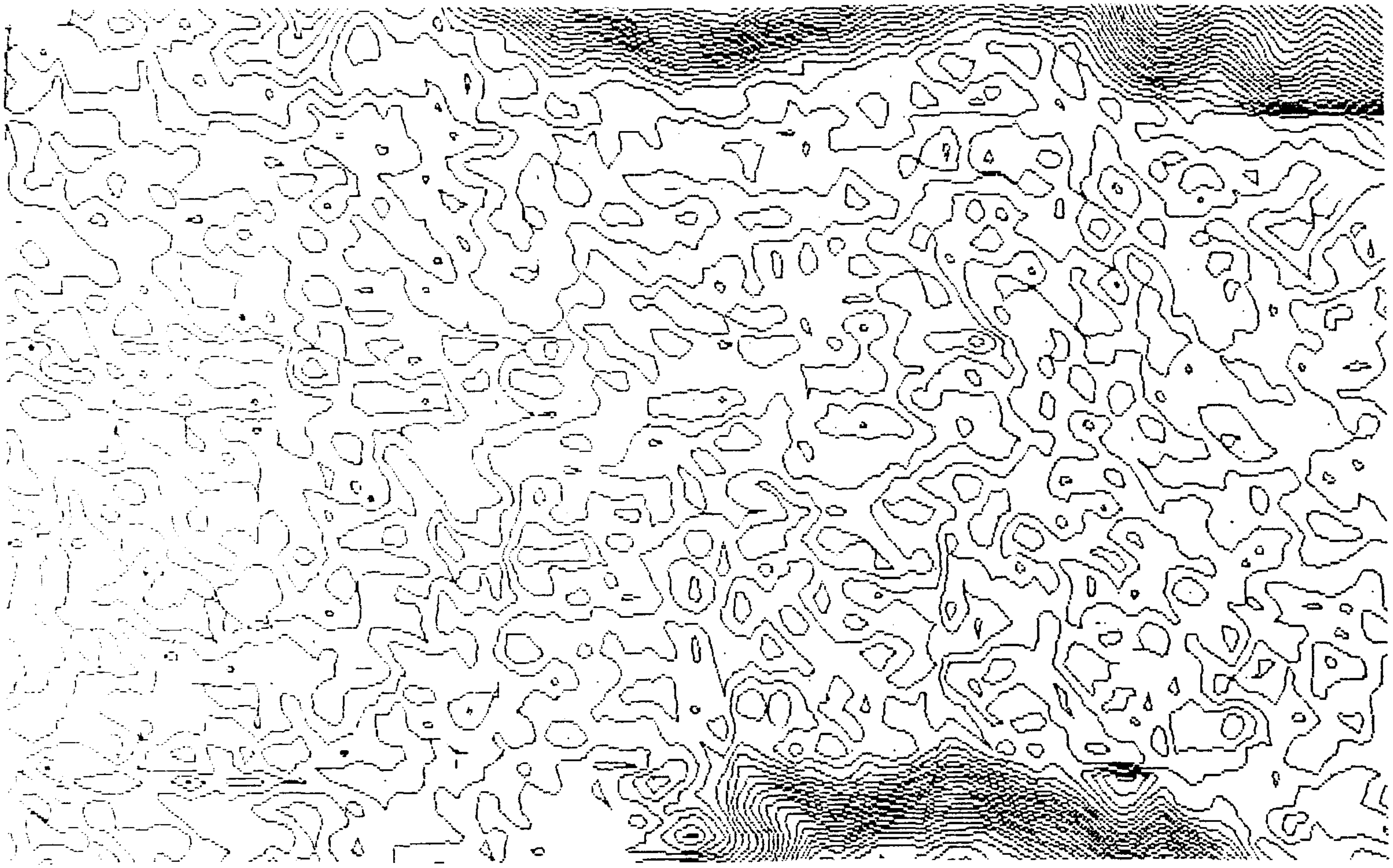

Figure 4 - Full 2-D Contour, North View

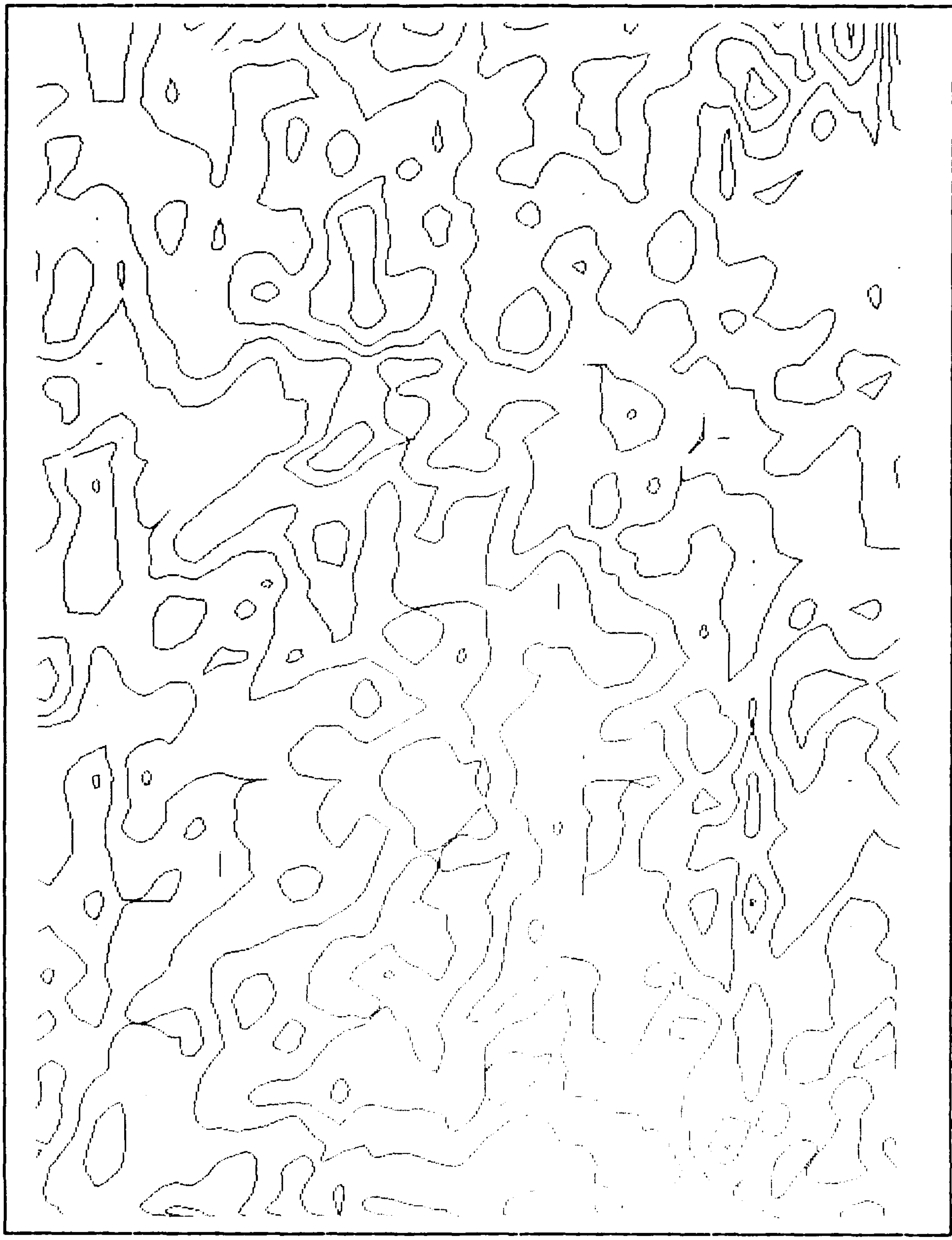

Figure 5 - S-W Quadrant 2-D Contour, North View

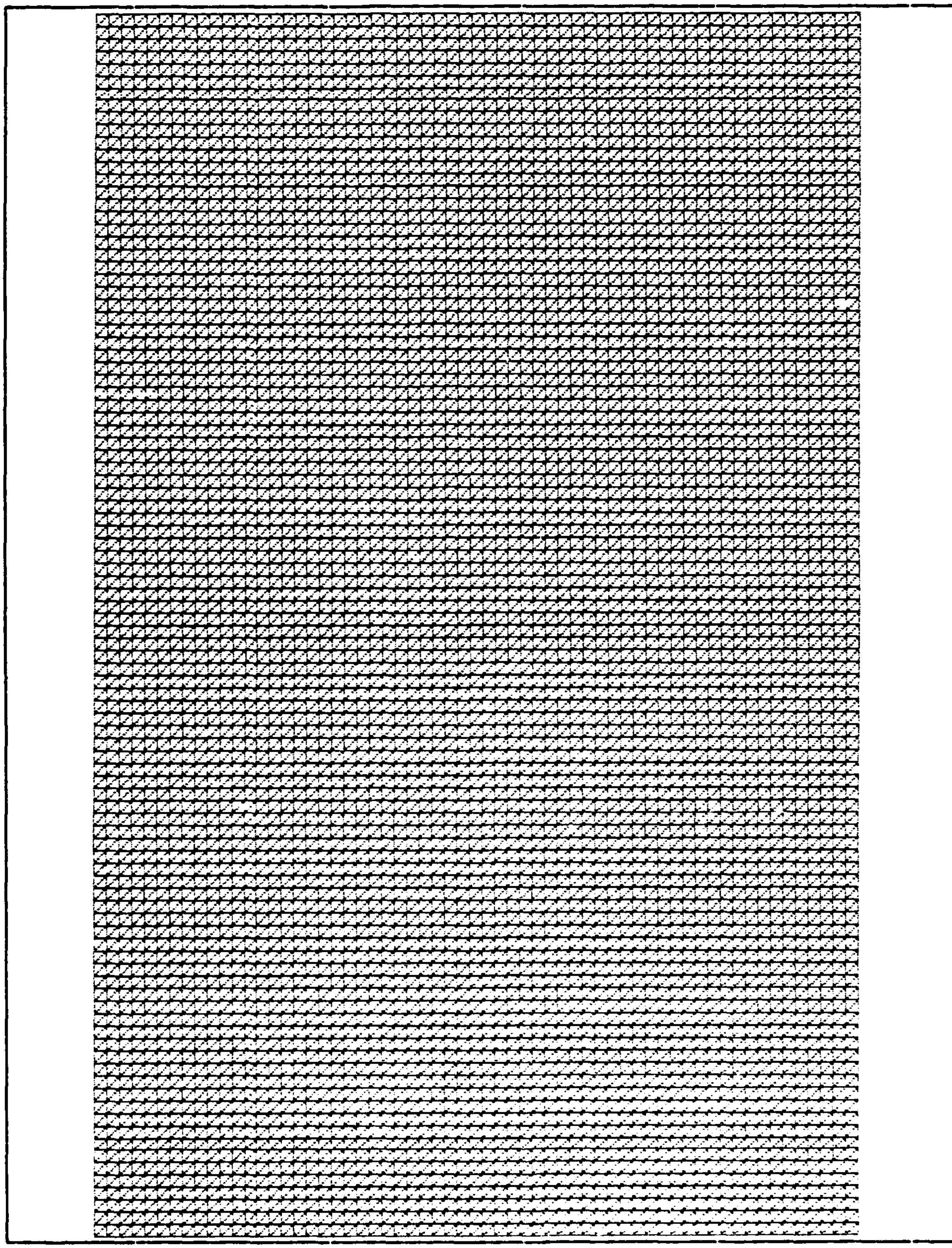

Figure 6 - Full 2-D TTM, North View

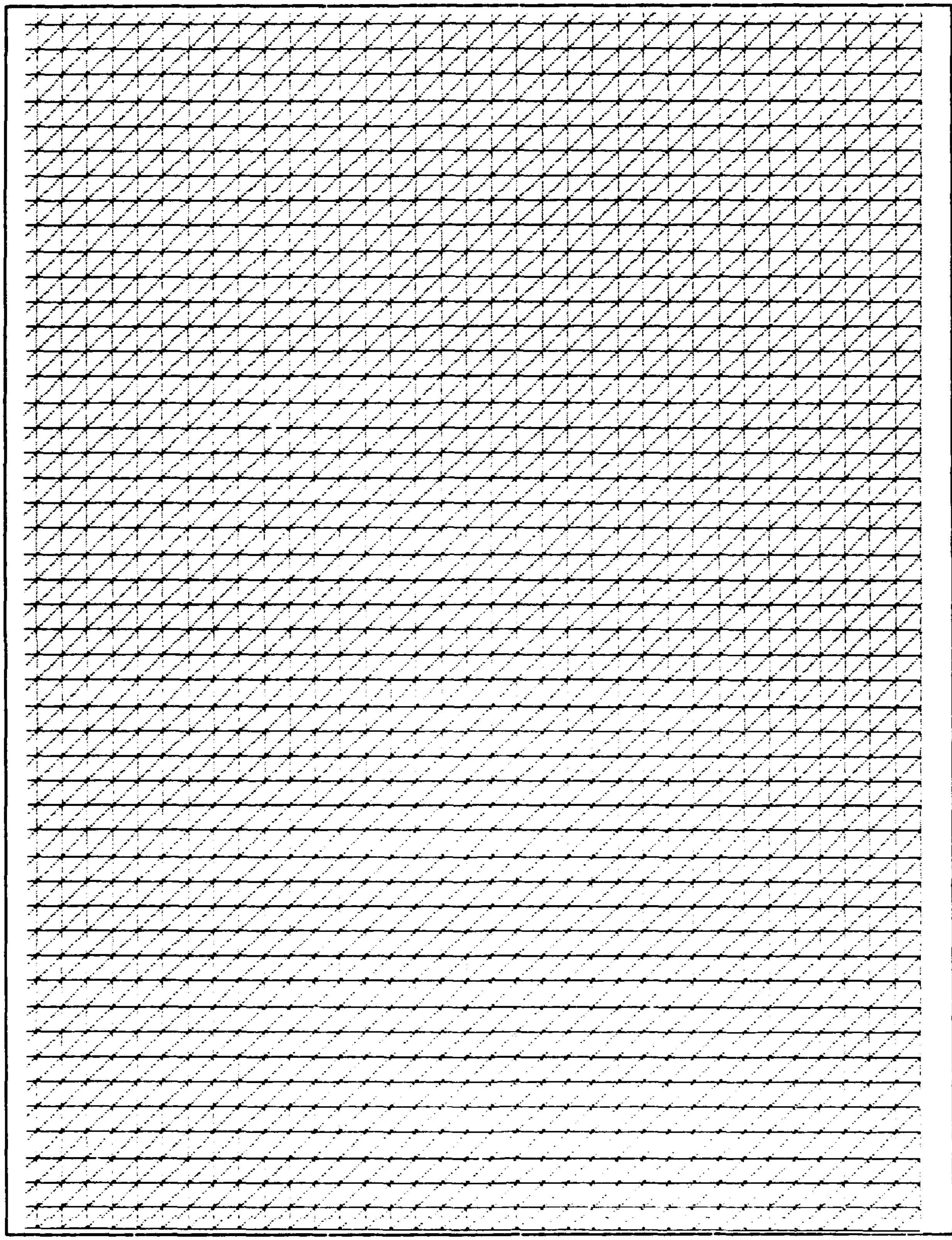

Figure 7 - S-W Quadrant 2-D TTM, North View

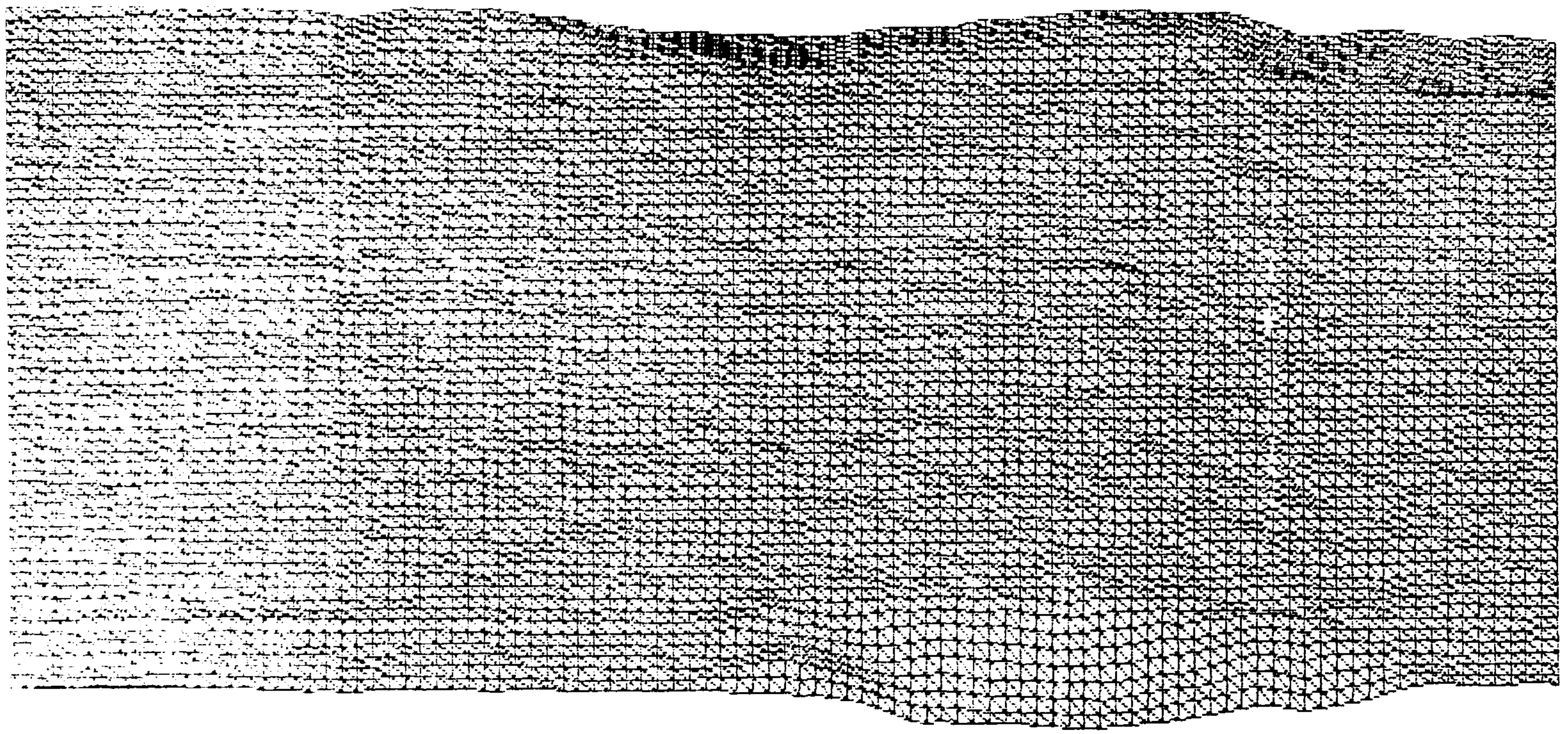

Figure 8 - Full 3-D TTM, North View

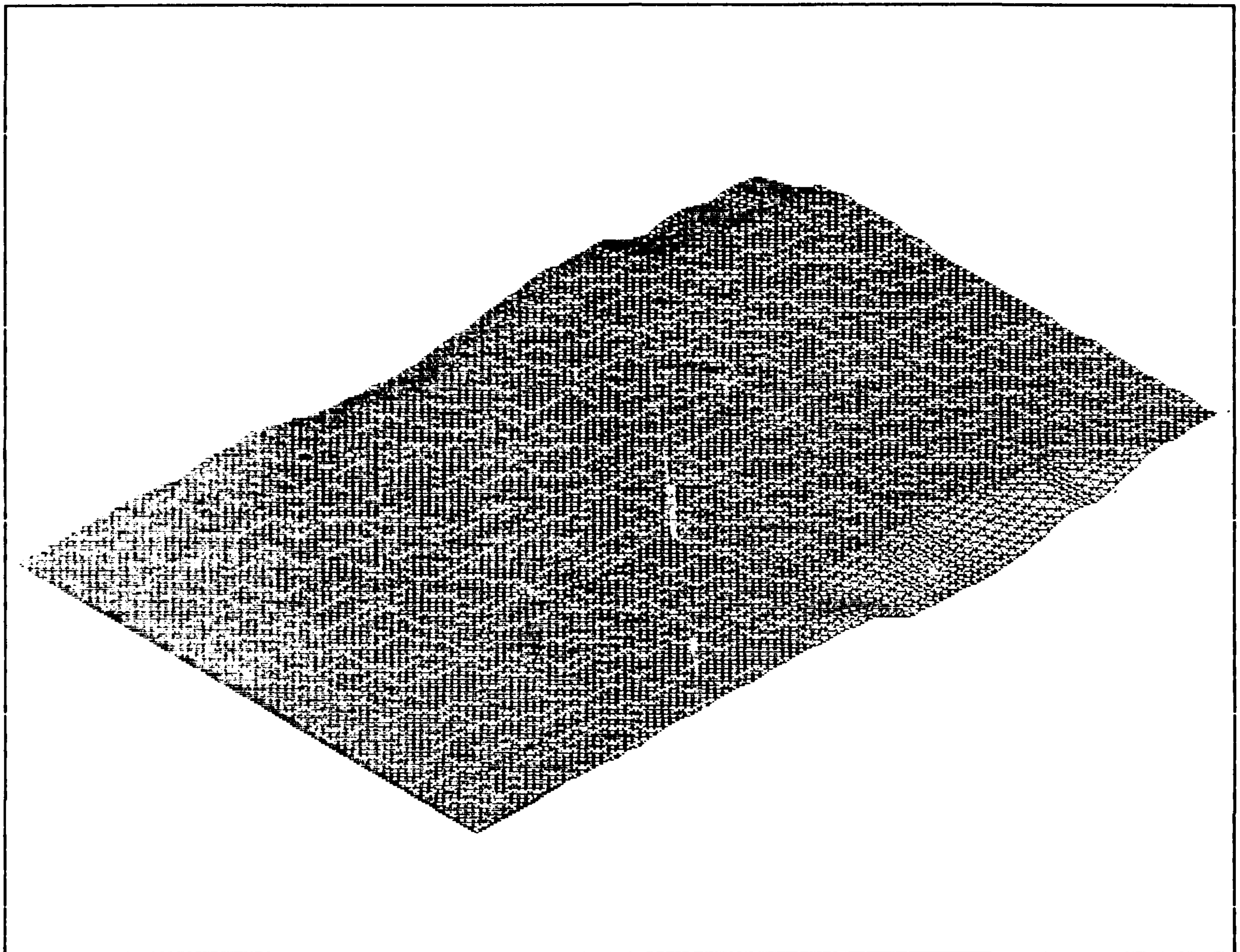

Figure 9 - Full 3-D TTM, Northeast View

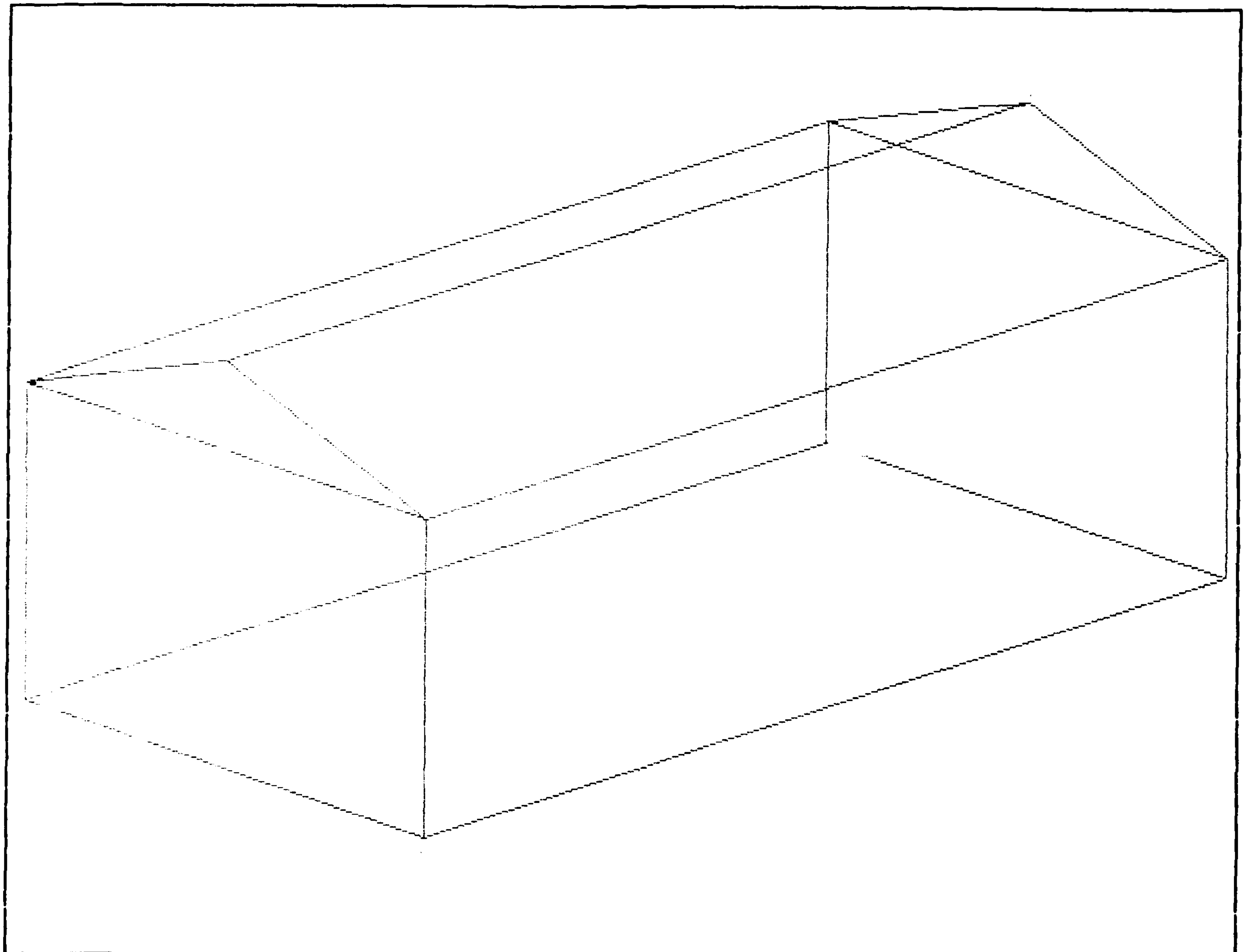

Figure 10 - Facility, Wire Frame, North View

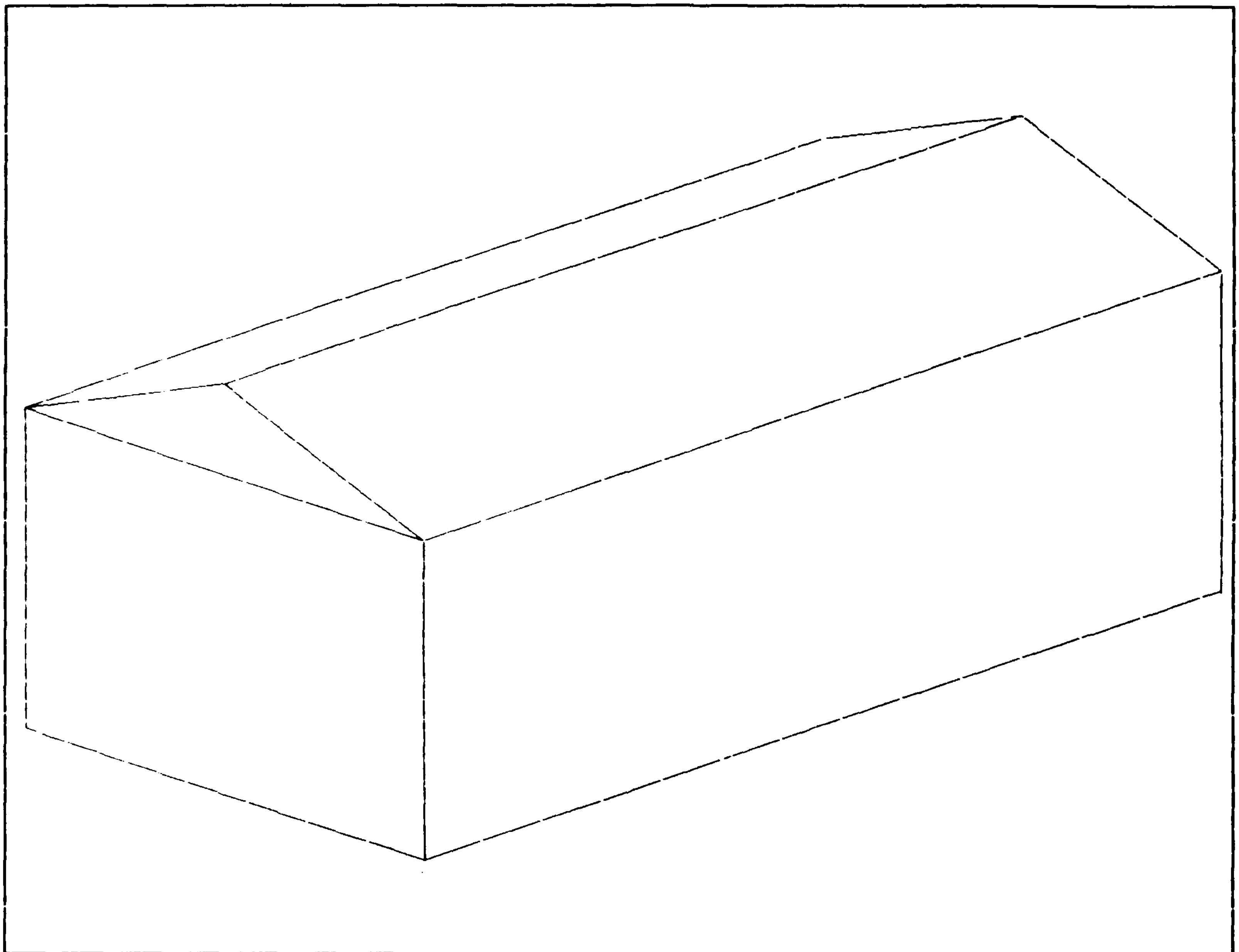

Figure 11 - Facility, Hidden Line, North View

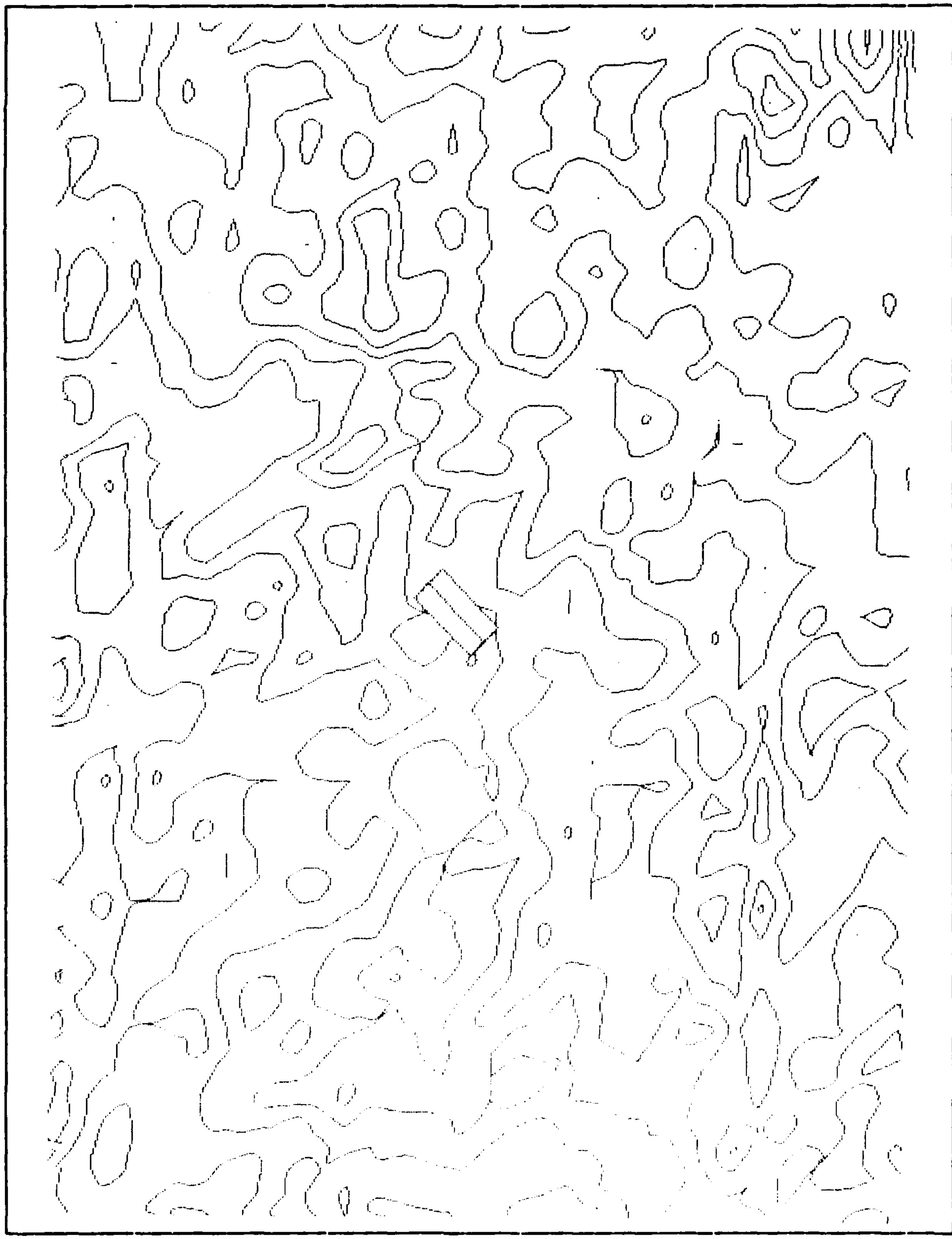

Figure 12 - S-W Quadrant 2-D Contour, North View

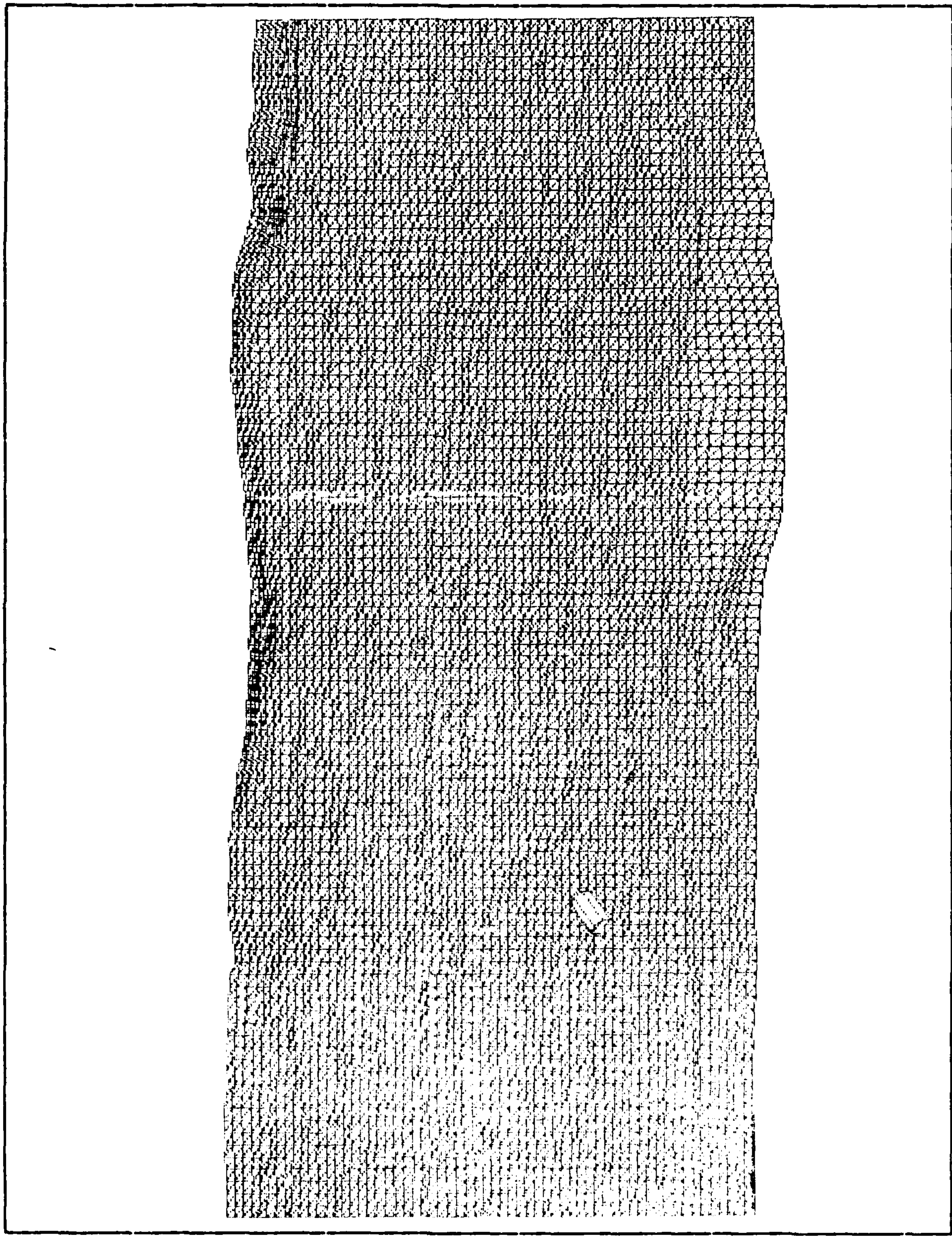

Figure 13 - Full 3-D TTM, North View

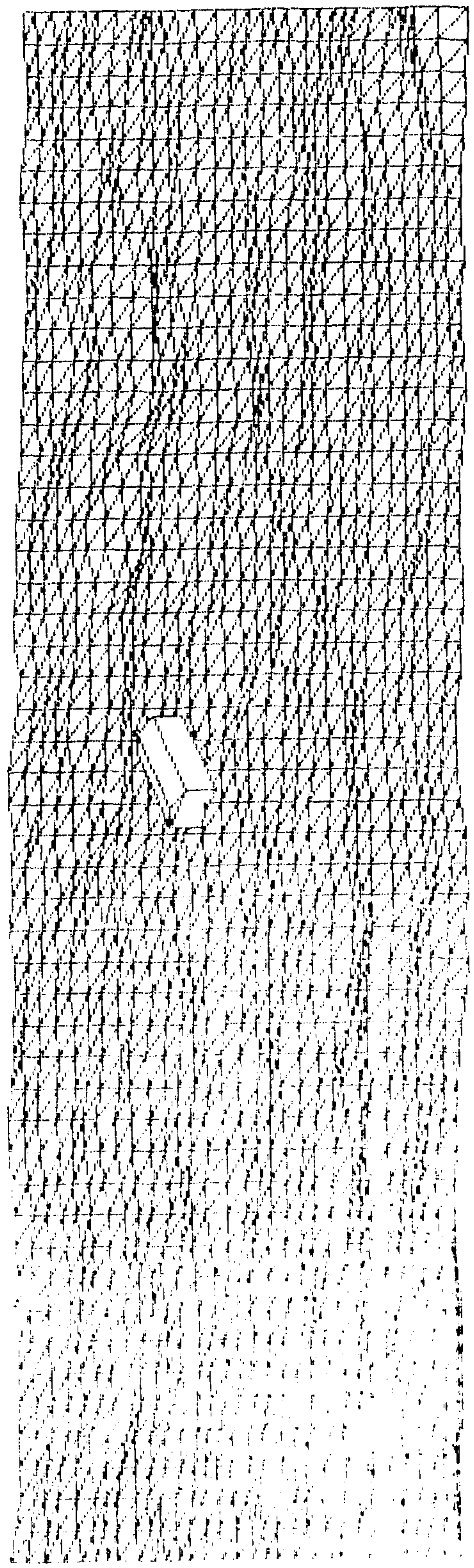

Figure 14 - S-W Quadrant 3-D TTM, North View

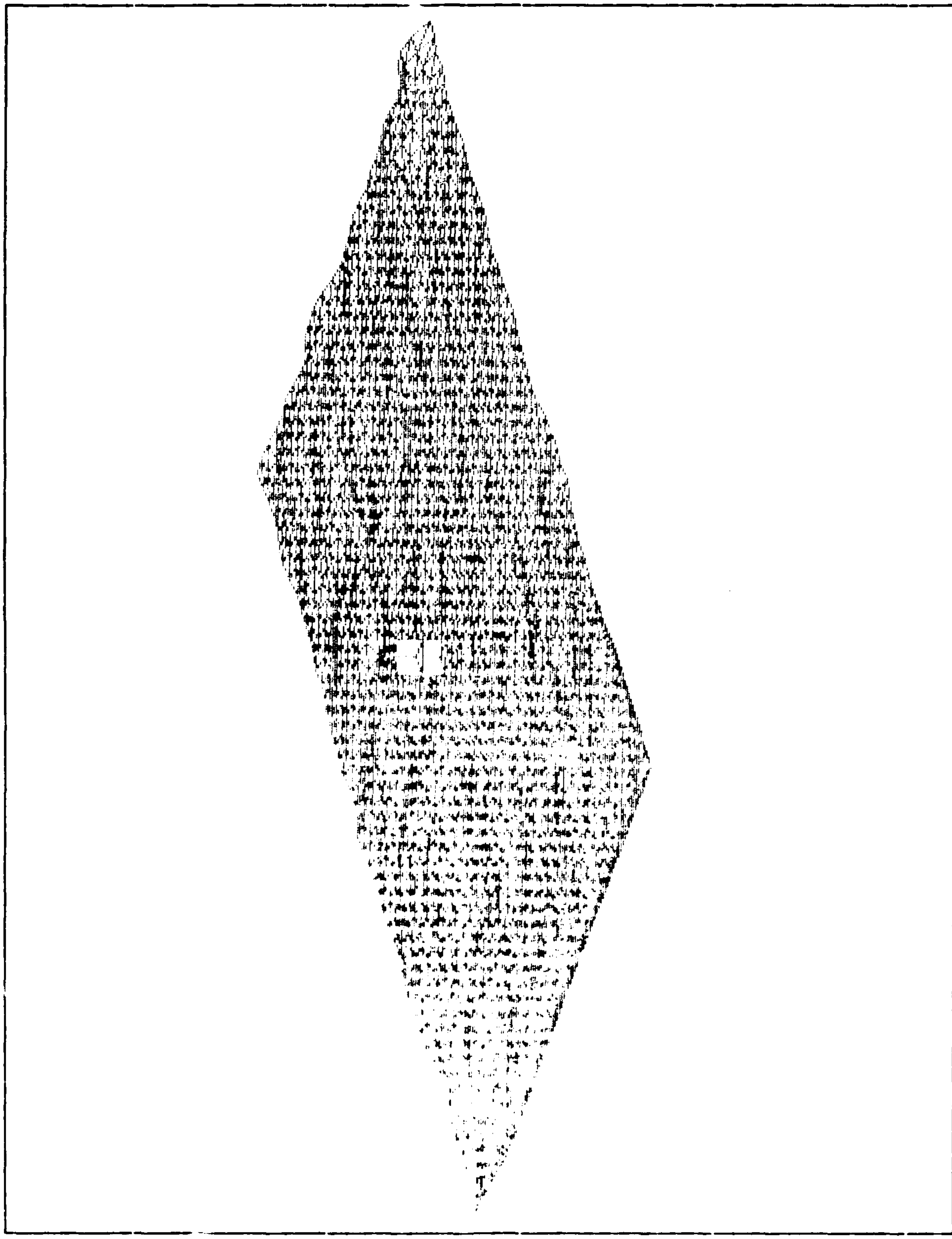

Figure 15 - S-W Quadrant 3-D TTM, Northeast View

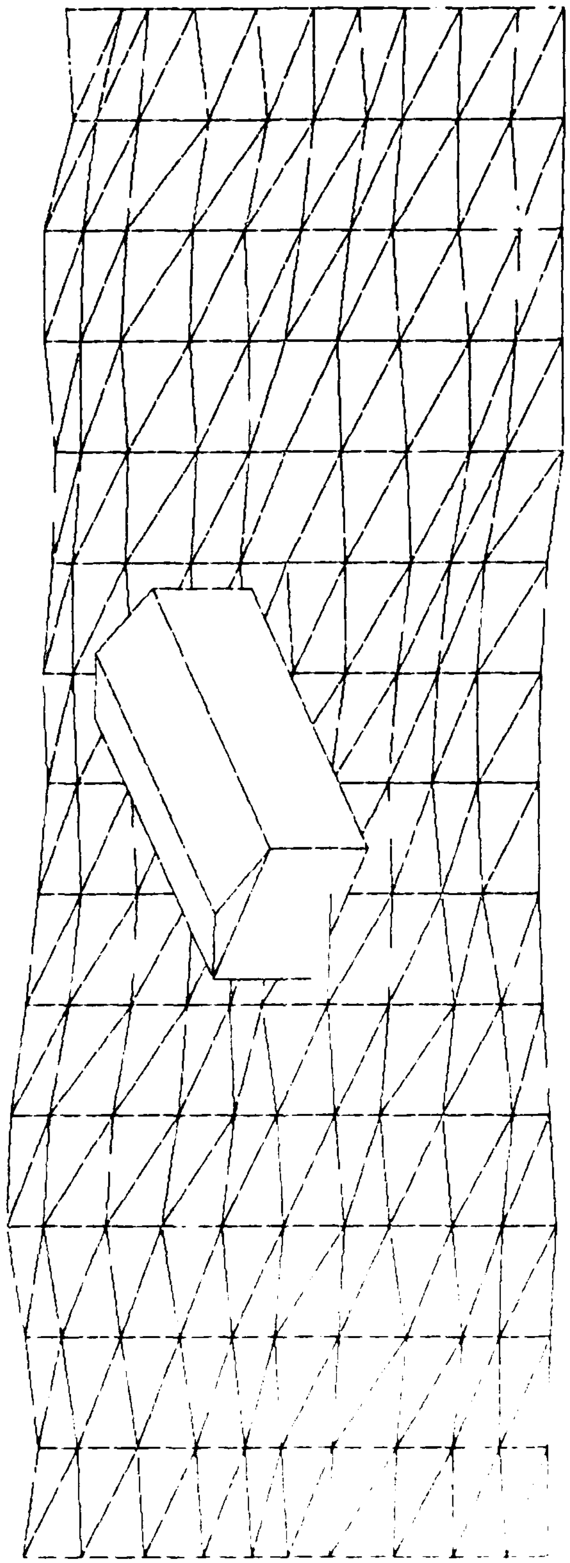

Figure 16 - Zoomed Section 3-D TTM, North View

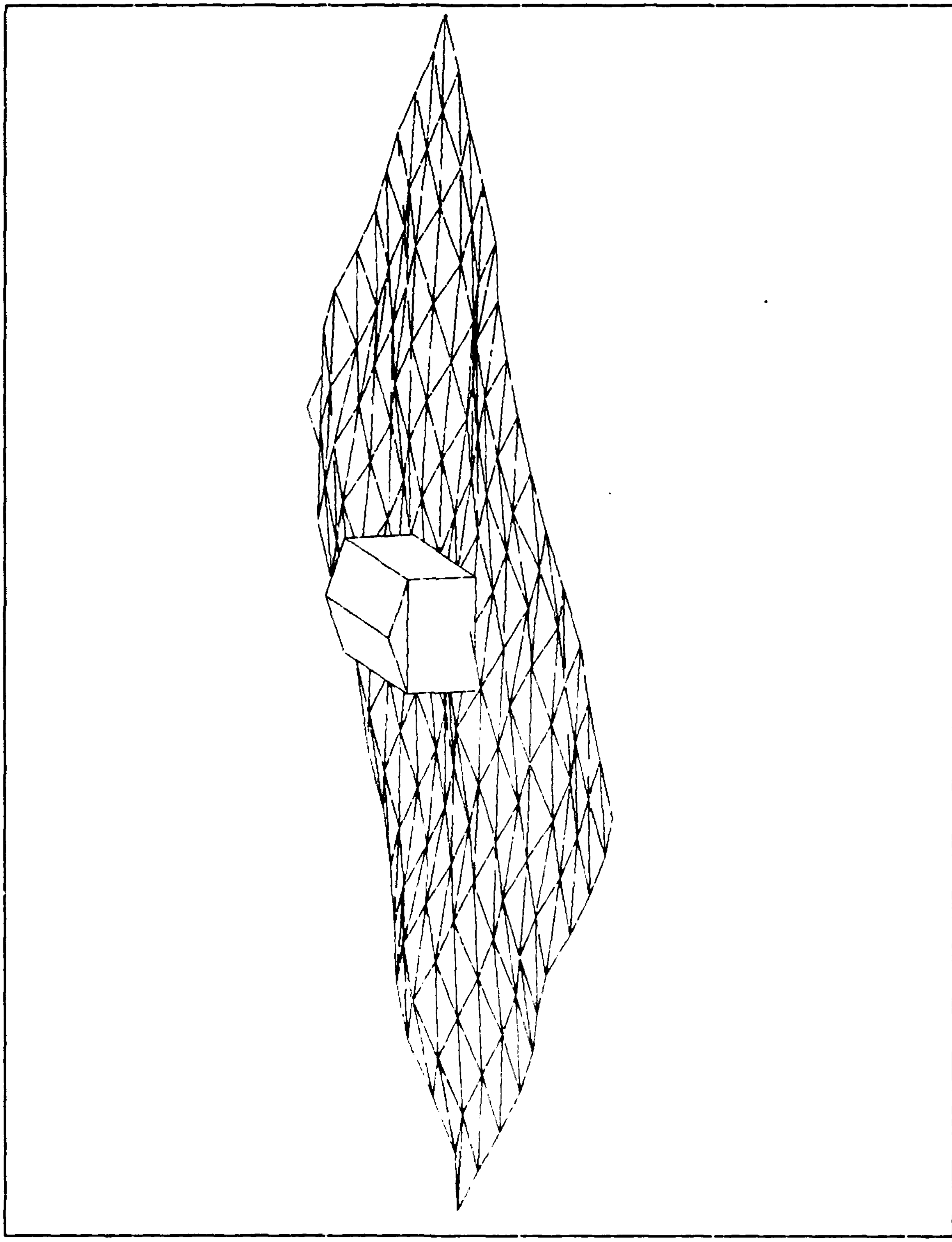

Figure 17 - Zoomed Section 3-D TTM, Northeast View

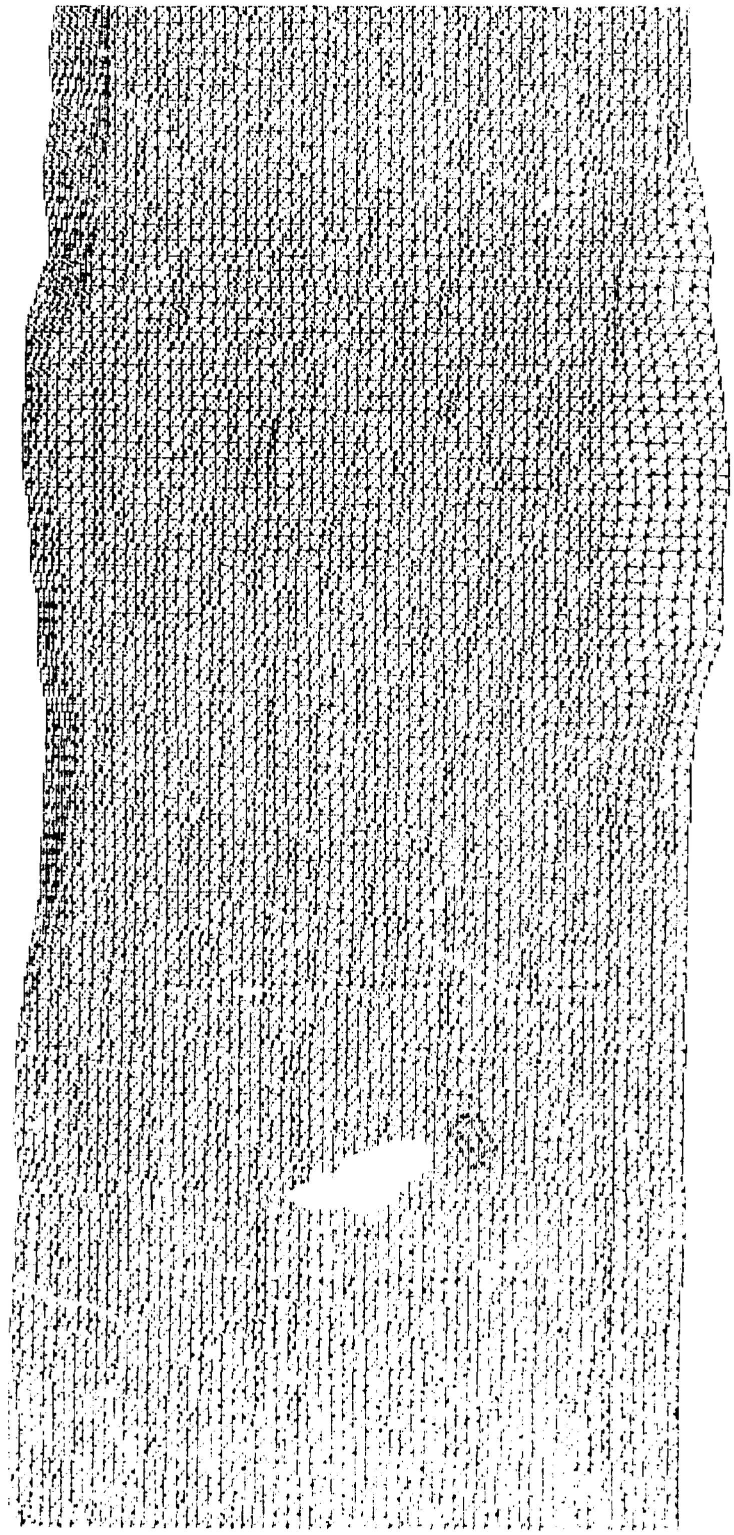

Figure 18 - Full View 3-D TTM, North View

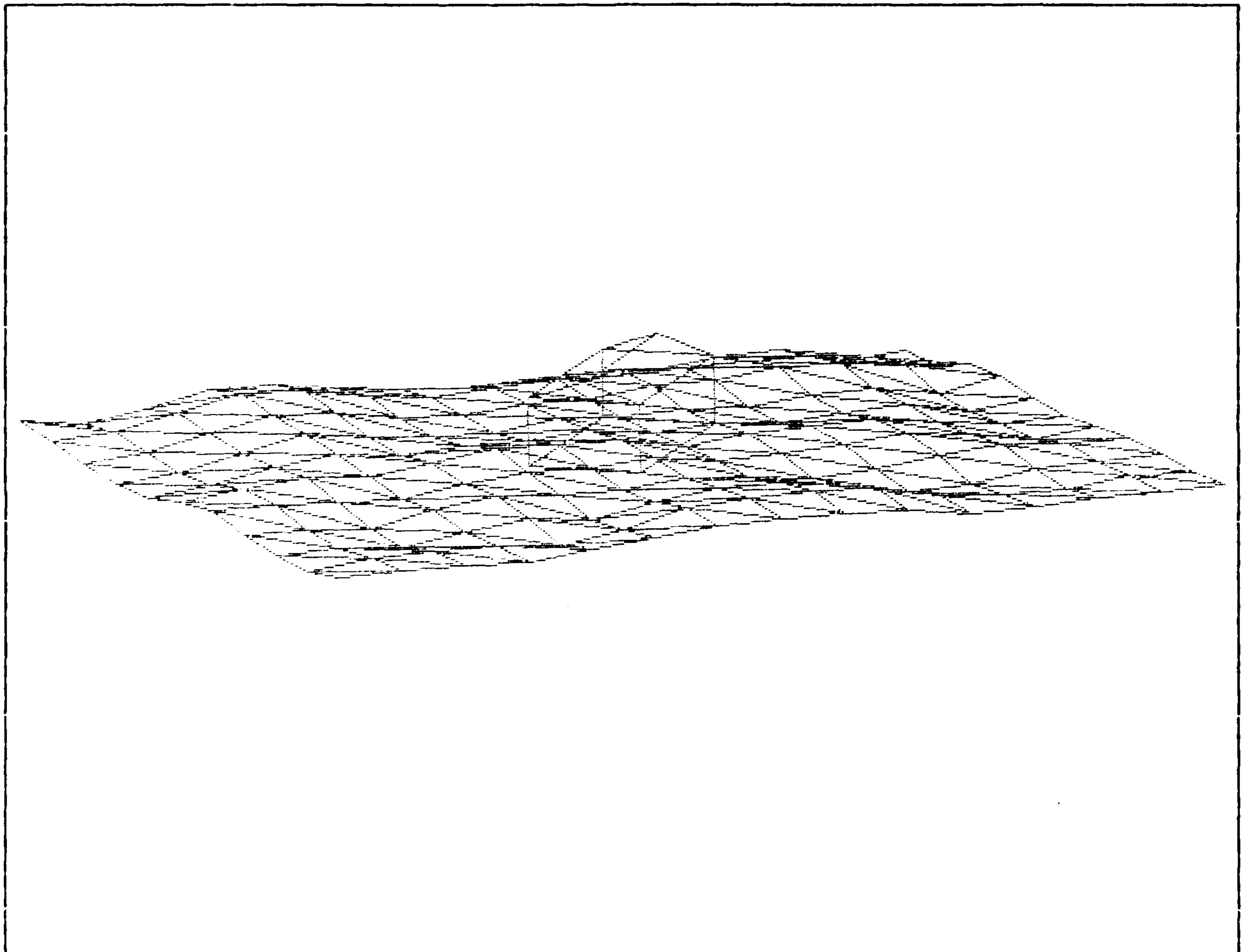

Figure 19 - S-W Quadrant 3-D TTM, Northeast View One

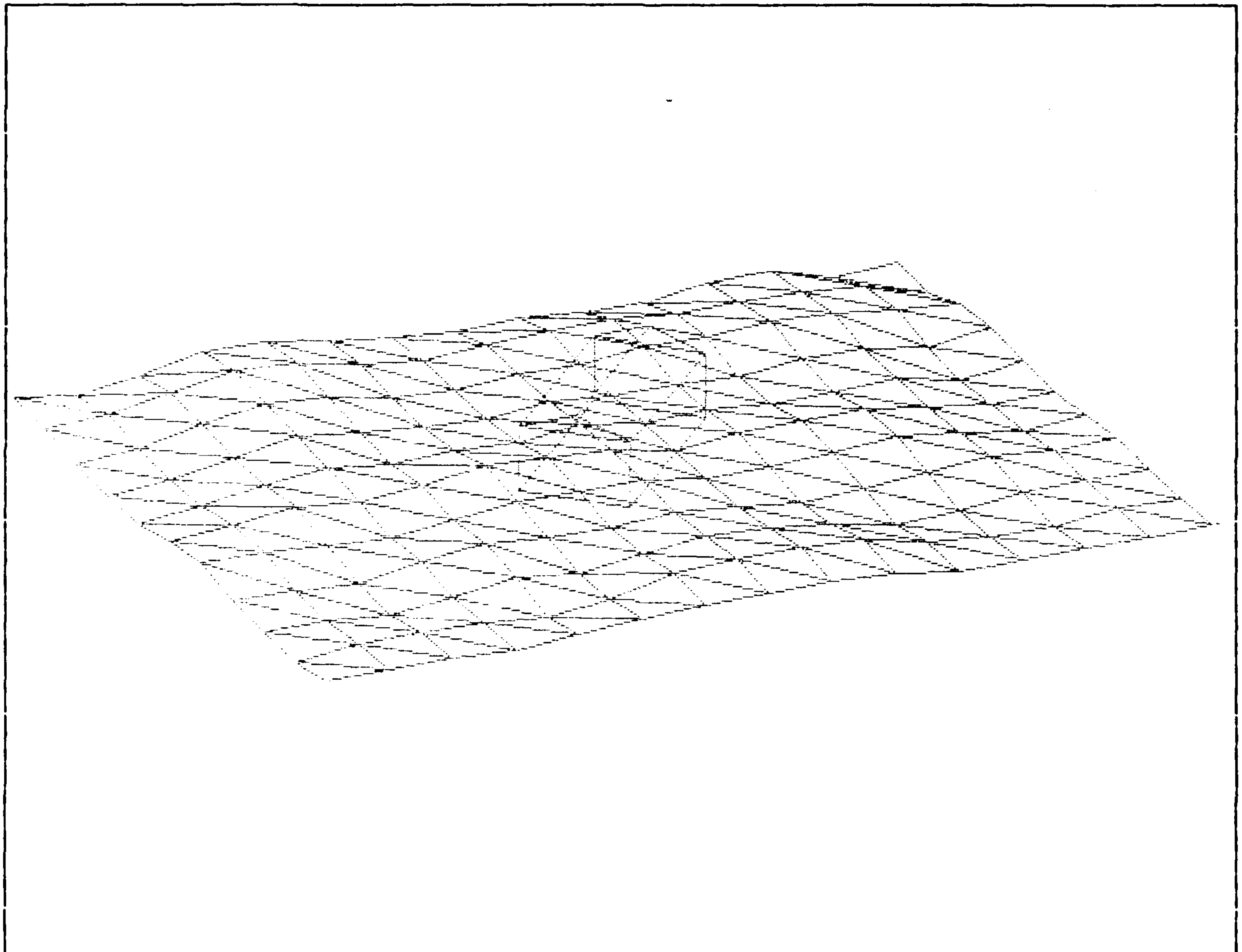

Figure 20 - S-W Quadrant 3-D TTM, Northeast View Two

CHAPTER 7

CONCLUSIONS

The conclusions will be presented in three parts, the first two loosely following the goal structures presented in Chapter 1 - Introduction and Chapter 6 - Discussion. The first part addresses the broad goals of this research while the second part deals with the evaluation of the test system. The final part is a summary of the project conclusions.

Project Goals

Hardware and Software Availability

The search for systems and software capable of performing the necessary functions was by no means exhaustive; that was not required. What was revealed was that there are at least half a dozen packages, with or without hardware, that can do the job with little or no modification. A larger question confronts subsequent researchers. That is, should any one of these systems be used at all. Though each brings significant capabilities to the user, each also carries its own excess baggage in the form of unnecessary features, high initial cost, and structures not geared to the work at hand. Thought should be given to programming a custom system.

Data Availability

First, 30 meter data is not adequate for the detailed engineering work. This is apparent from viewing the results. Perhaps 10 meter data is fine enough resolution but that will have to be determined through subsequent research. Certainly data within these ranges is widely available for a significant portion of the earth's land mass. Whether images or digitized data will be available for a specific proposed site cannot be predicted. But data collection capabilities exist within the military and intelligence communities that can cover the entire globe. Though resolution may prove to be a problem, actual data availability should not.

Acquire Data Set

Simply put, a data set was acquired which was adequate to demonstrate the basic capabilities of the software and system. From that standpoint this task was a success. The resultant TA2 ASCII file was 190 kilobytes.

Choose Software-Hardware Combination

Two of the three stages of this task were very cut and dry. First, the hardware used was chosen because it was the hardware owned by the researcher. Though not an optimal system, it proved adequate for preliminary work. Second, the CAD system chosen was the only one available for use by the researcher. The third task, choosing an importation and terrain modelling package was not as simple. Though many systems are available commercially, cost prohibited purchase for this project. The GWN Systems software was available in demonstration form, but the demo software would not handle the test data set. However, the owners of GWN Systems were kind enough to process the data and provide some limited software to manipulate that data. Their generosity dictated the use of their system.

Manipulate and Import Data

Actual data manipulation and importation proved to be a time-consuming proposition. Generating the contour DXB files required only 5 minutes processing time. Converting the TA2 files to TTM files took approximately 25 minutes processing time on an 80286 10 megahertz AT compatible machine. Converting the TTM to a DXB file took 8 minutes on the test system. The DXBIN command (importation) averaged 8 minutes on the test system, resulting in a 1.29 megabyte drawing file. Loading that file into AutoCAD required an average of 3 1/2 minutes. Every drawing regeneration caused by changing views or viewpoints required an average of 3 1/2 minutes. Care must be exercised when operating in the drawing to minimize regenerations. Otherwise, productivity can be severely hampered. Achieving the desired views is fairly straightforward with the viewpoint (VPOINT) command. This easily rotates the views to those required by the user.

Another caution is worth noting here. Be very careful when issuing the hide command on these large drawing files. Doing so requires over 4 1/2 hours processing time to do the line hiding.

Facility

Creating and inserting the facility is another straightforward operation. Of course the first step is to draw the facility and this was done in a separate drawing file. For this project a simple wire frame rectangular structure with a pitch roof was chosen. The facility was sized at 100 meters long by 50 meters wide by 38.33 meters high. The odd height was a result of the 4 in 12 pitch roof. Though the size of the facility may seem large for practical utilization in a bare base situation, it could simulate a large-bodied aircraft maintenance hanger or a regional medical warehouse. Moreover, the dimensions were chosen so the facility would stand out in the graphical representations.

Creating the facility was accomplished using the elevation command (ELEV) to draw the four sides and the 3 dimensional face command (3DFACE) to draw the roof and gables. Once constructed, the facility was saved as a block using the BLOCK command with the foundation center as its insertion point. The block was then written to disk with the WBLOCK command and the working drawing was closed. The data set was then opened and the placement was a simple matter of using the INSERT command to place the facility at the desired location. The ground elevation at the center of the facility location is 477 meters. The facility was placed with its long axis orientated along a bearing north 45 degrees east. The base of the foundation was placed 2 meters below the ground level at 475 meters. The resultant facility displays well on the various models.

Output

Graphical output was continually displayed on the monitor screen during data manipulation. Hard copy output was accomplished using the PLOT PRINTER command, printing the various displays as they were brought on screen. These drawings were the culmination of the actual work on the system and are presented in the chapter on results.

Working Conclusions

Determine Area(s) of Interest

For this project the data set location was not as important as the availability of the data. However, in a field setting, it must be noted that the selection of candidate sites will likely occur independent of the computer system. If, however, the system is based around a worldwide GIS with a data base which contains sufficient information, the actual search for candidate sites may conceivably begin with data base retrieval from the GIS.

The criteria for actual selection of the candidate bare base sites will likely be less a factor of topographic suitability than of factors such as political events, world tension, and host nation acceptance. More important is the fact that such a GIS would entail data storage requirements of such magnitude that even the largest mainframe computers would have difficulty maintaining the data base. Consequently the prospect of fielding a micro-based portable system with such broad-reaching capabilities seems impractical.

Acquire Data Sets

If one accepts the premise that a GIS encompassing the entire globe is impractical for this application then it is logical to assume that the selection of candidate sites will require the acquisition of data sets. While a great deal of the earth's land r ,s has been imaged, it is also logical to assume there will occur situations where adequate imagery does not exist for one or more candidate sites. If the imagery does exist, then it is just a matter of requesting the information from the appropriate source. That source will depend on the service using the system, but ultimately, requests for imagery will be processed through the DMA. If the imagery does not exist the request for acquisition is generally requested through the same channels but will necessitate that either an orbiting platform, aircraft, or ground survey team obtain the data. In either situation a predetermined procedure, backed by written agreement, must be established to expedite the process. That agreement should also specify the delivery time requirements.

Determine Required Processing

As previously stated, raw imagery data is of very little use to an engineer. Processing of that data into a coordinate-based, usable topographic or cartographic form is a prerequisite and entails some very sophisticated transformations. Systems exist, however, which perform these transformations quite adequately. The agreement between the user and the agency that provides the data should include the level of processing required and acceptable error tolerances. These agreements are crucial if data is to be provided quickly enough for decisions to be made in a timely manner.

Process Data

The goal here should be to minimize any additional processing the end user must apply to the data prior to importation into the system. It would be wise to totally eliminate any additional processing. Doing so would reduce the time, equipment, and manpower necessary to operate the system. And because the providing organizations already possess the technology to do the processing, it seems unwise to either reinvent the wheel or even include that wheel in the portable system. Stereo analytical plotters (as an example) are very bulky, delicate pieces of equipment that are difficult to transport. More important, the skills to operate such a system do not exist within the typical engineering and design organization. Including such a system would necessitate that additional skills be acquired. The goal here should be to develop a system capable of being operated by existing disciplines within the engineering organization.

Import Data

The results demonstrate that importation, though time consuming, is a fairly straightforward task, requiring only a basic understanding of the CAD program and the importation software. The task might be further simplified by employing an all-in-one system that integrates the conversion, importation, and manipulation utilities with the CAD program in a single environment.

Determine Optimal Site

While this task was not explored by the researcher, it seems plausible that, with practice, the individual manipulating the data can develop views that will provide very informative perspectives of the sites. Programs can be developed to automate the generation of those drawings or views. Further, automation can be applied to the processes of acquiring other data about each site such as total area;

maximum, minimum, and average slopes; and water coverage. Additionally, if digital feature data is included, the location of timber stands, roads, and other important features can be ascertained and this process can be automated also. The system should be flexible enough to add or remove algorithms as criteria are added or deleted.

Analyze Selected Site

At this point either the user has fine enough resolution data to adequately engineer and design the site or additional data will be required. This issue was thoroughly addressed earlier. Once adequate information is on hand the detailed site work can begin.

Here is where the actual site design and engineering work begin. Construction entities are created and placed as required on the site. The tested system possesses sufficient power to accept and create the required templates, perform the cut-and-fill calculations, produce sections and profiles, and provide high quality hard copy output of drawings.

Several important capabilities have not been explored. The first is the potential of the tested system to develop material and manpower estimates from the input data. The second is the potential for generating equipment requirements, such as for earthwork or material movement. The capability to do material estimates, however, has been demonstrated by others.[8] A third capability not explored is the automation of facility placement. While this may be a goal of such a system, the ability of the tested system to perform such work is doubtful without additional software.

Summary

In general, this project revealed that the technology exists today to field a system capable of the proposed functions. While that technology exists, for the most part, in commercially available systems, it does not come together in any one system. Consideration should be given to eschewing the use of existing systems and designing a task-specific system around a graphics kernel. Doing so, the developer could eliminate the overhead associated with maintaining a broad application system and design an efficient one capable of only the tasks necessary. Resident memory requirements could be reduced and more efficient storage methods for data sets could be developed.

CHAPTER 8

RECOMMENDATIONS

Recommendations for future research will be addressed on a point-by-point basis in four categories: system use, software, hardware, and general recommendations.

System Use

Research should be conducted to determine if there is a definite need for such a system. Does one branch of the military services generate a sufficient level of demand or should it be tailored as a multiservice system, capable of more generalized siting and design work? The actual criteria for selecting a site and for analyzing a chosen site are also topics for further research.

Is there merit in extending the system to accomplish more than just bare base siting and construction? Could it be economically expanded to aid in subsequent long-term follow-on maintenance and repair of the facilities? Moreover, could it be designed as a tool for military engineers in wartime, establishing an operational data base and aiding in damage assessment and facility and utility recovery after attack? By broadening the system's capabilities would it prove attractive to a larger group of users? These are questions which warrant future study.

Software

Research should be done to compare existing software and to determine relative strengths and weaknesses of each. This will likely require acquisition of those packages and head-to-head testing and evaluation. Restating from the conclusions, consideration should be given to designing a system from the ground up. Using a graphics kernel, or starting from scratch, the design could be tailored to the user's specific needs, thereby eliminating unnecessary features and reducing total system cost. Certainly the costs of designing such a system would far exceed those of purchasing an off-the-shelf package. Sufficient system demand would have to be established to warrant the capital investment for system development.

For the system to be practical, the user should have access to a data base of standard facilities. Each facility file could include full working drawings which would only require site adaptation. Represented in 3-D, the facility files could be placed as desired by the user in the bare base drawing. The data that would make up these files is available as standard drawings through the respective military services. Research could be done which would collect the data, compare it across the services, and distill out the common features, thereby producing a generic facility data base. This potential should be explored.

Research could also be conducted into the potential of automating the siting of facilities based on existing standard siting criteria. Factors such as wind direction and slope (for runways), sound abatement and fire lanes (for facilities), and frost line (for depths of utility lines and foundations) could be menu-entered items which would result in a standard siting configuration. The user might then make either semiautomatic or manual changes to the plan to fine tune it. The potential for this kind of algorithm has been demonstrated for single crane siting optimization on a construction site[9] and should be explored further.

Research should be conducted to find system designs that store data files in the most compact form. File size reduction would serve to speed retrieval and storage of drawings and would reduce mass storage requirements. Fractal image processing is a very new field that is showing impressive reductions in image storage requirements.[10] Although the work is primarily focused on raster processing, the techniques may be adapted and extended to vector processing.

Graphics image screen regenerations were painfully slow on the test system. This is a function of the processing software and hardware, including the graphics card and video drivers. Research should be conducted into the state-of-the-art of such devices. The focus should be on finding faster methods of screen regenerations.

Regarding graphics, surface modeling and shading capabilities would significantly enhance site depiction graphics. A study should be conducted of how these enhancements would affect data processing times, screen regenerations, and file size and how they would improve system effectiveness.

Some question exists regarding usefulness of 30 meter data. Because 10 meter data was not available to this researcher, its merit could not be tested. Success of the proposed system depends greatly on the resolution and accuracy of the source data. Much of the existing data is classified as are the resolution and accuracy figures for each of those data sets. Because of the military focus of the proposed system, consideration should be given to obtaining appropriate security clearances for subsequent researchers. Doing so would allow access to and review of otherwise unavailable data sets. Additionally the sources of the best data could be pre-identified to the user, thereby expediting the retrieval process.

Hardware

Portability of the system is an issue not addressed in this report. Depending on the ultimate system use, portability may or may not be required. If the system is extended to include field use during contingency situations research should be conducted into the capabilities of portable machines, including speed, RAM, mass storage, switchable and uninterruptable power supplies, battery operation, system size weight, and durability.

Should an analytical stereo plotter be included in the system package? This will depend on to what extent the available data has been processed. That option is one that should be explored.

A total electronic station should also be considered as part of the package, along with the necessary software and hardware to interface directly with the system. It seems likely that no matter how detailed the remote sensing data imagery is, there will be missing or additional data the designer will need to complete his or her work. And if the system is extended to include the follow-on maintenance and repair and wartime functions addressed above, on-site data collection will undoubtedly be required. A total station would serve both needs. Research should be conducted as to available instruments and their capabilities.

General

In addition to topographical data, remote sensing offers other capabilities which include, but are not limited to, detection of features such as roads, rivers, lakes, rail beds, vegetation, and even soils classification. This potential was not addressed in this work but would be an excellent avenue for further research. Can this data be included or overlaid on the topographical data set and would it contribute to the function of the proposed system?

The focus of this paper was on importing data into a CAD package. A further question is whether this is the most prudent track. Geographical information systems possess the capabilities to efficiently process very large quantities of data and some can even convert raster files to vector files automatically. Would it be more cost effective and efficient to insert a CAD system into a GIS environment, such as that of Erdas? This approach might yield a more capable system and should be explored further.

APPENDICES

APPENDIX A - SATELLITES[11]

Satellite	LANDSAT 1,2	SKYLAB
Sensors	Multispectral Scanner	Multispectral Camera
	Return Beam Vidicon	Photographic Camera
Altitude	919 km	435 km
Nominal Scale	1:1,000,000	MSC - 1:2,860,000 PC - 1:948,500
Ground Resolution	79 meters	MSC - 30 meters PC - 20 meters
Width of Cover	185 km	MSC - 150 km PC - 108 km
World Land Coverage	82 deg N-S almost complete	negligible
Operational Period	MSS - 1972 - 1978 RBV - 1975 - 1982	1973

APPENDIX A - SATELLITES cont'd

Satellite	Landsat 3	Seasat
Sensors	Multispectral Scanner Return Beam Vidicon	Synthetic Aperture Radar
Altitude	919 km	794-808 km
Nominal Scale	MSS - 1:1,000,000 RBV - 1:500,000	1:500,000
Ground Resolution	MSS - 79 meters RBV - 40 meters	25
Width of Cover	185 km	100 km
World Land Coverage	by request	72 deg. N-S Selected Coverage
Operational Period	1978 - 1983	1981 - present

APPENDIX A - SATELLITES cont'd

Satellite	ESA - Spacelab	Landsat 4 and 5
Sensors	Metric Camera	Thematic Mapper MSS
	Synthetic Aperture Radar	Multispectral Scanner
Altitude	250 km	705 km
Nominal Scale	1:820,000	N/A
Ground Resolution	30 meter	TM - 30 meter MSS - 79 meter
Width of Cover	MC - 190 km SAR - 9 km	N/A
World Land Coverage	Initially Negligible	by request
Operational Period	1981 - present	1982(4) - present

APPENDIX A - SATELLITES cont'd

Satellite	SPOT 1	Shuttle 1981/1983
Sensors	Multispectral Scanner (MSS) Panchromatic Scanner (PS)	'81 - Shuttle Imaging Radar '83 - Large Format Camera
Altitude	822 km	'81 - 278 km '83 - 227-417 km
Nominal Scale	1:760,000	'81 - 1:500,000 '83 - 1:912,000
Ground Resolution	20 meters (MSS) 10 meters (PS)	'81 - 40x40 meters '83 - 10 meters
Width of Cover	60 km	'81 - 50 km '83 - 208x417 km
World Land Coverage	Global eventually	both by request
Operational Period	1984 - present	Late 1981 and 1983

APPENDIX B - DATA SOURCES

Defense Mapping Agency
Office of Distribution Services
ATTN: DOA
Washington, DC 20315-0020
Commercial Telephone: (301) 227-2495
Toll-free Telephone: 1-800-826-0342
Autovon: 287-2495
TELEX: 710-824-0293

SPOT Image Corporation
1879 Preston White Drive
Reston, Virginia 22091-4326
Commercial Telephone: (703) 620-2200
TELEX: 4993073

World Data Bank I and II
Produced by the Central Intelligence Agency
Available through:
U. S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
Commercial Telephone: (703) 487-4807
TELEX: 89-9405
FAX: (703) 321-8547

United States Geological Survey
Distributed by:
National Headquarters, National Cartographic Information Center
United States Geological Survey
507 National Center
Reston, Virginia 22092
Commercial Telephone: (703) 860-6045
Federal Telephone System: 945-6045

APPENDIX B - DATA SOURCES cont'd

Earth Observation Satellite Company (EOSAT)
4300 Forbes Boulevard
Lanham, Maryland 20706
Commercial Telephone: (301) 552-0500
Toll-free Telephone: (800) 344-9933
FAX: 605-594-6589
TWX No: 910-668-0310 USGS EROS SFL
Telex: 277685-LSAT UR

APPENDIX C - SAMPLE USGS DEM DATA

```
\NEW_HOME.DEM^@NEW HOME  GEORGIA                 GA- 85 30  0
34 52 30  450  450GPMII/2   03/1979
    1     1     1    16   0.0                              0.0
             0.0                        0.0
0.0                     0.0                        0.0
           0.0                        0.0
0.0                     0.0                        0.0
           0.0                        0.0
0.0                       2     2     4
0.625668600000000D+06   0.385984630000000D+07
0.625478100000000D+06   0.387370920000000D+07
0.636886000000000D+06   0.387387340000000D+07
0.637093900000000D+06   0.386001020000000D+07
0.189000000000000D+03   0.534000000000000D+03   0.0
             00.300000E+020.300000E+020.100000E+01      1
387
     1     1    53     1   0.625500000000000D+06
0.387213000000000D+07   0.0
0.193000000000000D+03   0.286000000000000D+03   286    284
279    276    272    265    256    255    252    246    240    239
233    228    220    212    205    206    193    193    193    193
193    193    193    193    193    193    193    193    193    193
197    204    206    202    200    204    210    216    210    205
212    219    221    224    220    221    226    223    219    218
223
     1     2   126     1   0.625530000000000D+06
0.386994000000000D+07   0.0
0.193000000000000D+03   0.497171630859375D+03   497    494
493    492    494    496    494    490    492    494    496    491
493    494    492    490    489    487    482    482    486    484
483    482    480    478    480    483    479    475    473    472
477    476    480    478    472    466    465    458    456    452
450    444    435    425    415    401    388    378    369    364
359    354    348    340    334    328    325    329    326    321
319    298    293    289    286    284    281    286    290    291
288    286    281    276    274    271    265    259    258    254
247    241    239    234    231    223    213    206    209    207
200    194    194    194    194    194    194    194    194    194
194    194    194    193    199    203    203    201    206    214
222    215    208    211    215    218    221    218    219    223
225    223    223    230
     1     3   199     1   0.625560000000000D+06
0.386775000000000D+07   0.0
0.193000000000000D+03   0.502260742187500D+03   477    480
479    476    477    474    476    477    472    471    471    476
```

470	472	479	485	482	477	473	475	470	469
474	471	465	461	462	464	462	457	452	453
456	456	460	465	470	468	463	464	466	470
472	467	468	472	474	469	472	476	479	480
482	482	487	483	480	481	480	488	493	494
492	492	492	494	492	491	491	489	491	492
493	495	491	491	491	496	502	499	493	493
497	498	495	495	496	492	488	487	488	482
481	481	479	480	480	482	482	482	484	480
475	474	471	472	477	476	477	472	466	460
456	457	452	448	442	434	423	412	398	386
376	366	359	353	347	341	335	332	332	331
335	332	327	324	305	300	297	294	295	291
293	295	294	288						
282	277	275	273	269	261	254	254	252	248
244	239	233	229	220	209	202	208	211	205
203	206	202	195	193	193	193	193	193	193
193	193	193	193	203	208	203	205	211	217
211	205	208	213	219	224	222	222	227	230
230	230	236							

1 4 271 1 0.62559000000000D+06

0.38655900000000D+07 0.0

0.19400000000000D+03 0.50747753906250D+03 453 457

461	463	460	463	463	463	465	463	461	461
463	466	469	467	467	472	475	470	471	476
479	479	479	483	487	489	487	485	490	495
496	500	501	501	501	507	504	503	503	500
498	496	496	497	498	494	492	489	485	483
483	481	479	477	478	477	477	475	474	474
474	474	475	477	479	479	481	476	474	473
474	477	476	474	474	475	480	483	477	473
474	478	473	474	480	484	482	478	482	479
475	473	471	469	471	466	461	463	461	457
453	455	459	459	463	465	466	470	468	465
465	468	473	469	469	474	477	472	472	474
477	481	485	482	485	486	484	477	476	490
493	490	490	490	490	494	491	487	489	489
486	489	493	497						
490	488	492	498	499	497	495	495	495	496
498	496	493	489	486	483	483	479	479	482
481	478	480	483	485	484	486	485	481	477
476	471	473	479	479	471	464	458	458	460
455	447	439	429	419	410	398	386	376	366
359	353	345	338	341	341	340	339	342	337
330	327	314	309	306	304	306	302	301	299
295	288	281	275	268	267	268	260	253	249
247	244	240	235	231	224	217	208	203	209
213	211	211	213	210	204	201	206	209	210
194	194	194	194	194	194	197	202	201	207
215	216	210	203	203	210	219	225	224	225
231	236	237	237	241					

```
        1      5    344        1    0.62562000000000D+06
0.38634000000000D+07         0.0
0.19300000000000D+03         0.50800000000000D+03     420     422
422     424     424     421     422     425     428     431     432     429
430     431     433     431     434     437     434     431     434     437
437     437     436     435     437     440     441     440     439     439
435     435     439     444     443     443     448     447     443     440
438     439     437     440     443     446     444     446     449     451
449     450     453     452     451     452     453     456     457     454
454     457     459     459     460     459     460     463     460     455
453     453     458     465     465     459     463     464     464     466
464     462     464     465     466     468     469     470     471     470
465     465     473     479     479     479     482     485     489     488
485     489     493     494     497     500     503     504     508     505
505     505     502     498     495     497     498     496     492     488
484     482     482     483     481     479     478     479     476     473
471     471     473     472     470     471     475     477     475     480
475     473     472     472
473     471     470     474     476     480     483     480     477     477
479     471     473     480     484     479     474     478     478     472
473     475     471     469     464     459     461     460     461     458
457     455     456     460     461     463     469     472     467     464
468     473     473     472     472     475     476     476     473     474
478     482     484     484     484     480     475     476     487     489
485     486     489     490     492     488     486     489     492     487
487     494     499     490     490     491     493     494     496     500
499     496     496     498     498     497     491     486     484     484
479     476     480     482     478     477     478     480     480     482
486     486     480     476     470     470     478     480     473     466
459     458     458     457     450     442     432     421     412     400
388     376     365     356     349     346     345     350     353     348
346     349     343     336     332     323     318     316     314     316
311     305     299     293     286     277     269     263     259     260
253     247     246     246     242     237     236     232     225     220
214     210     210     213     217     219     219     216     212     210
216     219     216     215     193     193     193     193     193     193
196     200     207     214     211     204     198     200     206     213
219     218     222     230     238     237     235     236
        1      6    417        1    0.62565000000000D+06
0.38612100000000D+07         0.0
0.19400000000000D+03         0.50812329101562D+03     416     416
416     416     418     419     416     415     416     417     417     416
413     414     414     413     416     414     409     404     400     399
403     407     407     409     413     416     421     422     421     421
421     423     425     425     424     424     424     424     424     425
424     427     428     432     436     433     431     432     432     433
430     426     424     423     421     421     421     424     422     421
421     421     421     419     420     420     420     421     419     418
419     421     425     425     424     424     422     422     423     426
430     431     429     430     432     432     431     433     437     437
434     436     439     440     440     438     438     441     441     441
```

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440   443   443   440   439   441   445   444   446   450
449   445   441   441   441   439   441   444   445   446
448   449   451   451   453   456   454   452   453   454
458   459   456   456   458   461   464   464   460   460
463   460   459   457
458   460   463   464   461   464   464   463   463   465
468   468   467   469   469   469   472   473   470   466
466   474   480   481   480   483   487   490   489   488
490   492   497   501   501   502   503   507   505   508
506   504   501   499   498   498   496   492   487   483
483   484   485   483   480   480   481   478   475   475
475   473   470   468   468   472   476   475   482   477
474   474   473   475   472   470   471   474   479   484
485   483   478   476   469   471   479   484   476   470
474   474   471   474   477   474   469   464   460   458
456   458   459   456   452   452   456   461   465   468
473   469   468   469   476   476   474   471   476   481
482   477   476   482   482   480   483   479   476   473
475   486   485   480   482   487   490   493   492   488
488   491   489   491   490   494   491   495   493   494
494   497   500   498   493   493   494   494   498   493
489   488   488   484   481   480   479   474   472   478
481   477   476   481   482   476   471   469   468   473
476   470   464   461   464   459   457   451   443   434
424   414   400   388   379   370   360   353   353   356
361   365   359   355   357   352   346   342   333   328
327   325   325   318   311   304   296   288   279   272
266   260   259   254   246   245   244   239   233   231
226   225   223   222   218   217   218   221   224   224
222   220   218   224   226   223   222   217   194   194
194   194   194   194   202   209   210   205   202   203
201   206   213   220   222   227   230   234   234   232
232
      1       7    462       1    0.62568000000000D+06
0.38598600000000D+07    0.0
0.19300000000000D+03    0.50900000000000D+03    414   412
415   418   418   415   412   412   411   411   409   409
410   413   414   415   418   421   418   416   419   421
422   424   423   425   426   429   433   437   435   434
437   439   436   435   435   436   434   432   432   429
427   423   420   418   420   419   417   420   420   417
414   413   414   413   414   412   414   413   412   413
410   406   402   399   401   405   408   407   408   411
414   421   420   419   421   423   424   422   422   424
422   421   424   427   424   423   430   430   432   432
431   430   429   429   428   425   423   422   421   420
423   423   421   419   419   420   420   418   415   416
416   417   419   418   418   420   423   428   428   427
426   425   425   424   426   427   427   425   426   429
430   430   433   439   438   436   438   440   439   436
438   441   442   440
```

441	442	442	441	442	442	439	441	445	448
449	448	446	442	443	440	439	440	442	444
450	450	451	453	451	453	455	454	453	451
451	454	455	453	455	459	460	464	463	458
457	460	461	462	460	459	458	458	460	462
463	460	461	465	465	467	468	466	468	470
469	471	471	469	465	468	477	482	482	480
482	488	490	489	487	488	491	497	501	500
500	503	509	505	507	507	505	503	502	499
497	495	492	488	484	482	483	485	483	480
481	483	480	478	479	478	474	471	469	466
468	471	470	476	473	474	472	471	472	472
472	474	476	479	481	482	480	477	475	470
470	476	478	472	470	477	476	471	469	474
475	472	466	460	457	457	455	453	451	451
451	454	460	465	472	474	469	466	469	474
472	474	470	474	479	482	478	476	479	478
482	482	479	477	475	476	485	482	477	478
483	487	492	493	488	483	484	483	486	490
493	488	491	489	489	491	494	494	492	492
492	492	492	492	491	493	491	481	481	484
480	476	471	469	473	477	476	476	476	478
475	471	467	468	470	471	470	463	461	466
464	458	450	441	432	424	416	408	391	383
376	368	361	361	364	369	372	366	362	364
359	354	350	341	337	334	332	331	323	315
308	302	294	285	277	270	264	262	257	249
244	239	234	233	229	228	230	229	226	221
224	224	223	225	226	225	220	219	223	223
221	224	223	193	193	193	193	193	193	202
209	206	199	197	200	201	207	216	222	226
229	224	225	226	225	226				

APPENDIX D - USGS DEM DATA ELEMENT DESCRIPTIONS[4]

Record A

Data Element	Contents	Comments
1	File Name	Up to 144 characters
2	DEM Level Code	Level 1 Level 2 Level 3
3	Code defining elevation pattern	1 = regular 2 = random
4	Code defining ground planimetric reference system	0 = geographic 1 = UTM 2 = State Plane plus 17 others
5	Code defining zone in ground planimetric reference system	Set to zero for 1 degree DEM's
6	Map projection parameters	15 elements, all are set to zero when UTM, State plane or geographic coordinates are used
7	Code defining unit of measure for ground planimetric coordinates through-out the file	0 = radians 1 = feet 2 = meters 3 = arc-seconds Normally code 2 for 7.5 minute DEM's
8	Code defining unit of measure for elevation coordinates through-out the file	1 = feet 2 = meters Normally code 2 for 7.5 minute DEM's

APPENDIX D - USGS DEM DATA ELEMENT DESCRIPTIONS cont'd

Record A cont'd

Data Element	Contents	Comments
9	Number (n) of sides in the polygon which defines the coverage of the DEM file	n = 4
10	A 4,2 array containing the ground coordinates of the four corners for the DEM	Ordered in a clockwise direction beginning with the southwest corner. Array is stored row-wise as pairs of eastings and northings
11	A two-element array containing the minimum and maximum elevations for the DEM	Expressed in the units of measure of element 8
12	Counterclockwise angle (in radians) from the primary axis of the ground planimetric reference to the primary axis of the DEM local reference system	Normally set to zero to align with coordinate system specified in element 4.
13	Accuracy code for elevations	0 = unknown accuracy 1 = accuracy is given in logical record C
14	A three-element array of DEM spatial resolution for X,Y,Z. Units of measure for these resolution elements are consistent with those indicated by data elements 7 and 8 in this record.	These elements are usually set to 30, 30, 1 for 7.5-minute DEM's. These units should not be confused with the accuracy of the data.

APPENDIX D - USGS DEM DATA ELEMENT DESCRIPTIONS cont'd

Record A cont'd

Data Element	Contents	Comments
15	A two-element array containing the number of rows and columns (m,n) of profiles in the DEM	The row value m is set to 1. Thus, the n value describes the number of columns in the DEM file.

APPENDIX D - USGS DEM DATA ELEMENT DESCRIPTIONS cont'd

Record B

Data Element	Contents	Comments
1	A two element array containing the row and column identification number of the DEM profile contained in this record	Numbers range from 1 to m and 1 to n. Rows are set to 1 and should be disregarded. The column identification is the profile sequence number.
2	A two-element array containing the number of rows and columns (m,n) of elevations in the DEM profile	First element is the number of nodes in this profile. Second element is set to 1, specifying 1 column per B record.
3	A two-element array containing the ground planimetric coordinates of the first elevation in the profile	
4	Elevation of local datum for the profile	The values are in the units of measure given by the data element 8 in the A record.
5	A two-element array of minimum and maximum elevations for the profile	The values are in the unit of measure given by data element 8 in the A record.
6	An array of m x n elevations for the profile. Elevations are expressed in units of resolution elements.	A value in this array would be multiplied by the spatial resolution value and added to the elevation of the local elevation datum for the profile (data element 4 in this record) to obtain the elevation for the point.

APPENDIX D - USGS DEM DATA ELEMENT DESCRIPTIONS cont'd

Record C (not shown in Appendix C)

Data Element	Contents	Comments
1	Switch indicating availability of statistics in data element 2	Code 1 = available 2 = unavailable
2	RMSE of file's datum relative to absolute datum (x,y,z)	In same units as indicated by elements 7 and 8 of record A.
3	Sample size on which statistics in data element 2 are based	If 0, then accuracy will be assumed to be estimated rather than computed.
4	Switch indicating availability of statistics in data element 5	Code 1 = available 2 = unavailable
5	RMSE of DEM data relative to file's datum (x,y,z)	In same units as indicated by elements 7 and 8 of record A.
6	Sample size on which statistics in data element 5 are based	If 0, then accuracy will be assumed to be estimated rather than computed

APPENDIX E - DMA DTED CHARACTERISTICS[12]

DATA SET CONTINUITY

A. A data file of DTED Level 1 is a 1 degree by 1 degree cell defined by whole degree latitude and longitude lines on WGS. A data file of DTED Level 2 may be less that a full 1 degree cell. A DTED data file shall not cross whole degree latitude or longitude lines.

B. Adjacent data files shall not have gaps between them and the only overlap that exists is along adjacent boundaries. All adjacent boundaries shall be coincident.

SURFACE CHARACTERISTICS

The following terrain characteristics shall be discernible in the data set:

A. Water

1. Open water (lake, ocean, sea) with a diameter equal to or greater than 1200 meters. Sea/ocean elevations shall be zero. Elevation values within a lake must be identical.

2. Drains (rivers, streams, etc.) with a width equal to or greater than 183 meters and drains with a linear ground distance equal to or greater than 10,000 meters.

B. Land

1. Shoreline/coastline elevation values shall be higher than the adjacent water elevations. Extremely shallow land just interior to coastlines shall have a 1 meter elevation to force land boundary portrayal.

2. Islands with a length or width equal to or greater than 600 meters ground distance shall be included in the data set. Smaller islands shall be shown if the relief is equal to or greater than 15 meters above water level.

3. Ridges and cliffs with a linear ground distance equal to or greater than 10,000 meters.

C. Negative elevations shall occur only where landforms and water bodies are below see level.

APPENDIX F - DMA DTED FILE DESCRIPTIONS[12]

The DMA Standard Terrain Format is DMA's standardized system of recording terrain elevation data on magnetic tape. The format is intended for the purposes of production, storage and exchange of terrain elevation data.

Files are recorded in the 9 track format on 1/2 inch by 2400 feet magnetic tape. Data is odd parity and recorded at either 800, 1600, or 6250 BPI in ASCII code.

Records are of variable length: maximum 7214 frames, minimum 14 frames, model average 2414 frames. Blocking factor is 1:1 (block size = record size).

APPENDIX F - DMA DTED FILE DESCRIPTIONS cont'd

A. Volume Header Label

Field Contents	Field Length	Character Start	Description
VOL	3	1	Recognition sentinel.
1	1	4	Fixed by standard
	6	5	Reel Number. Six alphanumeric characters
Blank or Nonblank	1	11	*Nonblank indicates restricted access, as the tape reel is privately owned
Blanks	26	12	Un-required available space
Account Number	14	38	*Account number of owner
Blanks	28	52	Fixed by standard
1	1	80	Fixed by standard

*These fields, to be defined by the producer, may be left blank.

APPENDIX F - DMA DTED FILE DESCRIPTIONS cont'd

B. File Header Label

Field Contents	Field Length	Character Start	Description
HDR	3	1	Recognition sentinel
1	1	4	Fixed by standard
Filename	17	5	*Left-justified filename.
UNIVAC	6	22	*Fixed as set identifier
0001	4	28	*Reel sequence number within a file.
0001-NNNN	4	32	*File sequence number with a reel
0001 00	4 2	36 40	*Generation and version numbers which are fixed at 1 and 0.
bYYDDD	6	42	Creation date of tape
bYYDDD	6	48	Expiration date of tape
A space indicates unlimited access to this reel	1	54	*Accessibility
Block count	6	55	*Fixed at zeros.
Qualifier	13	61	*Used by Executive Operating System
Blanks	7	74	Fixed by standard.

*These fields, to be defined by the producer, may be left blank.

APPENDIX F -- DMA DTED FILE DESCRIPTIONS cont'd

C. User Header Label

Field Contents	Field Length	Character Start	Description
UHL	3	1	Recognition sentinel
1	1	4	Fixed by standard
DDDMMSSH	8	5	Longitude of origin (lower left corner of data set). H is the hemisphere of data
DDDMMSSH	8	13	Latitude of origin
SSSS	4	21	Longitude data interval in seconds (decimal is implied after third integer)
SSSS	4	25	Latitude data interval
0000-9999 or NA	4	29	Absolute vertical accuracy in meters. With 90% assurance that linear errors will not exceed this value at MSL.
T-Top Secret S-Secret C-Confidential U-Unclassified R-Restricted	3	33	Security Code
Unique Reference Number	12	36	*Unique reference number (provide pointer to file containing detailed file description).
Number of longitude lines	4	48	Count of the number of profiles

APPENDIX F - DMA DTED FILE DESCRIPTIONS cont'd

C. User Header Label cont'd

Field Contents	Field Length	Character Start	Description
Number of longitude points	4	52	*Count of the number of latitude points per longitude line
Multiple accuracy	1	56	0 - Single 1 - Multiple
Reserved	24	57	Unused portion for future use

*These fields, to be defined by producer, may be left blank.

APPENDIX F - DMA DTED FILE DESCRIPTIONS cont'd

D. Data Set Identification

Field Contents	Field Length	Character Start	Description
DSI	3	1	Recognition sentinel.
T-Top Secret S-Secret C-Confidential U-Unclassified R-Restricted	1	4	Security Classification Code
	2	5	Security Control (For DoD use only)
	27	7	Security Handling Description
	26	34	Reserved for future use
DTED1 or DTED2	5	60	DMA Series Designator for product level.
	15	65	Unique reference number (for producing nation's own use)
	8	80	Reserved for future use.
01-99	2	88	Data Edition Number.
A-Z	1	90	Match/Merge Version.
YYMM	4	91	Maintenance Date.
YYMM	4	95	Match/Merge Date.
0000	4	99	Maintenance Description Code
CCAAABBB (Country - Free Text)	8	103	Producer Code

APPENDIX F - DMA DTED FILE DESCRIPTIONS cont'd

D. Data Set Identification cont'd

Field Contents	Field Length	Character Start	Description
	16	111	Reserved for future use
SPECDTED2	9	127	Product Specification Stock Number.
00-99	2	136	Product Specification Amendment and Change Number.
YYMM	4	138	Product Specification Date.
MSL	3	142	Vertical Datum (Mean Sea Level)
WGS72 or WGS84	5	145	Horizontal Datum Code
	10	150	Digitizing Collection System (Free text).
YYMM	4	160	Compilation Date.
	22	164	Reserved for future use.
DDMMSS.SH	9	186	Latitude of origin of data. H is the hemisphere of data
DDDMMSS.SH	10	195	Longitude of origin of data.
DDMMSSH	7	205	Latitude of SW corner of data.
DDDMMSSH	8	212	Longitude of SW corner of data.
DDMMSSH	7	220	Latitude of NW corner of data.

APPENDIX F - DMA DTED FILE DESCRIPTIONS cont'd

D. Data Set Identification cont'd

Field Contents	Field Length	Character Start	Description
DDDMMSSH	8	227	Longitude of NW corner of data.
DDMMSSH	7	235	Latitude of NE corner of data.
DDDMMSSH	8	242	Longitude of NE corner of data.
DDMMSSH	7	250	Latitude of SE corner of data.
DDDMMSSH	8	257	Longitude of SE corner of data.
DDDMMSS.S	9	265	Clockwise orientation angle of data with respect to true North
SSSS	4	274	Latitude interval in tenths of seconds between rows of elevation values (decimal point is implied after third integer).
SSSS	4	278	Longitude interval in tenths of seconds between columns of elevation values.
0000-9999	4	282	Number of Latitude lines Actual count - number of latitude points
0000-9999	4	286	Number of Longitude lines

APPENDIX F - DMA DTED FILE DESCRIPTIONS cont'd

D. Data Set Identification cont'd

Field Contents	Field Length	Character Start	Description
00 or 01-99	2	290	Partial Cell Indicator 00 = complete 1 deg. cell 01-99 = percentage of coverage completed.
	101	292	Reserved for DMA use only
	100	393	Reserved for producing nation use only
	156	493	Reserved for future use

Subsequent records will not be displayed here but include the following:

E. Accuracy Description

F. File Trailer Label

G. User Trailer Label

H. Data Record Description

APPENDIX G - TYPICAL FILE SIZES

The first group of information is based on the test subset of data from a USGS quadrangle which has been converted into the indicated file types. The data set is a quadrangle measuring approx 1.15 miles by 1.9 miles. and comprising 6138 data points.

The triangulated terrain model is generated directly from the TA2 format. From there, the model must be converted into either a DXB or DXF format to be read by AutoCAD as a 3-D face drawing.

FILE DESCRIPTION/TYPE	FILE SIZE (KILOBYTES)
Basic ASCII TA2 Format	190.3
Triangulated Terrain Model	721.7
AutoCAD DXB file	1215.0
AutoCAD DXF file	2983.2
AutoCAD 3-D Drawing file	1252.5
AutoCAD Contour drawing file	762.8

The following data are extrapolations of file sizes of a 4 square mile data set based on the above information. The 30 meter resolution data comprise 11,664 points while the 10 meter resolution data comprise 110,224 points.

FILE DESCRIPTION/TYPE	FILE SIZE (KILOBYTES)	
	30 METER	10 METER
Basic ASCII TA2 Format	360.9	3410.5
Triangulated Terrain Model	1368.6	12933.2
AutoCAD DXB file	2304.1	21773.6
AutoCAD DXF file	5657.3	53461.1
AutoCAD 3-D Drawing file	2375.2	22445.5
AutoCAD Contour drawing file	1446.6	13670.3

APPENDIX H - SOFTWARE LISTING

AutoCAD
AutoDesk Inc.
2320 Marinship Way
Sausalito, California 94965
Tel: (415) 331-0356

AutoCAD is a full feature CAD program that is a very versatile tool. It is not designed specifically to do any one type of work. Its open architecture and relatively easy-to-learn AutoLISP programming environment makes easily adaptable with many third party programs designed to enhance the basic software. AutoCAD, beginning with Release 9, provides full 3-D capabilities. AutoCAD is designed primarily for personal computers.

Intergraph Corp
One Madison Ind. Park
Huntsville, Alabama 35807-4201
Tel: (205) 772-2000

Southeast Regional Office: Atlanta, Georgia
Tel: (404) 434-5598

Intergraph offers a full line of software and hardware which they can tailor to the user's needs. From structural design, to cartographic work, to extensive CAD capabilities Intergraph's systems are turnkey, in that they can perform virtually all the manipulation and calculations necessary to accomplish the total project. Intergraph offers full 3-D capability, solids, and shading. Also, the system is fully capable of mapping, civil design, architectural design, and surface modeling. Intergraph offers specialized equipment such as E-size raster scanners with raster-to-vector conversion utilities. Their software is extensive and is designed for mainframe, micro and personal computers.

APPENDIX J - SOFTWARE LISTING cont'd

McDonnell Douglas Engineering Manufacturing & Systems Company
115 Perimeter Center Place, Suite 600
Atlanta, Georgia 30346-1238
Tel: (404) 390-6000

McDonnell Douglas (MD)offers a system called the General Drafting System (GDS) which is a base CAD system with a variety of module enhancements available. GDS is a full-featured CAD system which compares favorably with Intergraph. MD offers full 3-D capability, solids, and shading. Also, the system is fully capable of mapping, civil design, architectural design, and surface modeling. MD's systems are designed for 32-bit PRIME and Digital Equipment Corporation VAX mini and microcomputers.

terraCADD
Plus III Software, Inc.
One Dunwoody Park
Atlanta, Georgia 30338
Tel: (800) 235-4972
or (404) 396-0700

TerraCADD is primarily a land design tool. It is stand-alone software designed to handle coordinate geometry, contouring, digital terrain modeling, road and highway design, site design, storm and sanitary sewer design, and mapping. It runs on IBM and compatible machines under the DOS operating system.[13]

APPENDIX J - SOFTWARE LISTING cont'd

D. C. A. Engineering Software, Inc.
P. O. Box 955
Henniker, New Hampshire 03242
Tel: (603) 428-3199

D. C. A. Engineering Software is designed to operate completely inside AutoCAD. It is primarily a COGO system designed specifically for AutoCAD. It does have an add-on module, available separately, called AutoMap. This module provides the 3-D grid modeling capability. It will operate on either a DOS operating system or Unix operating system.[14]

PacSoft
P. O. Box 3419
Kirkland, Washington 98083-3419
Tel: (206) 827-0551

The PacSoft system is a stand package capable of GOGO, surveying, highway design, and data collection. It handles alignments, cross sections, template design, plans and profiles. Additional modules handle more advanced work such as digital terrain modeling and storm water hydrology. PacSoft is not a CAD system. With the CADLINK module it is capable of converting its data files into standard drawing file formats for use inside packages such as AutoCAD, VersaCAD and Intergraph. PacSoft is designed to operate on Hewlett-Packard (H-P) 9000 family workstations and Vectra (using H-P Basic). It will also run under DOS on IBM and compatibles running with the 80286 or better.[15]

APPENDIX J - SOFTWARE LISTING cont'd

Erdas
Erdas Incorporated
430 Tenth Street, N. W. Suite N206
Atlanta, Georgia 30318
Tel: (404) 872-7327

Erdas designs and fields GIS's. Their focus is on processing storage and retrieval and display of remote sensing data. Erdas software performs vector-to-raster and raster-to-vector data conversion and handles 3-D modeling. Erdas software operates on IBM and compatibles (80286 and 80386); Sun 386i, Sun 3, and Sun 4 series; DEC MicroVAX and VAX; Prime; and Data General Computers.[18]

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