DRAFT

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e-maps

PRIMER ON

COMPUTERIZED GEOGRAPHIC

INFORMATION

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CHAPTER ONE

INTRODUCTION

101. Purpose: To help the user of computerized geographic information understand the key issues and their impact when viewing data on maps.

102. Background

a. General. There has been a revolution in creating and working with maps. Gone are the days of paper maps made by cartographers with years of professional training and experience. The introduction of technology, reflected by computers and electronic location equipment, has changed the way maps and data are used. This revolution is so new that there are no concise instructions covering critical concepts for working with computerized geographic information. This manual fills that need.

b. Computers. Computers present new capabilities to collect, manipulate, store, and disseminate information accurately and quickly. These capabilities introduce new problems because computers and information without knowledge and understanding are not useful. The pressing issue has moved from insufficient information to information overload. The cartographer faces the same problem - identifying important data and visually presenting it on a map. Before the introduction of computers, geographic information was stored in a multitude of separate documents (e.g., books and maps). It was difficult to place maps on top of one another and look through them or even to place maps side-by-side. It was also difficult to compare geographic information covering the same area in two different books. All of that is easily accomplished using computers.

c. Cartography. Using paper maps, users could safely assume that the information portrayed on the map was accurate enough for their needs. Paper maps were used for specific purposes such as driving, land management, field survey, or military uses. With the introduction of electronic equipment able to precisely determine location, the accuracy of the maps became very noticeable. Many of the issues involved in making specific maps required the application of cartographic principles to emphasize important features, often at the expense of accuracy. The ability to integrate and use maps for other than their intended purposes with computers and various data emphasized the need to better understand the impact of displaying data on maps.

d. GPS Equipment. GPS (global positioning system) equipment allows users to obtain extremely accurate location down to the centimeter level. Problems arise when users try to put accurate location data on maps that are less accurate. Because of cartographic principles, cartographers must take liberties with accuracy to display information. As an example, the specifications for a NIMA 1:50,000 scale Topographic Line Map states that objects plotted on the map sheet are accurate to within 50 meters of their true position. The resulting problem can be a mismatch of very accurate data on inaccurate maps. GPS users must understand these implications; they will be discussed in detail in a later chapter.

PRIMER ON COMPUTERIZED GEOGRAPHIC INFORMATION

103. Geographic Information Defined

Geographic information is any information that includes a location. Location can be defined in many ways. Some are latitude and longitude, a coordinate system such as Universal Transverse Mercator, street address, zip code or a city name.

104. Geographic Information Systems (GIS)

a. This manual addresses a much broader area than GIS. Often people think geographic information and GIS are interchangeable. A simple definition of GIS is a collection of software, hardware, data, trained personnel, repeatable procedures and applications. We mention GIS because it is a familiar term and greatly misunderstood by the public.

b. We emphasize this because when one mentions maps or geographic information there is an automatic association with GIS. We want to draw a distinction and focus on the key issues that impact geographic information. The topics discussed in this manual are pertinent to GIS even though the majority of people look at GIS as only a collection of hardware and software.

105. Overview of the Primer

This primer introduces the reader to many key issues impacting on the use of computerized geographical information. After this introduction, chapter two discusses paper and digital maps - their uses, advantages, disadvantages and considerations when using them. Chapter three discusses in a general way some technical areas that are critical to understanding and using maps while chapter four looks into the cartographic process and its consequences for users of digital cartographic information. Chapter five discusses how people process information and chapter six discusses map metadata (information about the data) and why it is particularly important to digital map use. Addressing a computer's ability to bring together large amounts of data, chapter seven provides a brief discussion of databases. Finally, with the widespread use of GPS equipment, chapter eight is a discussion of some GPS equipment and map use considerations. Appendix A, the Basics of Computer Map Displays, details basic concepts for understanding computer map displays.

CHAPTER TWO

PAPER AND DIGITAL MAPS

201. Introduction

Most of the maps used in the world are paper maps. The introduction of computers drove the need for digital maps. Because the world is a big place, creating digital maps of the entire world would be an extremely lengthy process. Therefore, there will probably be a mix of both types of maps used in most places except for map users without computers. Digital maps have two types, vector and raster; an introduction to their advantages and disadvantages follows.

202. Paper Maps

Older maps were drawn on paper. The biggest decision faced by the paper mapmaker was what kind and types of data to include on a map. There wasn't room enough to display all the data available on a specific area. The solution was to create a map for a specific use; this eliminated the requirement for certain types of data. An example of a specific use map would be a road map that might not include topographical data to reduce clutter and that emphasizes roads and landmarks for navigation. Each paper map was a separate stand-alone product.

203. Digital Maps

a. Using a vector digitizer or a raster scanner to convert a paper map to digital form creates digital maps. Digital maps can be used to take advantage of the computer capabilities for manipulating large amounts of data.

b. Computers and GIS software can divide large aggregations of data on paper maps into a multitude of discrete pieces. These pieces can be stored as separate databases items and aggregated for custom displays on computer monitors, printed on paper or both. These aggregations of data can be varied by purpose. The digital map user has the capability to select the information to be displayed and, thus, the ability to make his/her own map.

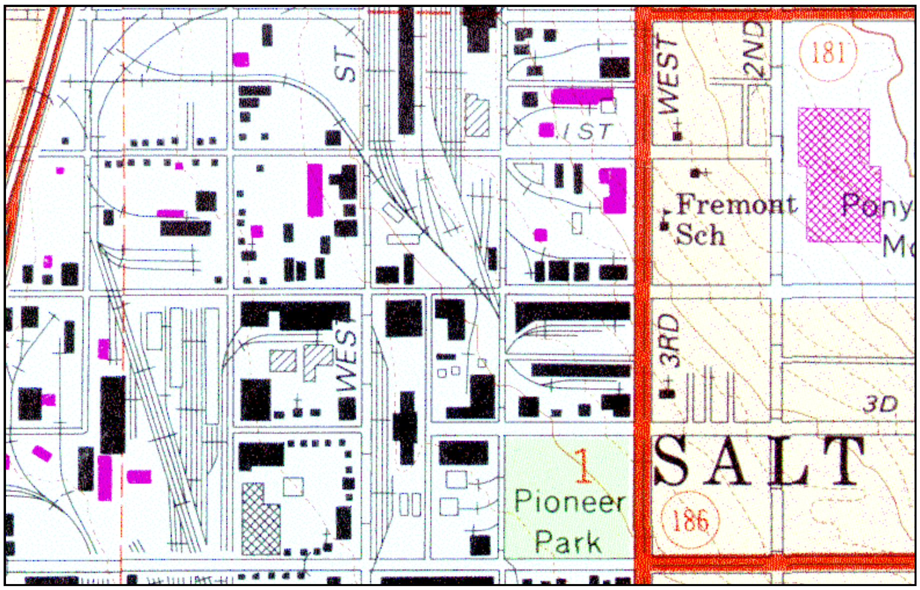
c. A significant issue concerning the production of digital maps is that cartographers lose the control they previously exercised over the information displayed on a map. Now non-cartographer, digital map users can select the information they want to include in their visual map display. Additionally, base maps, made for a specific purpose, can now be manipulated by computers to create new maps that are used for purposes other than what the base mapmaker intended.

204. Types of Digital Maps

a. Raster Map

(1) A raster map is created by scanning a paper map into digital form. It is a bitmapped display where the image on a monitor corresponds dot-by-dot, line-by-line, with a set of memory locations (in the same order). These maps capture the artistic features of paper maps, which usually are more appealing than vector maps. With these maps the user only gets what was on the paper map - no more and no less.

(2) The picture below is an example of a raster map.



(3) A raster map is often used as the base or foundation map on which overlay data is displayed. In applications where a map is the data source, a raster map has significant advantages.

(a) Advantages

1) Fast and easy to make raster maps by scanning paper maps.

2) Inexpensive to make changes.

3) Overlay data is stored separately from the base map so the map is quickly displayed.

(b) Disadvantages

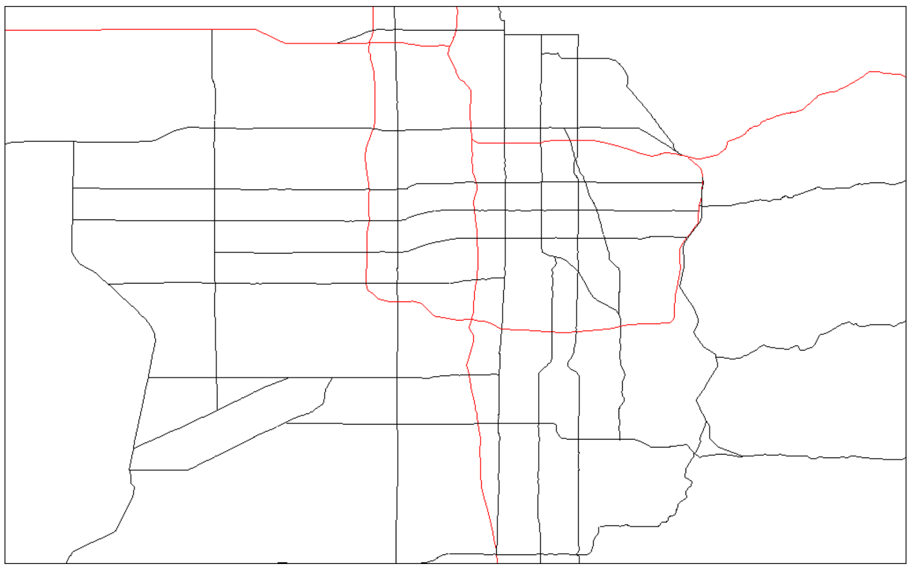
1) A raster map is not interactive. It provides a base or foundation background upon which the overlay data is placed.

2) Stored images can often be quite large (i.e., require large amounts of disk/

hard drive space).

b. Vector Map. A map in which data is stored as a collection of points which can be joined similar to "connect the dots" to form points, lines and areas. A vector map is a digital map in which the map and any overlay data are stored abstractly in a database or database-like organization on a disk. Features such as points, lines, and areas are the elements of the vector data model and are combined to form maps. For applications where the map is the data, vector GIS's excel.

(1) The picture below is an example of a vector map.



(a) Advantages

1) The user can interact with the map and obtain attribute data on all features.

2) Well-developed and useful technology.

3) Used by the majority of GIS systems today.

(b) Disadvantages

1) Very difficult, time consuming and expensive to add data to a database.

2) Database use is very complicated; requires a skilled operator; and is difficult to understand.

3) Requires powerful computer systems to run; is slow and difficult to use.

205. Computer Maps Have Many Advantages

a. The ability to combine different kinds and types of data to see relationships not previously available. Analysis can be facilitated by quickly spotting changes in patterns and cause and effect relationships.

b. Rapidly transmit and receive data from distant locations.

c. A map can easily be updated with minor changes rather than having to update and redraw an entire image - as is required when producing paper maps. What formerly took days, weeks or years can now be done in seconds.

206. Computer Maps Also Have Disadvantages

a. Because of the ease of merging data from numerous sources, the user must be aware of the metadata (information about the data) to a degree not required before. Users can actually build their own maps, so information about the relevance, timeliness, accuracy, and source of the data is crucial. Using paper maps, the product was complete including margin and legend data. Although, adding data or drawing on a paper map limited its usefulness.

b. With digital maps the user has the ability to easily edit or change the map. If an inexperienced user inadvertently makes changes and saves them by mistake, the base map can contain critical errors.

c. Cartographers have lost map production control. Repairing map damage done by inexperienced personnel is virtually impossible to detect and effect.

207. Summary of Paper versus Digital Maps

Paper Map	**Computer Digital Map**
Scale is important (i.e., miles per inch)	Zoom levels allow choice of detail
Sheet size limits scope of map	While the view is limited to the screen size and the screen resolution (number of pixels across and down), the viewer usually can “move across the map” (i.e., display different parts of the map as desired)
Color (palette) is set by mapmaker	Color can be changed
Symbols differ from map to map	User can make own symbols or establish a standard
All information is on the map	Information can be easily added
Information is fixed in time	Information can be updated
Cannot easily relate to other maps	Can compare and contrast with other maps

CHAPTER THREE

THE SHAPE OF THE EARTH, THE ROLE OF DATUMS AND PROJECTIONS

301. Introduction

Mapping involves determining the geographic locations of features on the earth, transforming these locations into positions on a flat map through the use of map projections, and graphically symbolizing these features. Positions on the earth are frequently designated by latitude and longitude in numbers usually specified in degrees. To be able to establish locations in latitude and longitude coordinates, we must know the size and shape of the earth.

302. Determining Location on the Earth

a. We have been taught since childhood that the earth is round as depicted on globes in classrooms and in homes. More correctly stated, the earth is a spheroid or ellipsoid with opinions varying for centuries as to its exact size and shape. Most people know positions on the earth are usually designated by latitude and longitude, which have their origins in history and mathematics. Prior to modern times and the use of more accurate measurement equipment, there were many procedures for measuring distance and many opinions for establishing reference points. From this arose many different systems of measurement; most tailored to a specific area of the world. Many of these systems exist and are used today because it would be very expensive and time consuming to correct and standardize them.

b. With the development of more accurate measuring equipment and the use of satellites, man was able to obtain measurements of the entire earth at one time and a set of "best" numbers was determined. These have been formally adopted under international conventions with the names "General Reference Spheroid - 1980" (GRS80) and the "World Geodetic System - 1984" (WGS84) using a system of latitude and longitude.

303. Datums

a. Because of the different perspectives on the size, shape, and center of the earth as previously discussed, not everyone agrees on how to measure latitude and longitude. The result is that there are numerous systems, all quite close but different enough to make their use not quite interchangeable. For this reason the systems are quantitatively characterized by numerical specifications called "datums," which are simply mathematical models of the earth used to calculate coordinates on any map, chart, or survey system.

b. Since there are many systems of measurement, we need a tool that enables us to convert from one system to another. Using simple arithmetic and identifying certain parameters, it is possible to convert from one system of latitude-longitude to another quite precisely. These parameters are compiled for a large number of different local coordinate systems, and are widely published.

c. Tremendous amounts of data have been collected using measurements based on assumptions that various models of the earth were correct. Since so much data was collected, it cannot be discarded. Without the means for converting data between datums, many good and very accurate maps would be useless. It is impossible to expect that all maps would be converted to the latest and most accurate datum, but with the capability of switching between datums, various data and maps can be used interchangeably.

d. Below are some sample datums:

!DATUM TAG	ELLIPSOID TAG	DX	DY	DZ	DESCRIPTION
NAD83	GRS1980	0	0	0	N. American Datum 1983
WGS84	WGS1984	0	0	0	WGS 1984
WGS72	WGS1972	0	0	4	WGS 1972
NAD27	CLARKE1866	-8	160	176	N. American Datum 1927
ADINMEAN	CLARKE1880	-166	-15	204	Adindan-Mean
ADINBUR	CLARKE1880	-118	-14	218	Adindan-Burkina Faso
ADINCAM	CLARKE1880	-134	-2	210	Adindan-Cameroon
ADINETH	CLARKE1880	-165	-11	206	Adindan-Ethiopia
ADINMALI	CLARKE1880	-123	-20	220	Adindan-Mali
ADINSEN	CLARKE1880	-128	-18	224	Adindan-Senegal
ADINSUD	CLARKE1880	-161	-14	205	Adindan-Sudan
AFGOOYE	KRASSOVSKY	-43	-163	45	Afgooye-Somalia

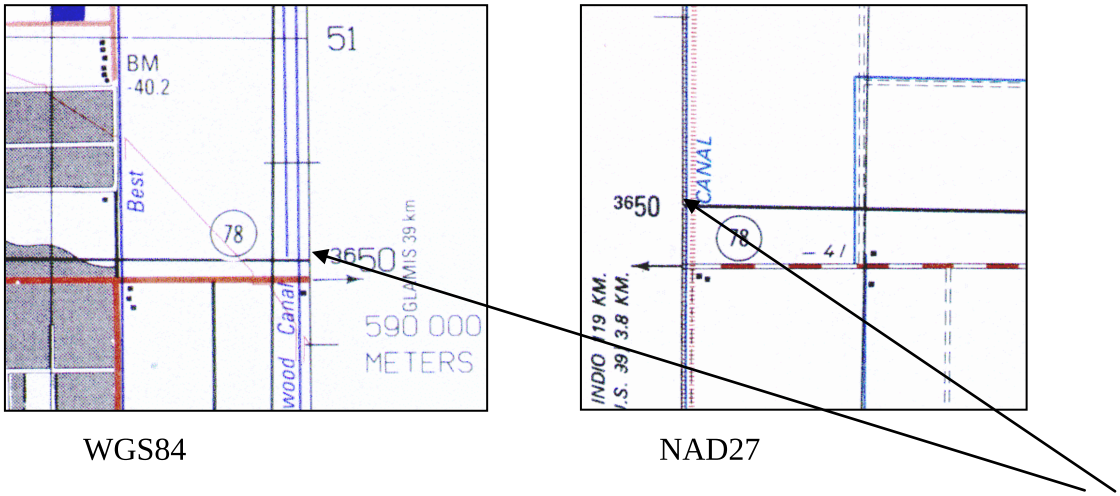
304. Working with Datums

a. The emerging use of GPS equipment has reinforced the need to understand datums because many maps made years ago are still used as base maps with data overlays. In North America, a significant number of maps were made using North American Datum 1927 (NAD27), using equipment and technology common to 1927. Maps made or edited after 1983 took advantage of advancements in technology to include satellites and used North American Datum 1983 (NAD83). Soon thereafter, the World Geodetic System 1984 (WGS84) was adopted; it is used as the default datum in most GPS equipment.

b. Other places in the world have a similar problem with numerous datums that have accumulated over time. Many current maps are simply reprints from products made by other countries and organizations using local datums. There are literally thousands of different datums so that working with maps and data from other countries creates problems that can only be resolved if one understands datums and how to use them.

c. Map users must be sensitive to data sources and types particularly which datum was used to collect map data. When placing data on a map, care must be taken to ensure the data and map use the same datum or else problems will arise. Examples of the impact of mixing map datums and data are the recent military targeting problems in the raid in Libya, B-52 missions in Desert Storm, and the Grenada invasion – where intended targets were missed. Ordnance was dropped and fired consistently off target because of a misunderstanding that data and maps were in different datums.

d. The picture below is an example of different datums on adjoining maps.



WGS84 NAD27

Notice how the road lines up on both maps but notice the difference in Grid Line 3650 because the maps use different datums.

e. As a means of checking the datum of a map, use a GPS device and obtain readings from known locations (road intersections, bridges, etc.). Compare the GPS readings with those on the map. For example, a consistent shift to the northeast might indicate a datum mismatch between the map and the data.

305. Grid Systems

a. Grid systems make maps easier to use. They are usually represented on a map by a regular "grid" of straight, parallel lines - one set running North and South and the other set running East and West.

b. Grid systems use offsets from a reference point to determine specific locations, often referred to as "Easting" (east of the reference point) and "Northing" (north of the reference point). The most common grid systems are the Military Grid Reference System (MGRS) and the State Plane Systems used throughout the United States. These systems have different datums so once again, the map user must be aware of which datum is in use. Explaining these systems is very complicated. There are numerous reference books available.

c. Below is an example of how a MGRS location would appear:

18 S	UT	12352	35540
Zone Number	Square Within the Zone	East of Reference Point	North of Reference Point

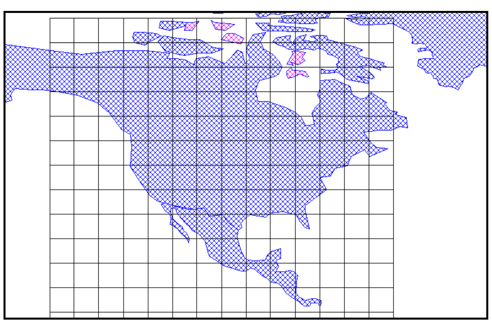
The number would probably appear in the window of the GPS device as a string such as 18SUT1235235540, or might have spaces to differentiate each element such as 18 SUT 12352 35540.

306. Projections

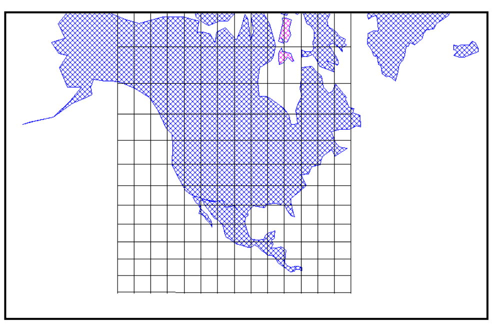
a. Because the earth is round, it is impossible to accurately represent earth locations on a flat map surface. Map projections use mathematics to convert a coordinate position on a "round" earth into a two-dimensional position on a flat surface. Distortion occurs in this process. For small maps, distortion can be quite small, but for large area maps distortion can be quite significant and severe.

b. Over the centuries, cartographers developed hundreds of projections to minimize distortion for specific map uses or specific areas. As an example, the Mercator projection is quite accurate at the equator and for a band above and below for a few degrees, but it causes large distortions as one moves north or south towards the Polar Regions. In contrast, Russia, which lies significantly north of the equator, uses an obscure projection that minimizes distortion in the area contained within its borders.

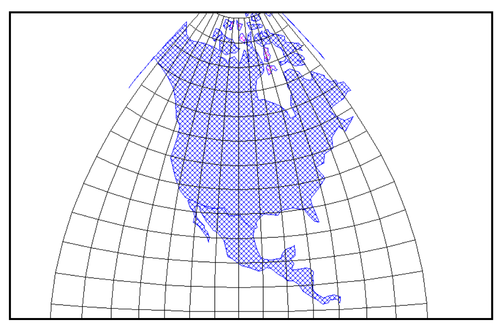
c. Below are some sample projections:



Linear



Mercator



Transverse Mercator

CHAPTER FOUR

THE CARTOGRAPHIC PROCESS AND ITS IMPACT FOR USERS OF DIGITAL GEOGRAPHIC INFORMATION

401. Introduction

Maps are made for specific purposes. A road map is used for travel; a topographical map is used for overland navigation; and a land parcel map is used for property and tax issues. Each map emphasizes what is important to the user while de-emphasizing unnecessary information that clutters up a map. In making maps, it is the cartographer who determines which features to display and how best to do it. Some of the issues that impact the cartographer's judgment are discussed below.

402. Purpose of a Map

a. The initial step when making a map is to determine the basic reason and intended use of the map – these factors will influence the amount of map generalization. Will it be used for navigation, vehicle transportation, or environmental studies? Will the map be used in a presentation and shown briefly on a computer screen, or will it be used over a long period of time like a reference atlas? Does it need to show a great deal of geographic information or will it show general location data? Will it be manipulated by its user or will it be a stand alone product?

b. The objectives of cartography range from the general reference map, which aims to display a variety of geographic information to the thematic map, which displays specific information such as rainfall or population. Most maps contain a combination of both.

403. Selection

The next step in the cartographic process is selecting which features (roads, buildings, rivers, etc.) are to be displayed on the map. The challenge here is to limit the amount of information necessary to support the purpose of the map. Next, the challenge is to portray the desired information appropriate to the scale of the map and, finally, to accurately communicate the information to the user.

404. Generalization

A cartographer strives for accuracy when making a map. However, it is impossible to accurately locate features when the variables of distortion and scale are introduced. As an example, placing the exact location of a building on a 1:50,000-scale map next to other buildings or a road may be impossible because several buildings would cluster together and overlap onto a single point. Deciding to emphasize a road might mean it would overlap or hide a building. For these reasons, cartographers arrange features to accurately portray geographic relationships as well as locations while maintaining the intended purpose of the map. To accomplish this, cartographers use these cartographic principles:

a. Classification - grouping of similar information into classes such as roads, rivers, or forests. Features can be grouped and a typical location can be designated to represent the group.

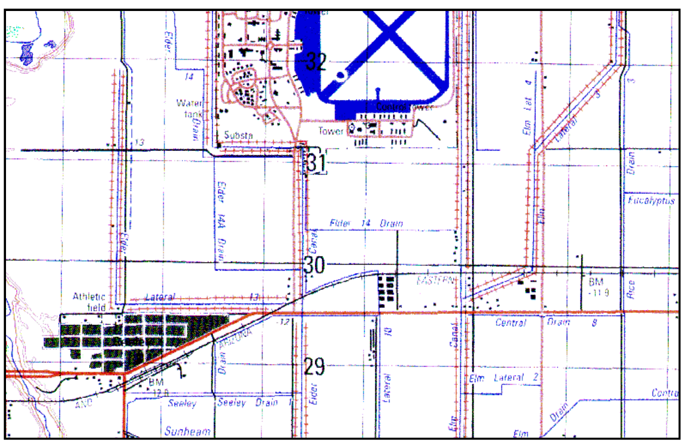
b. Simplification - determining the important characteristics of feature attributes and eliminating unnecessary detail. Reducing the number of points in a curved line but still retaining enough detail to show the curve is an example of simplification.

c. Exaggeration - deliberately enlarging or altering a feature to emphasize its importance. Enlarging a road or a river on a small-scale map is an example.

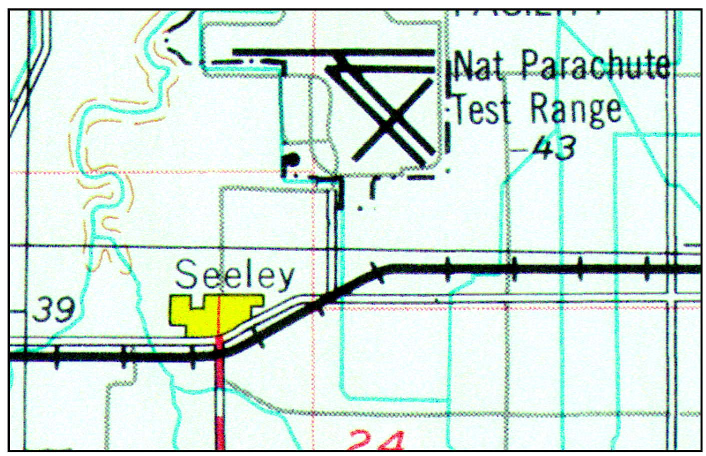
d. Symbolization - transferring features to a graphic mark on a map. The size, shape and color of a symbol are key ingredients to represent feature attribute values.

e. Scale - influences the amount of generalization. The smaller the scale, the more generalization will be required. At large scales, most of the generalization is classification and symbolization while at small scales simplification and exaggeration become more important. Scale impacts differently on digital maps and is discussed below in paragraph 405.

f. Below are maps of the same area in different scales. Note the application of Simplification, Exaggeration, and Symbolization on both maps.



1:50,000 Scale



1:250,000 Scale

Symbolization on both maps.
Simplification of road network and lack of detail on both maps.

Exaggeration of railroad on 1:250,000 map.
Simplification on 1:250,000 map.

g. Accuracy.

(1) Depending on map scale, accurate information can be displayed inaccurately because of generalization. Users must understand the relationship between the accuracy of a map and the accuracy of the data to be displayed. As previously mentioned, paper maps have an acceptable variance in accuracy. For this reason, not all maps should be used to obtain precise location data.

(2) Often users confuse accuracy with precision. Precision is a measure of how exactly a location is specified without any reference to its true value. Accuracy refers to a measure of how close a recorded location comes to its true value. This is why you often see accuracy defined as +/- a stated distance, such as +/- 10 meters.

(3) Different mapmaking organizations, such as the U.S. Geological Survey (USGS) and the National Imagery and Mapping Agency (NIMA), have published accuracy standards whereas other paper maps, produced by other agencies often contain the information in the map legend.

405. Scale of Digital Maps

a. The issue of scale, resolution and accuracy of maps and data is not as simple with digital maps as it is with paper maps. With paper maps, a map's scale greatly influences map content and resolution. What to display on a map is significantly influenced by how much information can be viewed at a particular scale.

b. With digital databases, data is stored at the level of accuracy and detail that was captured at its creation. Many databases are used for purposes other than mapping, so their format and content are not designed or influenced by the need to fit on maps. Much of the data gathered is influenced by the resolution capability of the collection equipment. When data is digitized from existing maps, both the content and resolution are influenced by the capability of the digitizing equipment and the cartographic principles used by the mapmaker.

c. With paper maps, the scale is fixed and stated on the map in the legend information. With digital maps, the scale is determined by several variables such as computer screen size (e.g., 800 pixels by 640 pixels), pixel density set when the maps were scanned (e.g., 300 pixels per inch), and the scale of the original map (e.g., 1:50,000). When using digital maps, the point of the cursor might represent 50 meters, in which case displaying a point with an accuracy of 10 meters is impossible.

d. Most mapping programs have a zoom feature that allows the map to be viewed in greater detail. Because computer maps are scanned and digitized from a paper map of a set scale, zooming in does not provide more detail, only a magnified image of the same level of detail (see the 1:250,000 scale map diagram on page 12). Often users think they can achieve a greater level of detail when zooming in, only to find that the resolution of the image is often degraded.

CHAPTER FIVE

UNDERSTANDING AND WORKING WITH DIGITAL MAPS

501. Introduction

a. The value of using digital maps is to exploit computer capabilities. If users only view a graphic picture of a map, then they are not fully using the computer capabilities available with a digital map. The value of digital maps lies in their ability to integrate tremendous quantities of information very quickly and accurately.

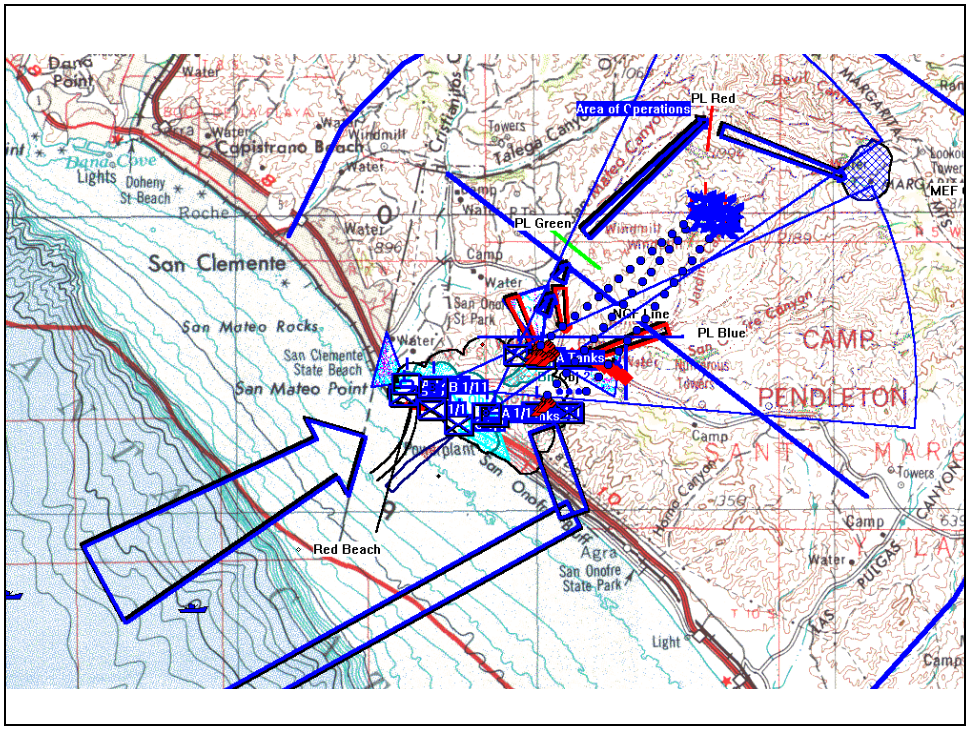
b. To be useful, however, information must be understood by the viewer. The challenge for a skilled cartographer is to understand how humans think and comprehend information since the task is to express information visually. The digital map user must have a similar understanding because of the newly acquired capability for making or editing an electronic map.

502. The Human-Computer Relationship

a. There is a complimentary relationship between people and computers. Computers are very capable of storing and processing large amounts of information very quickly and accurately but are unable to distinguish between right and wrong. People are able to store and adapt experience, and quickly grasp the overall picture of even very chaotic situations. This relationship is tenuous because of the potential problems posed by information overload, which may confuse decision-makers.

b. Whereas the technological movement is to increase the computer capacity for processing information, the human ability to assimilate information is relatively constant. Most psychologists state that the human mind can only handle 3 - 7 variables at one time. Given more than that, our ability to fully understand more information makes us vulnerable to emotional influences. This devalues past experience and reduces our confidence when dealing with complex situations. Studies suggest decision making declines with too much information because of the difficulty of integrating all of it. Keeping it simple is the same challenge faced by cartographers, so that what is important is not lost in volumes of detail.

c. The dilemma then is the proper balance between the ability of the computer to furnish an almost unlimited amount of data and the user's ability to make sense of the displays on a computer screen. Techniques to do this have existed for centuries as commanders have attempted to simplify requirements for subordinates by identifying the most necessary and most important pieces of information. The picture on the next page demonstrates an excessive amount of computer information commonly referred to as "information overload."



Information Overload

503. The Information Hierarchy

a. The focus of today's technology effort is to improve the capacity to gather information as opposed to improving the quality or clarity of information. It is important to (1) recognize that information is transformed as it moves up the hierarchy and (2) understand what causes this transformation. The hierarchy flow can be described as follows:

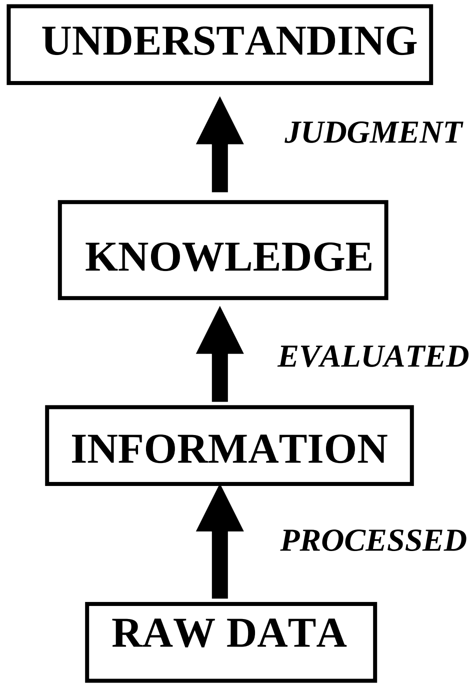
(1) Data - raw data or signals that have not been processed, correlated, integrated, evaluated, or interpreted in some way to give meaning.

(2) Information - puts raw data in an understandable form: formatted, plotted, translated, and/or correlated. Information adds context through relationships between data, and possibly other information. This is where the majority of attention is focused with today's technology.

(3) Knowledge - gives some meaning and value to data. It is evaluated, integrated and analyzed. It is here that inferences are drawn about data.

(4) Understanding - gives greater situational meaning to the information. It is synthesized and visualized. Information is diagnosed, explained, and outcomes are predicted. Understanding reveals the critical factors, patterns and logic of a situation. It is here that successful managers focus their attention drawing inferences and making projections rather than collecting more information. The successful cartographer must also select from an overwhelming amount of data and present that which is relevant so the viewer will better understand.

(5) Below is a diagram of this process:



504. True and Relative Information

a. The value of a map is in conveying information that assists the viewer in understanding a situation. When displaying information in conjunction with the cartographic principles already discussed, we need to understand the difference between true or real and relative and virtual information. Overwhelming viewers with extremely accurate "true information" confuses more than it helps when a better answer is in the display of relative information.

b. Overlay data can accurately represent information relative to a particular topic and help a viewer easily understand large amounts of detail. Decisions are not based on individual facts, but on the differences between new information and the viewer's perception of the depicted situation. This relative or virtual picture might be better than an actual photograph because it allows viewers to focus on change, which is easier to detect and understand.

505. Graphics

a. The process of creating symbols to represent features on a map is called symbolization. Whereas there are numerous variables that impact on the graphic presentation of data, we will only briefly discuss three - color, size and shape.

(1) Color – is the most basic map variable because it is impossible to have visualization without variations in color values. Studies have shown that color significantly influences information absorbed by the viewer. Conversely, the lack of a variation of color (e.g., grayscale map) can accentuate overlay data to emphasize map data.

(2) Size - symbol sizes indicate differences in values or quantities. Usually the larger the symbol, the more important the data item. It is one of the most useful variables in cartography.

(3) Shape - also used to denote differences in values, particularly when applied to lines. Solid, dashed, and dotted lines are easily distinguished on a map.

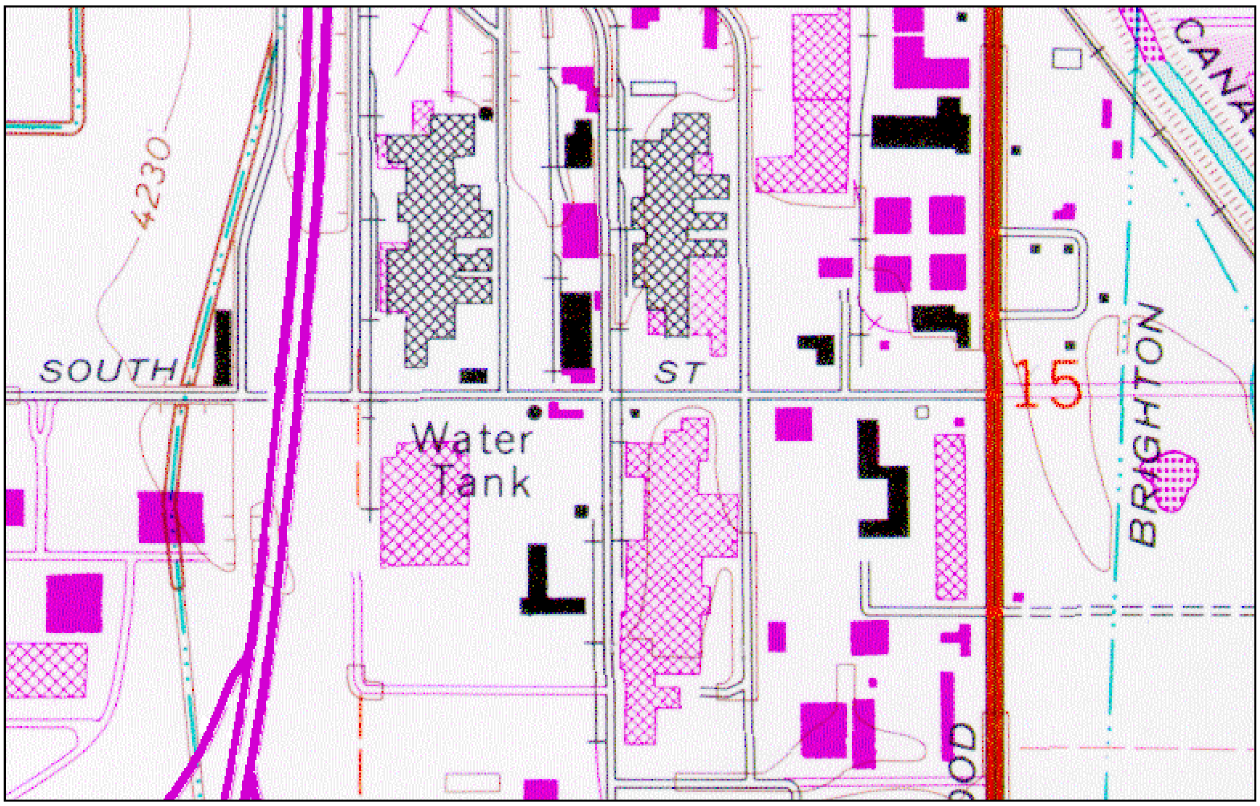


Diagram showing Color, Size, and Shape variations used with maps

506. Better Information or Better Analysis

a. To fully exploit the ability of computers, the real value lies in a viewer's ability to analyze map data and establish relationships. These relationships help the viewer move from simply seeing information to better understanding the impact of data.

b. One of the most useful visual applications is the examination of different combinations of information in a timed sequence. The visual effect of such combinations often provides an overall understanding that exceeds the information contained in each individual feature or symbol. A good example is television weather reporters' use of moving displays of clouds and weather fronts to better visualize future weather patterns in different parts of the country. Other ways of using displays to assist in visualizing map information are:

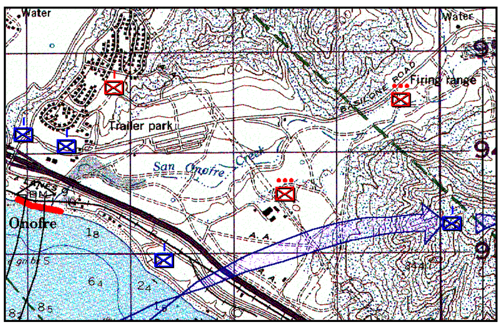
(1) Overlaying maps from different sources or with different types of information (which facilitates comparisons and helps to spot changes).

(2) Showing changes over time by the sequential display of overlay information.

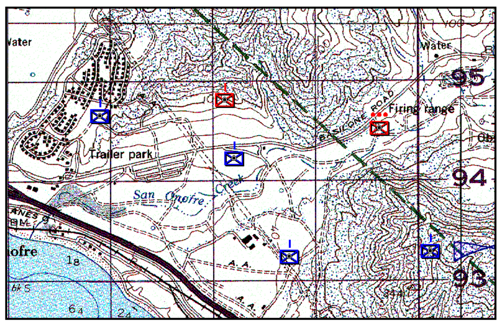
(3) Showing changes over time by displaying data collected at different times using different colors.

(4) Using color, size and shape differences to identify the results of database queries.

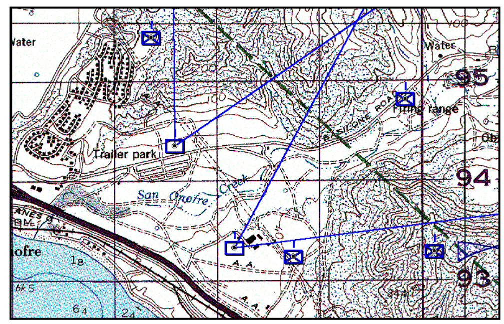
c. The pictures below are a time sequence of an amphibious landing:



0700



0900



1000

CHAPTER SIX

METADATA

601. Definition

a. Metadata is information about the content, quality, condition and other characteristics of data. It is information about data, or the characteristics and history of data. It usually includes reliability, precision, accuracy, completeness and consistency of data.

b. In its broad sense, map metadata is all the information concerning map data and the overlay data that is displayed on the map. In a more narrow sense, map metadata refers to a standard information content for a set of digital geospatial data.

602. Objectives of Metadata

a. Because map displays draw data from many sources with a variety of accuracies and generalizations, there must be a means to check the source and accuracy of its data. There is a common tendency to accept data from a database as accurate and appropriate for any display on a digital map. An important issue is that a user understand the data source and content to ensure they are appropriate for display. Establishing standards for digital data is an important step in controlling data so a user can determine if it is appropriate for his or her needs. It is a user's responsibility to be aware of metadata and to inquire as to the data's appropriateness.

b. A standard establishes the names of data elements and groups of elements to be used, the definitions of elements, and information about the values that are provided for data elements. The uses of metadata are:

(1) To maintain an organization's internal investment in geospatial data;

(2) To provide information about data holdings for data catalogs, clearinghouses and brokerages; and

(3) To provide information needed to process and interpret data received from an external source transfer.

c. Roles that metadata play include:

(1) Availability – information needed to determine the sets of data that exist for a specific geographic location.

(2) Fitness for use – information needed to determine if a set of data meets a specific need.

(3) Access – information needed to acquire an identified set of data.

(4) Transfer – information needed to process and use a set of data.

603. Metadata Example

Spatial Metadata Categories and Their Descriptions	
Identification information	Description of data set
Contact information	Organization to contact to obtain data
Transfer information	Details to obtain data
Status information	Completeness of the data
Coordinate system information	Data set coordinate and map projection
Source information	Description of the origin of the data set
Processing history information	Information about processing steps performed on the data set
Data quality information	Measures used to provide user information on which to judge if the quality of the data set is suitable for planned use
Feature/attribute information	A detailed description of the information about features, attributes, and attribute values

CHAPTER SEVEN

DATABASES

701. Introduction

a. The primary purpose for digital maps is to exploit a computer's ability to gather together large amounts of information. Much map information is stored in databases. This introduction does not discuss databases in detail but highlights those areas that are significant when working with geographic information. The same general results can be obtained by using spreadsheets; however databases provide more flexibility when manipulating data. For this reason, databases with geographic information are more prevalent than spreadsheets; this discussion will focus on databases.

b. When working with database data, a user must understand how the database is organized and works because damage can be easily done to both the data in the database and its visualization on a map. A database is a collection of records and files that are organized for a particular purpose. A database stores data in tables that contain information about a particular subject, such as maps, companies or employees. Tables are composed of fields with different kinds of data such as names, addresses and records. Each field contains information about a particular item such as information about a map (its maker, date, accuracy, etc.) or a person or a building.

c. In databases, large quantities of data are broken into small pieces. Thus, a town can be represented with 100,000 separate records (one for each building, street, length of sewer, etc.) with 50 fields defined for each record. The result can be millions of data elements that are assembled into reports that present the few pieces of information important to a problem at hand.

702. Terminology

a. For the significant to be separated from the insignificant, there must be a common language or established standards. The capability of computers, and particularly databases, to combine data as required for a particular problem must be exploited for data visualization. The key is developing an appropriate system of categorization. Standards are needed to ensure data quality, data exchange, hardware and software interoperability and data collection.

b. A data dictionary defines a framework of terms used to label tables, records and fields. Existing standard terms should be used to reduce confusion as much as possible. Databases are very powerful but something as simple as a misspelled word can have unforeseen catastrophic results. A common word such as "tank" can have several meanings ranging from a container for storing gas to a mobile vehicle with a mounted gun.

703. The Use of Databases with Digital Maps

a. Since there are two types of digital maps, vector and raster, a brief description of how each type works with a database is necessary to better explain the unique features of each type.

b. This discussion will briefly cover those areas not previously addressed because most cartographic principles pertain regardless of which type of map is used. The basic principles of database use also pertain; however, this explanation will focus on the unique application of geographic information.

704. Vector Map Databases

a. A vector map holds all its data in databases. The location of features is obtained by digitizing existing cartographic products. In essence, a map is built by appending different layers of information such as elevation contours, roads, buildings, populated places and the outlines of metropolitan areas.

b. A vector map can also work with information from external databases. All geographic data may or may not be contained in the same database. A distinction is made between the data used to make a vector map which is referred to as cartographic data and other data gathered from the environment called geographic data. Often geographic data is gathered with the help of GPS equipment or other survey type instruments.

c. Problems surface when there is a map and database discrepancy as to the location of a specific feature. A map may show a building at one location and a GPS device shows it at another. Additional problems arise when geographic data is integrated and conflicts with cartographic data. An example would be the integration of geographic overlay information in which a database road has a location different from the cartographic data. When the data merges, which one is correct?

705. Databases with Raster Maps

a. A digital raster graphic map stores data as bitmapped images rather than as data points. This circumvents the database creation problem by allowing existing paper maps to be converted into a properly geocoded form and used as a geographic context for relevant user data. This permits the capture of significant cartographer contributions in a pleasing-to-view format.

b. Overlay data to be placed on a raster map is stored in a separate database or databases. A user must still be aware of the potential location discrepancy between a features located on a map and the location of features captured with a GPS device.

706. Importance of Metadata

a. Special attention must be taken when entering geographic information into a database to ensure its accuracy. When data is entered into a database, the appropriate metadata must also be entered to provide the ability to sort out inevitable discrepancies. If data can be shared to maximize its benefits, it is important that there be some standard to allow for the multiple use and transfer of data between unrelated parties.

b. When using data from a database, a user must check the data's metadata to ensure the data is appropriate for its intended use. A user cannot assume all data is accurate and appropriate as might have been the case with paper maps years ago. Without checking metadata, there is a potential to draw incorrect conclusions from data presentations on maps. As previously mentioned, a user must check the metadata of a map as well as geographic data to eliminate a potential mismatch.

707. Scale

a. A brief discussion of scale is necessary so that a user understands that database data is without scale. This reinforces the need to understand and use metadata to resolve discrepancies.

b. A user must understand the relationship of spatial resolution to scale so that visual presentation is not distorted. Sometimes these distortions can only be resolved using other source materials, imagery or fieldwork. Terms such as (1) accuracy refer to spatial accuracy which is how close a recorded location comes to its true location, and (2) precision, which measures how exact a location is specified without reference to its true value. Understanding these terms will help a user work with databases.

CHAPTER EIGHT

GPS

801. Introduction

a. A discussion of the Global Positioning System (GPS) is necessary because much of today's geographic data is collected with GPS equipment and stored in databases.

b. GPS was developed by the Department of Defense (DOD) because of DOD's need for very accurate location data for a variety of military uses. Additionally, non-military businesses developed commercial applications of GPS (e.g., the recent development of GPS use in automobiles to assist drivers with highway navigation).

c. GPS equipment has become so "user-friendly" that many untrained people are using it. The operation of most GPS equipment is simple, but as with any equipment, a user must understand its capabilities and how it works to obtain and use better information.

802. Definition of GPS

a. GPS is a constellation of 21 satellites orbiting the earth at a very high altitude. Each satellite is similar to an orbiting radio station that emits radio signals that are captured by GPS equipment. Because these signals are not encrypted and can be captured by any GPS device, the DOD created two types of radio signals, one for military use and one for civilian use.

b. The DOD was concerned that a potential enemy could have access to very accurate positioning data using GPS so they degraded its position accuracy for civilian use; this accuracy degrading is called "selective availability" or SA.

803. Using GPS Equipment

a. A user must know if he is using a military GPS device or a civilian GPS device. This is important because of its location accuracy capability. GPS positions are accurate to within about 100 meters for civilian use and to within 10 meters for military use. When DOD degrades the GPS signal (through selective availability), the horizontal accuracy for civilian GPS equipment is stated as approximately 300 meters.

b. Understanding the accuracy of data is one of the elements of metadata so critical to computerized geographic information. Understanding that positioning data might be anywhere inside a circle with a radius of 10 or 300 meters has a significant impact when viewing data on a map; this may contribute to a disaster if erroneous conclusions are drawn.

c. One way civilian GPS equipment can work better with degraded accuracy is to apply differential corrections to reduce the amount of error. Differential GPS measurements (DGPS) can be much more accurate than standard GPS measurements. Again, knowledge of how data is acquired and to what level of accuracy becomes another important part of metadata. This manual does not discuss details other than to make a user aware of possible degraded GPS signals and steps to work around them. There are numerous manuals available that discuss GPS technical issues.

d. GPS receivers usually have the option to read coordinates in various datums. Most current models of GPS equipment use WGS84 as a default datum. Again, as with accuracy issues, the datum used to capture data becomes part of metadata. This relatively simple issue has had catastrophic results because some GPS users have tinkered with their GPS equipment (i.e., turned knobs and switches) and inadvertently changed many important settings. Understanding GPS equipment can save many long hours recapturing data, often at great expense and time.

804. GPS Signal Degradation

a. Anything that degrades a radio signal will impact GPS equipment use. The atmosphere, ionosphere, snow, and rain all contribute to degrading the signal from GPS satellites. This manual does not go into detail other than to make a GPS user aware of some significant degradation issues.

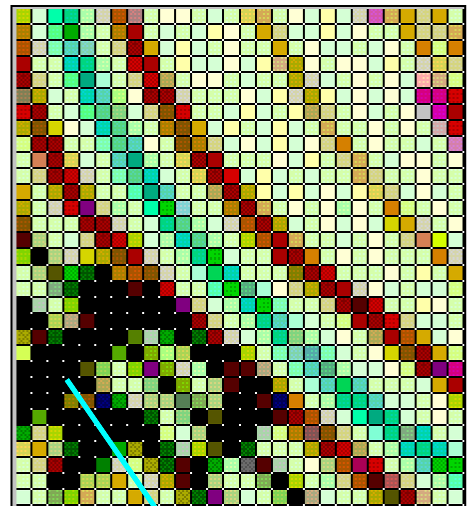
b. Buildings may cause radio signals to bounce or be blocked entirely. This may make GPS equipment use in cities or other built up areas very limited - often producing incomplete or inaccurate data. The same effect can be caused by anything that blocks a signal such as tall trees or heavy vegetation. The use of other navigation equipment, such as laser rangefinders, can help overcome the limitations of GPS and still contribute to gathering accurate location data.

APPENDIX A

BASICS OF COMPUTER MAP DISPLAYS

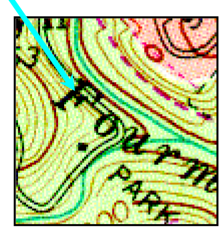
1. Purpose of Appendix. This appendix explains the basics of computer map displays.

2. Dividing a Large Single Object into Many Small Objects



a. The key to understanding how computers display maps is to understand that computer screens display many small picture elements (or pixels). Most computer screens can display 640 pixels horizontally and 480 pixels vertically. Other common pixel combinations include 800 horizontally/600 vertically and 1024 horizontally/768 vertically. The figure at right is a part of a computer screen display of a digital/electronic map that has been magnified so that each pixel is visible.

b. Each pixel is a separate entity. It has its own color and it (or a group of pixels) can be tied to its own record in a database. Because of their very small size, individual pixels are not easily viewed unless they are magnified, as was done to create the illustration at top right. When one looks at a computer screen, his/her eye blends pixels to together to create letters in text documents and lines, points, areas, figures and icons on digital maps. The second figure at right encloses the same area as the top right image (where individual pixels are visible). In the top right magnified image, the black pixels in the lower left corner are the letter "F" in "Fourm" in the lower image (see the blue arrow). The blue-green pixels in the middle of the magnified image represent a stream in the lower image.



3. Map Formats. The data displayed on a computer map is stored in a computer file either in a **raster** image format or in a **vector** format.

a. Raster images store the color value for each pixel separately. Each pixel is one piece of data different and separate from the next pixel. The limitation of raster images is that each image deals directly with color and not lines, areas, points, or feature types of such as streams, roads, and hills. The viewer of a raster image must draw his/her own conclusion concerning the entire display. Because the human mind is very good at drawing such conclusions, the raster approach can work very well. Indeed, it is why paper maps are an effective means for disseminating information.

b. Vector data is stored in a computer as a series of points. A single point can be (1) used to represent individual data (e.g., a person's location); (2) joined together to represent lines; or (3) joined together to represent areas. The significant difference between a line and an area in computer software terms is that the last point on a line is not connected to its first point while the last point of a line defining an area is connected to the first point.

c. Vector and raster data are both portrayed on a computer screen using pixels. In the case of the raster file, software converts each pixel color data into an array of pixels that fills the computer screen and creates a map image. With vector files, software converts the data for points, lines, and areas into an array of pixels that fill the computer screen and create a map image. The software used for creating a map display from raster data is different than that used for creating a map from vector data but the end result is identical - pixels take on different colors to create the appropriate images.

d. Raster and vector data are often intermixed in computer map displays. When used together, a raster image is usually a base map with vector data overlaid on it. The vector data may take the form of icons representing military units or a control measure representing a scheme of maneuver.

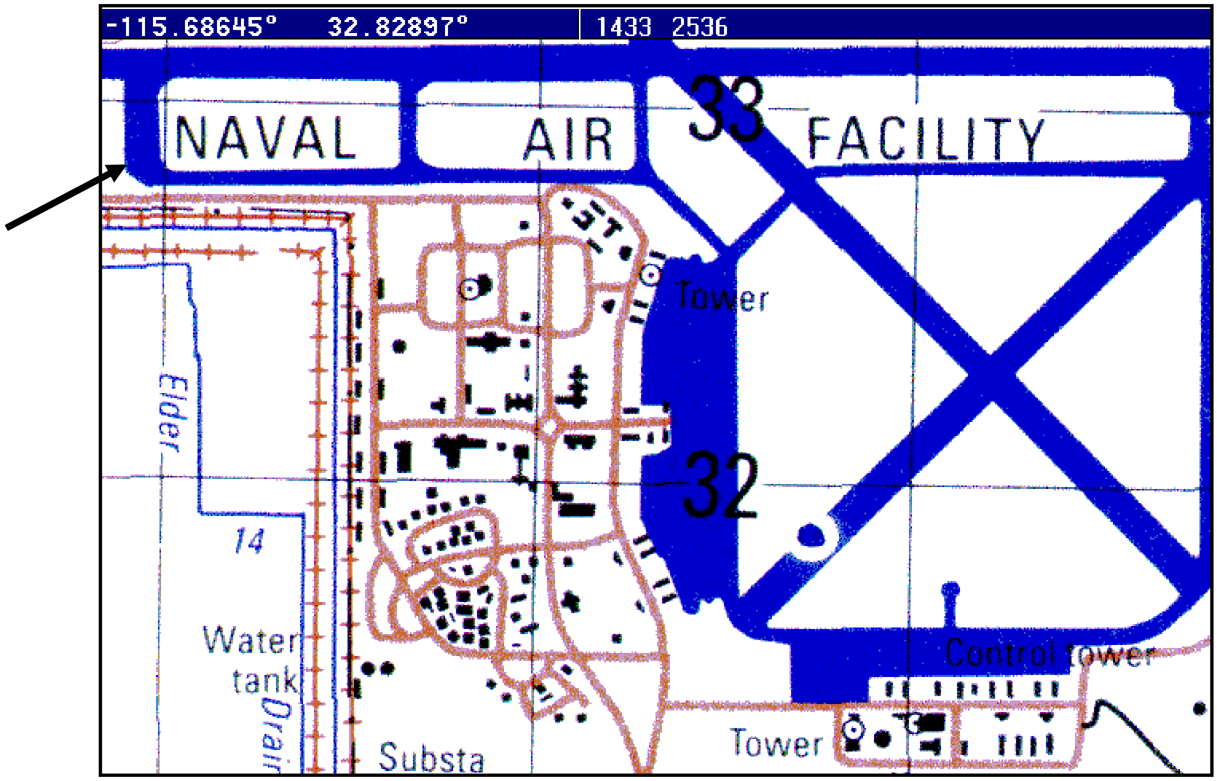
e. It is also possible to provide up-to-date vector data that overrides and obscures obsolete data on the raster image. To do this, vector data is used to overlay lines, areas or symbols on a raster image. Thus, if an infantry unit has an older raster image base map (e.g., a 1:50,000 scale NIMA map) displaying its area of operations, newer buildings, bridges, roads and feature changes not displayed on the raster image can be added and represented.

4. Correlating Positions on the Ground with Pixels on Raster Maps. This process of correlating a position on the ground with a point on a computer map is called geo-referencing. The basic process is explained below.

a. The key to understanding how computer-mapping software correlates a point (location) on the ground with a point on a digital map is to understand that every pixel point on a raster image has a unique address. A geo-referenced pixel address is determined by (1) its column number, (2) its row number and (3) the geographic reference point or point of origin of the upper left corner of the digital image. Thus, a point in an image that is located in column 10 (from the left) and row 25 (from the top) has an image relative address of (10, 25).

b. Because computer map images usually have thousands of rows and columns, a single pixel address may be quite large. The computer map at right displays the pixel address of a mouse pointer; its address is column 1744 and row 2603 (1744, 2603).

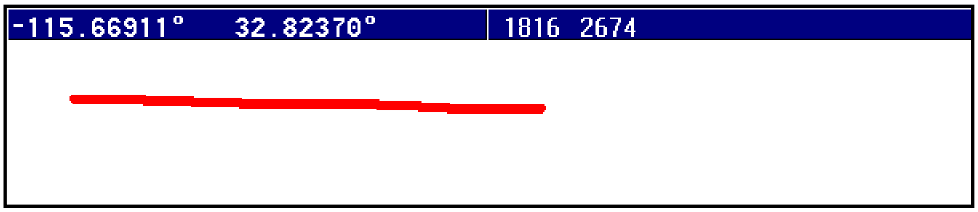
c. Locations on the earth's surface are often stated in a manner similar to that used for pixel addresses in raster images. For example, a specific latitude and longitude is a location stated as a number of degrees. Longitude degrees represent locations east or west of an imaginary line, the Greenwich Meridian, (1) connecting the North Pole and the South Pole and (2) passing through Greenwich, England. Latitude degrees represent locations north or south of the Equator. In the image below, the point marked with the arrow is 115.68645 degrees west of Greenwich, England and 32.82897 degrees north of the equator.



d. Locations on the ground and locations in a raster image are identified in basically the same manner - using numbers that state a location in uniform units (degrees or pixels, respectively) measured from a reference point (the intersection of the Greenwich Meridian and the Equator or the upper left corner of a raster image, respectively). This computer-mapping relationship is exploited by determining the geographic value of each pixel in terms of map units (e.g., degrees, meters, etc.). In the map above, each pixel equals approximately .00004 degrees. That value, plus the pixel's column and row location and the map's geographic reference point (its upper left corner) is used by computer software to determine the geographic latitude and longitude location any position on the computer map. As the pointer moves across the computer screen, the position readout is continually re-computed and displayed. Comparing the image below with the image above, the arrow is pointing to a more eastern location (i.e., longitude changed from –115.68645 to –115.67237 and pixel location has increased from 1433 to 1744).

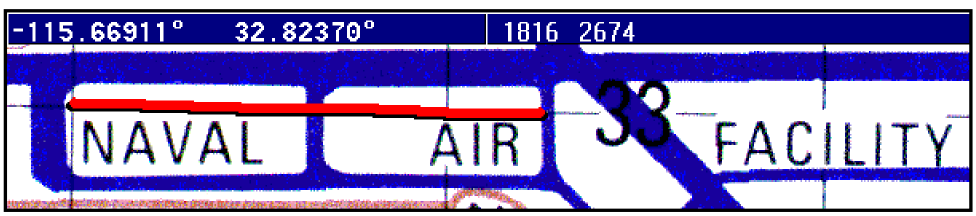
5. Correlating Positions on the Ground with Vector Map Data. Vector maps bypass the correlating of pixels on an image and pixels on a screen by storing map data not as images but as tables of data. The table at right is an extract from a computer-mapping program's data file representing a line when displayed by the mapping program. A computer-mapping program shows that data as the line in the image below.

```
"-115.6858618 ","
32.8281704 "
"-115.6803849 ","
32.8280556 "
```



6. Combining Raster and Vector Maps. The capability to store map information as raster images and vector data has great potential.

a. The image below shows a map that was created by overlaying the vector line in the image above on the raster map used in earlier images.

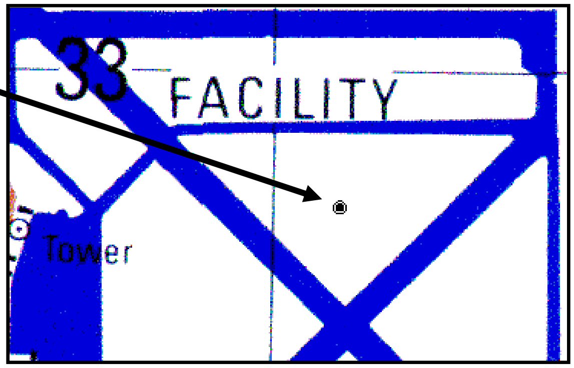


b. This is the same technique used by ground forces for decades when they mounted a paper map on a piece of plywood, used pieces of transparent acetate as overlays, and drew tactical control measures and unit locations on the acetate overlays.

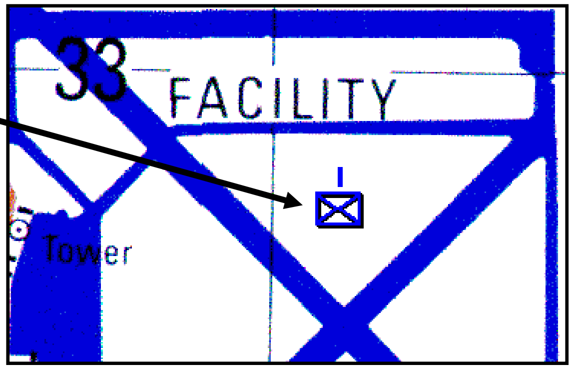
c. The advantage of computer-map overlays is the potential for the computer to automatically update the overlay as units move or other aspects of the situation change.

7. Nodes, Points, Lines, and Areas. Because the building blocks of vector maps are nodes, points, lines, and areas, a working understanding of vector map data includes understanding these elements and the relationships between them.

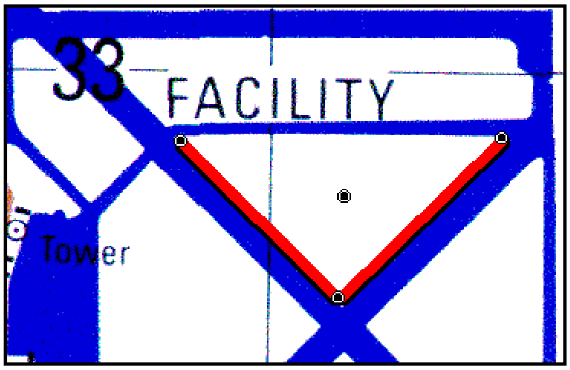
a. A node is a single place. It consists basically of location. The image to the right includes a vector node. All that is apparent is a location.



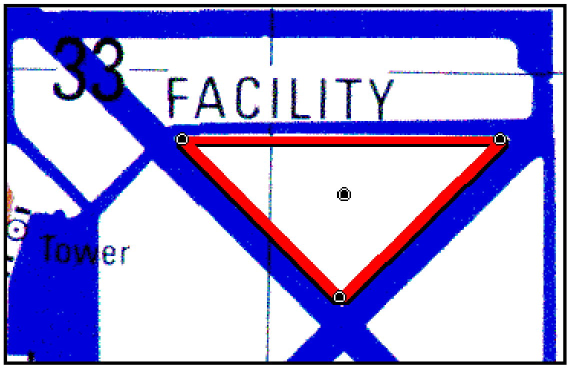
b. A point is also a single place. That is to say, a point has only one node. The image to the right shows a point that indicates the presence of an infantry company; it is location with data.



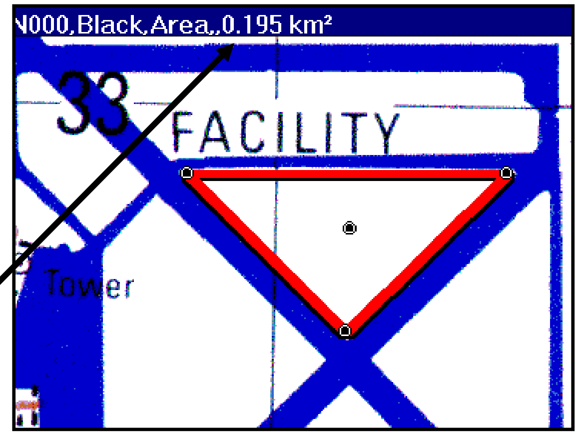
c. A line is a series of nodes. Often there is a "zero" node with which labels can be attached. The image at right shows a red line drawn with three nodes (on the line) and a zero node located between two segments of the line.



d. An area is a line that closes on itself. The image at right uses the same nodes as the line image (i.e., paragraph 7.c. above). The only difference is that the computer-mapping software used vector elements to construct a line segment (and define an enclosed area) between the last node and the first node.



e. While the difference between a line and an area is minor in terms of the basic vector elements, it is major in terms of the functions that computer-mapping software can perform. Mapping software can measure line length, but the area enclosed by a particular feature can be calculated only when an area is drawn around the feature. In the image at the right, mapping software has calculated the area between the runways and taxiways to be .195 square kilometers.



8. Benefits of Vector Maps. Recording all map features as a series of nodes provides little practical use without the ability to manipulate, analyze and use the vector data.

a. As we have seen, once an area is defined by its line segments, computer-mapping software can calculate its size. Similarly, software can compute the length of any vector line.

b. Vector representation of points, lines, and areas is usually disseminated far faster than raster maps with the same data. This is because far less data is required usually to represent a vector point, line, or area than is required to represent a raster image of the same area. Further, tools for creating vector overlays are easier to use than software tools for adding features to a raster image.

c. Constantly Accurate Maps. The potential benefit of keeping digital maps current through the rapid creation and dissemination of vector overlay features is significant. To understand this, three principles must be understood:

(1) Maps show selected features - not all features. All maps display only selected information about an area, not all information. If all information available about a specific location were placed on a map, the map would have so many lines, points, and areas it would be illegible. Map users, therefore, want a road map to show only roads and a map of the world to show only the international boundaries, oceans, and the locations and names of the major cities. Road maps that display too much other information would cover the roads and make the maps useless while world maps with too much topo-graphical information and detail are unsatisfactory because boundaries are hidden.

(2) Overlaying. The simple maps made by the tracing paper and acetate gave the military the capability to use a base map for important background information and context with the most important and changing pieces of information represented on the tracing paper and acetate overlays. Computer maps with vector overlays achieve the same effect, but the overlay data can be disseminated far faster than paper or acetate overlays.

(3) Updates and databases. Links established between computer maps and databases can be used to continually and automatically update databases and maps. The use of databases and computer-mapping software requires certain technical skills. However, once this investment is made, significant improvements in situational awareness can be realized.

9. Conclusion. The concepts of nodes, points, lines, and areas are important because understanding them provides the intellectual basis necessary for understanding the use of computerized geographic information and the improvement of situational awareness.

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