CONSIDERATIONS FOR IMPLEMENTING A MICROCOMPUTER DATABASE FOR VIRGINIA CONTROL SURVEY DATA

by

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(ABSTRACT)

Currently, geodetic control data are generally available only at the federal level. The National Geodetic Survey (NGS) publishes only the results of those surveys that their agency performs, as well as other surveys that meet certain criteria.

The advantages of a state office which would disseminate NGS control data as well as all other survey data within the state are discussed. Since NGS now distributes its data on floppy diskettes, the design of a microcomputer database to access this information is investigated.

This thesis focuses on such a database system operated mainly by the end-user of control data. An integrated software system, in which related computational programs are linked to the database, is also considered. The dBase III package, as one software alternative, is examined. Applicability to geographic information systems is also explored.

Data formats, file sizes, and administrative concerns are dealt with, and future research and development in these and related areas are proposed.

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CHAPTER I

INTRODUCTION

1.1 PROBLEM STATEMENT

There is an increasing need to reference engineering, boundary, and other surveys to a global framework. Scientific studies, such as crustal motion monitoring, and engineering projects covering a large area typically require such geodetic control. The implementation of many land and geographic information systems (LISs and GISs) requires a geodetic framework and, with surveying technology as advanced as it is today, tying most surveys into this framework is not as difficult as it once was. The Global Positioning System (GPS, or "satellite surveying"), which has become more affordable and accurate in the past few years, has made geodetic referencing of small-scale and remote surveys much more practical.

Land use planners depend on LISs for reliable information in order to responsibly monitor and develop our natural resources. LISs, then, must be spatially accurate, and reference to a national or global coordinate system is needed. The National Geodetic Survey (NGS) is the agency responsible for control stations within the United States. The problem is then three-fold, the last of which is the focus of this report:

1. Establishing the stations This is densification of the existing national net, and incorporates city, county, and state networks. Technology is now available to do this task with electronic survey instruments, photogrammetry, and GPS.

2. Maintaining the network This ranges from the physical preservation of the monuments, to the organized recording of accompanying data (coordinates, monument description, etc.).

3. Disseminating the information Users of control data (mainly surveyors and engineers) must have ready access to this information, which may be made available at local (city, county), state, or federal levels. Data are typically distributed in a hardcopy format, with computer-readable files being a recent alternative.

State-wide distribution of data is our main concern here: unless a state has a survey office, control information now comes from the federal level (NGS). Some state agencies may have their own control (e.g. state highway departments), but it may not be readily available.

A local or state distribution system can promote the use of a uniform coordinate system, a must for LIS work and/or mapping large-area projects. Considering also that the existing plane coordinate systems are state-wide by design, and that NGS is now encouraging states to assume distribution responsibility, it is likely that such a state system is apt to be more efficient than what is currently in use.

1.2 OBJECTIVES

The objective of this thesis is to examine the necessary parameters of a database for survey control data to be used for distribution of data to Virginia users through, but not necessarily limited to, computer software. The advantages of a local, computerized system over the current hardcopy distribution scheme will be analyzed.

The discussion will focus mainly on the design aspects of the proposed database system, software alternatives, and related computational programs such as state plane coordinate transformations.

Recommendations for future research in the actual development of the database system will be proposed. Not only do the technical aspects need further study, but also the administrative, by which an agency would be responsible for state-wide data distribution.

1.3 SCOPE

NGS collects, verifies, and adjusts survey data from several different sources. If the submitting agencies follow certain guidelines, these data are then published and made available to the public in one standard format. For this reason, the discussions in this report will be limited to horizontal data obtained through NGS. Neither will NGS vertical data be discussed, since heights for many benchmarks will not be available until 1991 when the NAVD 88 (North American Vertical Datum of 1988) has been completed and adjusted (Balazs and Zilkoski, 1987). However, elevation data and data from other sources will be mentioned when appropriate.

Other states considering or currently developing similar systems may find information in this report useful, since many concepts are general in nature and not just specific to Virginia.

CHAPTER II

BACKGROUND

2.1 CONTROL DATA USES

In the past, users of geodetic control data have typically been in the surveying, mapping, and engineering professions. Currently, in addition to these traditional fields, there are many other users. This is because of the demands on our natural resources, development of sophisticated navigation systems, technological advances in geodynamics, and the establishment of data banks for improved management of land and coastal zone uses (Spencer, 1979). The following list highlights the wide range of uses for control data:

- Planning, engineering, and construction activities for rural, urban, and regional development.

- Land-use and recordation management systems (LIS).

- All surveys defining boundaries, both public and private.

- Transportation systems involving airports, railways, and highways.

- Utility and energy assessment studies, including mining and offshore exploration.
- Navigation and positioning systems (waterways).
- Environmental, ecological, and agricultural programs.
- Crustal movement and seismic activity studies.
- All other operations requiring mapping or charting.

2.2 ESTABLISHMENT OF CONTROL

NGS is responsible for establishing and maintaining the national network which is comprised of the most accurate control stations. State and other federal agencies will often add to, or densify, this control in a specific area for their own use. The U.S. Geological Survey, the Army Corps of Engineers, and state highway departments are some of the agencies that establish their own control. This lower-order control is sometimes, but not always, sent to NGS for publication. Cities and counties may also densify control for land development purposes, but the results of these surveys are not normally published by NGS (Input Formats, 1980).

2.3 NORTH AMERICAN DATUM OF 1983

In 1974, NGS undertook the enormous task of adjusting and redefining the entire nationwide horizontal survey network. This mass revision, resulting in a new datum called the North American Datum of 1983 (NAD 83), meant that the geographic coordinates for every control station in the U.S. underwent a significant change (up to tens of meters). The NAD 83 is the result of both a datum redefinition and a readjustment of geodetic observations (Bossler, 1975).

2.3.1 Datum Redefinition

The NAD 83 uses an ellipsoid (GRS 80) that closely approximates the shape of the entire earth. NAD 27, the previous datum, used an ellipsoid (Clarke 1866) that was not a suitable world model, since it only "fit" North America, Canada and other portions of the earth (Doyle and Wade, 1987).

2.3.2 Readjustment

Also during this time, a readjustment of the entire horizontal network in the U.S. was underway. This readjustment, in which a least squares adjustment is applied to all original survey observations, was done to remove distortions to the network. These distortions came from several sources, including ground movements since the previous adjustment in 1927, accuracy deficiencies, and geometrically weak areas of the network. In addition, approximately 50,000 control stations, added since 1927, had not been included in the NAD 27 general adjustment. This resulted in unacceptable closures of subsequent surveys in certain areas of the country (North American Datum, 1971).

2.3.3 NAD 83 Benefits

The main result of the new datum is that surveys between control stations will now obtain better mathematical closure due to minimum distortion of the NGS network. Consistency with satellite-derived survey data is another desirable result, especially with GPS surveying being more commonplace in recent years (Doyle and Wade, 1987).

2.3.4 Datum Conversion

With the recent publication of NAD 83 coordinates, there is now no reason to reference new surveys to NAD 27. However, those who have computed previous surveys based on the NAD 27 may want to convert their coordinates to NAD 83 for consistency; in fact, this will be a necessity if local laws require subdivision or utility surveys to be tied to the state plane coordinate system. At the very least, NAD 27 and NAD 83 data mixed together in the same database will need to be tagged to distinguish one from another; this is merely an added code to the records.

To convert coordinates based on NAD 27, NGS suggests one of three methods. The first and best way is to recompute the survey from the original observations. NGS will compute, adjust, and publish such data if certain accuracy requirements are met. The second method utilizes a program that computes a least squares approximation provided there are at least four points having both NAD 27 and NAD 83 values. The third method is a rougher approximation which uses the average shift in latitude and longitude values for a given area.

The last two methods are the easiest to compute, but since they are only approximations, NGS will not publish the results. As a public service, NGS has published articles on the problem and also presents workshops to explain in detail the conversion methods (Doyle and Wade, 1987).

2.4 NGS HORIZONTAL DATA WITHIN VIRGINIA

There are approximately 7000 control stations in Virginia that NGS currently maintains. Until recently, a user requesting control information was limited to hardcopy station descriptions. Figure 1 is an example of a typical, computer-generated station description produced by NGS' mainframe system.

NGS now provides geodetic data in various computer-readable forms, either magnetic tape or floppy diskette. The information for each control station is available in two parts: positional and descriptive. The positional data, which contain the station coordinates and other quantitative information, are shown in Figure 2. The descriptive data are mostly qualitative, and, among other items, describes the physical location of the monument. Figure 3 illustrates a typical, computer-stored description.

Each record of positional data is 145 characters long, and a 360 Kb diskette can hold almost 2500 records. The average station description is 40 records (80 characters maximum), and a diskette can hold about 112 stations. For all the horizontal stations in Virginia, it takes three diskettes to contain the positional data, and about 65 diskettes for the descriptive information.

2.5 ACCESSING THE DATA

2.5.1 Automatic Mailing Service

NGS currently maintains an automatic mailing service in which subscribers purchase geodetic data for a specified area in the form of booklets. Data are generally distributed by

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US DEPARTMENT OF COMMERCE - NOAA          HORIZONTAL CONTROL DATA              QUAD N27081111  OSN 0001
NOS - NATIONAL GEODETIC SURVEY            NORTH AMERICAN DATUM 1927            CONTROL DIAGRAM NG 17-2
ROCKVILLE MD 20852 - JUL 1980             PROJECT ACCESSION NUMBER 03331       FL-OSCEOLA COUNTY

HORIZONTAL CONTROL STATION:  NITTAW
GEODETIC POSITION DATA-----------------------     STATION INFORMATION-------------------------------------------
                    DEG MIN SECONDS                  TYPE:  TRANSCONTINENTAL TRAVERSE
        LATITUDE:    27 58 20.05832N                 OBSERVATIONS BY US COAST AND GEODETIC SURVEY (NOW NOS) IN 1936
        LONGITUDE:   81 00 31.22568W                 ADJUSTED BY NATIONAL GEODETIC SURVEY IN 1937
        AZIMUTH 1:   73 33 06.5  FROM SOUTH          AZIMUTH REFERENCE OBJECT 1:  JACKSON 1936

        ELEVATION:     17.98 METERS                  ELEVATION DETERMINED BY DIFFERENTIAL LEVELING
                       59.0 FEET                        STATION IS ALSO A BENCH MARK
        GEOID HEIGHT:   6.5 METERS

STATE PLANE AND UNIVERSAL TRANSVERSE MERCATOR COORDINATE SYSTEMS-------------------------------------------------
                   X           Y        X/EASTING    Y/NORTHING   POINT SCALE  CONVERGENCE  GRID AZIMUTH 1  GRID AZIMUTH 2
 GRID  ZONE      FEET        FEET        METERS       METERS       FACTOR      DEG MIN SEC   DEG MIN SEC     DEG MIN SEC
FL-TM  E     497200.28  1322555.32    151546.949   403115.668   0.99994119    -0 00 14.6    73 33 21.1*
 UTM    17                            499146.935  3093955.555   0.99960001    -0 00 14.6   253 33 21.1*
 UTM    16                           1089850.248  3108454.982   1.00389721    +2 49 06.0   250 44 00.4*

                                                                  *CAUTION - ARC-TO-CHORD CORRECTION ASSUMED ZERO

STATION DESCRIPTION-------------------------------------------------------------------------------------------
ORGANIZATIONS MARK:  US COAST AND GEODETIC SURVEY (NOW NOS)                  HEIGHT OF TELESCOPE:    30 METERS
YEAR DESCRIBED:  1936    CHIEF OF PARTY:  RLP    REACHED BY:  CAR             PACK TIME:  00 HRS 00 MIN

CODE-- MARK-------- TYPE OF MARK---------------- SETTING/LANDMARK TYPE---------------------------- MAGNETIC PROPERTY
      SURFACE        TRIANG STA DISK       SET INTO THE TOP OF A SQUARE CONCRETE MONUMENT             UNKNOWN
D04   UNDERGROUND    SURVEY DISK           SET INTO THE TOP OF AN IRREGULAR MASS OF CONCRETE          UNKNOWN
D09   REFERENCE      SURVEY DISK           SET INTO THE TOP OF A SQUARE CONCRETE MONUMENT

 CODE------ REFERENCE OBJECT------- HEADING------------ DISTANCE----------- DIRECTION------ MAGNETIC PROPERTY
 D09    JACKSON                                                             000 00 00.0     UNKNOWN
 D09    NITTAW RM 2                              136.38 FEET                041 38 49       UNKNOWN
 D09    NITTAW AZ MK                      ESTIM APPROX 0.15 MI              078 35 00.7     UNKNOWN
 D09    NITTAW RM 1                              155.95 FEET                303 13 01       UNKNOWN

STATION IS ABOUT 12.5 MILES BY ROAD S BY E OF HOLOPAW, 6.7 MILES NORTHWARD OF KENANSVILLE, 3.6 MILES SOUTHWARD OF THE
ILLAHAW RAILROAD DEPOT, 1.5 MILES N OF THE NITTAW RAILROAD DEPOT, ON THE E SIDE OF STATE ROUTE 29, 0.18 MILE N OF A
CONCRETE CULVERT, AND 62 FEET E OF THE CENTER LINE OF THE ROAD.  MARK PROJECTS 3 INCHES.

SURFACE, UNDERGROUND, REFERENCE AND AZIMUTH MARKS ARE STANDARD BRONZE DISKS SET IN CONCRETE.

REFERENCE MARK NO. 1 IS SW OF THE STATION, ON THE FLORIDA EAST COAST RAILROAD RIGHT-OF-WAY, 34 FEET W OF THE CENTER LINE
OF THE ROAD, 9 FEET W OF THE FENCE LINE, AND 38 FEET E OF THE E RAIL OF RAILROAD TRACKS.

REFERENCE MARK NO. 2 IS NW OF THE STATION, 36 FEET W OF THE CENTER LINE OF THE ROAD, 10 FEET W OF THE FENCE LINE, ON THE
FLORIDA EAST COAST RAILROAD RIGHT-OF-WAY, AND 37 FEET E OF THE E RAIL OF RAILROAD TRACKS.

REFERENCE MARKS PROJECT 2 INCHES.

AZIMUTH MARK IS W OF N OF THE STATION, ON THE FLORIDA EAST COAST RAILROAD RIGHT-OF-WAY, 35 FEET W OF THE CENTER LINE OF
THE ROAD, 10 FEET W OF FENCE LINE, AND 37 FEET E OF THE E RAIL OF RAILROAD TRACKS.  MARK PROJECTS 3 INCHES.
```

Figure 1. Horizontal station description example

QIDQSN	STATION NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	NORTHING METERS*	EASTING METERS*	ZONE	CONVERGENCE	SCALE FACTOR	ELEV. (M)	GEOID HT(M)
370772140005	REEVES 1932	37 22 47.39167	077 09 59.14648	1116969.058	3618099.898	VA S	0 48 33.76	0.9999454	39 SC	-33.43
370761420039	REID VFC 1931	37 50 57.36594	076 19 30.37336	1170439.960	3691396.195	VA S	1 19 11.99	0.9999807	2 SC	-35.18
370764210014	REMLIK HALL WATER TANK	37 40 11.32178	076 36 13.02193	1149997.829	3667289.945	VA S	1 09 3.46	0.9999593		-34.96
370761440040	RENNIE 1955	37 57 21.15646	076 22 45.26167	1182161.424	3686367.137	VA S	1 17 13.71	0.9999980	6 SC	-34.92
370764330083	RESIDENT 1912	37 33 43.70378	076 57 15.14607	1137485.725	3636561.286	VA S	0 56 17.45	0.9999512	2 SC	-33.74
370774220007	REYNOLDS 1958	37 36 7.55105	077 31 6.34872	1141252.868	3586671.860	VA S	0 35 44.66	0.9999538	80.81	-32.31
370774220008	REYNOLDS 2	37 36 7.05545	077 31 6.20105	1141237.628	3586675.641	VA S	0 35 44.75	0.9999537	80.60	-32.31
370763210027	RICH	37 08 39.22731	076 31 29.16649	1091824.347	3675464.958	VA S	1 11 55.74	0.9999530	10.77	-35.72
370771220072	RICHARDS 1912	37 37 1.49252	077 05 58.25796	1143382.313	3623634.677	VA S	0 50 59.96	0.9999549	2 SC	-33.53
370763140017	RICHARDSON 2 1911	37 25 32.16494	076 43 24.14334	1122694.048	3657236.966	VA S	1 04 41.80	0.9999459	1 SC	-34.65
370763140018	RICHARDSON 3 VFC 1932	37 25 35.57675	076 43 27.11307	1122797.834	3657161.988	VA S	1 04 40.00	0.9999459	1 SC	-34.64
370761430019	RICHARDSON VFC 1931	37 52 1.69248	076 24 17.27031	1172264.114	3684340.124	VA S	1 16 17.87	0.9999834	1 SC	-34.94
370771330019	RICHMOND AMERICAN PAPER TANK	37 35 0.16345	077 24 42.25355	1139278.808	3596116.331	VA S	0 39 37.78	0.9999525		-32.42
370772440014	RICHMOND ARMY CMC N TANK	37 25 55.64654	077 27 2.54425	1122454.407	3592861.220	VA S	0 38 12.63	0.9999460		-32.36
370771330020	RICHMOND BARTON HEIGHTS BAP CH	37 34 1.85097	077 26 4.04951	1137458.333	3594129.960	VA S	0 38 48.13	0.9999515		-32.37
370771330021	RICHMOND BELLE ISLE WRNL MAST	37 31 43.40270	077 27 16.26170	1133170.639	3592405.293	VA S	0 38 4.31	0.9999493		-32.33
370772410021	RICHMOND BENCH MARK 39 1932	37 22 40.49203	077 19 15.80018	1110574.152	3604409.759	VA S	0 42 55.91	0.9999454	9.12	-32.78
370772420047	RICHMOND BENCH MARK 46 1932	37 21 2.14730	077 16 8.87643	1113601.393	3609047.463	VA S	0 44 49.36	0.9999454	7 SC	-33.03
370772410022	RICHMOND BENCH MARK 50 1932	37 22 42.68339	077 21 23.90498	1110601.151	3601110.050	VA S	0 41 34.52	0.9999454	13 SC	-32.64
370774220009	RICHMOND BON AIR NEW TANK	37 32 8.61400	077 33 33.11460	1133849.020	3582998.284	VA S	0 34 11.94	0.9999497		-32.27
370774220010	RICHMOND BON AIR OLD TANK	37 31 9.37110	077 33 4.17215	1132031.332	3583874.429	VA S	0 34 33.15	0.9999489		-32.27
370771330022	RICHMOND BR AND WILLIAMSON STK	37 33 24.83066	077 27 16.22779	1136297.326	3592371.497	VA S	0 38 4.33	0.9999508		-32.33
370771330023	RICHMOND BROOKS ROAD MUN TANK	37 35 19.22326	077 26 45.67367	1139832.005	3593081.962	VA S	0 38 22.87	0.9999528		-32.35
370771330024	RICHMOND BROOKS TRANSPORT TANK	37 34 4.72094	077 28 1.04598	1137515.174	3591258.142	VA S	0 37 37.13	0.9999515		-32.32
370771330049	RICHMOND CENTRAL NAT BANK VENT	37 32 38.50204	077 26 22.83459	1134883.785	3593697.874	VA S	0 38 36.73	0.9999501		-32.35
370771330050	RICHMOND CENTRAL NATL BK FLAG	37 32 38.56011	077 26 22.77938	1134885.590	3593699.209	VA S	0 38 36.77	0.9999501		-32.35
370771330025	RICHMOND CHEMICAL WORKS TANK	37 30 50.06015	077 24 55.94591	1131565.152	3595868.993	VA S	0 39 29.47	0.9999487		-32.40
370771330026	RICHMOND CITY HALL CLOCKTOWER	37 32 23.87052	077 25 58.43064	1134439.497	3594301.978	VA S	0 38 51.54	0.9999499		-32.37

Figure 2. Positional data: A computer file containing 28 records of data

```
000010*ZJ*HZTLDESCNGS    NATIONAL GEODETIC SURVEY                                   19820429
000020*10*083D                          *11*N370802120001      *12*D09           *13*D04
000030*14*BEVERLY                                              *15*VA/ROANOKE
000040*20*1/CGS                         *21*1958JCC            *22*              *23*1
000050*30*      FARM                                                              00000000
000060*30*D09 BEVERLY AZ MK                           SSE                A0.2 MI  09452394
000070*30*D09 BEVERLY RM 2                            W    130.1839.678           2224530
000080*30*      LEWIS MOUNTAIN LOOKOUT TOWER                                      26856220
000090*30*D09 BEVERLY RM 1                            NNW 62.35 19.004            3245348
000100*30*$$
000110*40*STATION IS LOCATED IN A NEW HOUSING DEVELOPMENT ABOUT 3
000120*40*MILES WEST OF SALEM (BEVERLY HEIGHT HOUSING DEVELOPMENT)
000130*40*AND IS ABOUT 0.4 MILE NORTH OF U.S. HIGHWAYS 11 AND 460.
000140*40*MR. C.C. KEESLING IS THE PRESIDENT OF THE HOUSING DEVELOPMENT.
000150*40*$
000160*40*STATION, STAMPED BEVERLY 1958, SET FLUSH WITH THE SURFACE
000170*40*OF THE GROUND, IT IS 196 FEET NORTHWEST OF THE CENTERLINE
000180*40*OF SURFACE ROAD, 106 FEET NORTHEAST OF THE CENTERLINE OF
000190*40*SURFACE STREET AND 8.8 FEET NORTH-NORTHEAST OF POWER POLE
000200*40*10436.
000210*40*$
000220*40*R.M. 1, STAMPED BEVERLY NO 1 1958, SET FLUSH WITH THE SURFACE
000230*40*OF THE GROUND, IT IS 119 FEET SOUTHWEST OF POWER POLE 1043A,
000240*40*70 FEET NORTH-NORTHWEST OF POWER POLE 10436 AND IS ABOUT 1
000250*40*FOOT ABOVE THE ELEVATION OF THE STATION.
000260*40*$
000270*40*R.M. 2, STAMPED BEVERLY NO 2 1958, SET FLUSH WITH THE SURFACE
000280*40*OF THE GROUND, IT IS 32 FEET NORTHEAST OF THE CENTERLINE
000290*40*OF SURFACED STREET, 3 FEET ABOVE THE ELEVATION OF THE STREET
000300*40*AND 1 FOOT ABOVE THE ELEVATION OF THE STATION.
000310*40*$
000320*40*AZIMUTH MARK, STAMPED BEVERLY 1958, SET FLUSH WITH THE SURFACE
000330*40*OF THE GROUND, IT IS SET IN A TRIANGLE FORMED BY THE ROADS,
000340*40*39 FEET NORTH OF THE CENTERLINE OF THE ROAD, 33 FEET EAST
000350*40*OF THE CENTERLINE OF THE ROAD AND 28 FEET WEST OF THE CENTERLINE
000360*40*OF THE ROAD.
000370*40*$
000380*40*TO REACH THE STATION FROM THE U.S. POST OFFICE IN SALEM, GO
000390*40*WEST ON U.S. HIGHWAYS 11 AND 460 FOR 3.0 MILES.  TURN RIGHT,
000400*40*GO NORTH PAST SIGN READING BEVERLY HEIGHTS FOR 0.15 MILE
000410*40*TO THE AZIMUTH MARK AT A Y-FORK.  KEEP LEFT FORK AND GO
000420*40*NORTH FOR 0.25 MILE TO A CROSS STREET.  CONTINUE STRAIGHT
000430*40*AHEAD FOR 0.05 MILE TO THE STATION ON THE RIGHT.
000440*40*$
000450*40*HEIGHT OF LIGHT ABOVE STATION MARK 1 METERS.
000460*40*$$
```

Figure 3. Description information (unformatted, as stored in computer)

30 minute quadrangles or smaller, depending on the density of control in the area. After the initial purchase, users automatically receive data updates if there has been recent NGS activity in their area. Figure 4 is a form used to execute this service (Spencer and Horn, 1981).

2.5.2 Questionnaire

In order to discover improved methods of data distribution, the type of user data requests must first be determined. A preliminary questionnaire sent out late in 1986 to current or potential users of geodetic data (mostly land surveying firms) resulted in very limited feedback. Of questionnaires sent to 25 firms, only 12 were returned. It did show, however, that the type of computer hardware owned by these firms is varied and that it cannot be assumed that most firms possess IBM or IBM compatible machines. A majority of respondants did not maintain any sort of a survey database, but there were a few who stated a desire for data in digital form. One firm indicated a need to obtain all available data for a given area through only one source. The quantity of data needed by users varied; about half needed localized data for city, county, or by USGS quad sheet, and the rest expressed a desire to have data for the entire state.

NOAA FORM 29-3
(8-81)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

CUSTOMER ID NUMBER
(For Agency Use)

GEODETIC CONTROL DATA
AUTOMATIC MAILING SERVICE AGREEMENT

INSTRUCTIONS – Complete items 1 – 6 and return to the National Geodetic Information Center, OA/C18, National Geodetic Survey, National Ocean Survey, NOAA, Rockville, Maryland 20852.

1. APPLICANT'S NAME AND ADDRESS

TELEPHONE NO. AND AREA CODE

2. Indicate below the types of data desired. If you require more than one copy of any item checked, indicate the number of copies needed.

✓	GEODETIC CONTROL DATA	NO. OF COPIES	✓	GEODETIC CONTROL DATA	NO. OF COPIES
	Horizontal Data – 30' quadrangle booklets			Vertical Data – 30' quadrangle booklets (or level line format in certain areas)	
	Horizontal Data Projects (Manuscript form)			Vertical Data Projects (Manuscript form)	
	Horizontal Control State Diagrams			Vertical Control State Diagrams	
	Geodetic Control Numbered Charts or City Insets			Geodetic Control Diagrams (1° x 2°)	

3. INDICATE AREA TO BE SERVICED BY PROVIDING REQUIREMENTS LIST, A DETAILED DESCRIPTION, OR A SMALL ATTACHED MAP *(e.g., states, counties, 30' quadrangle areas or latitude and longitude boundaries).*

4. ☐ Check here if the applicant desires an initial shipment of above requested data. The purpose of this shipment is to establish an initial file for new subscribers.

5. AGREEMENT – The applicant agrees to accept all requested geodetic control data and to pay for the same upon receipt. Prices will be based on the current price list.

6. AUTHORIZED OFFICIAL *(Applicant)*	NAME	TITLE	
	SIGNATURE		DATE
7. ACCEPTED BY NATIONAL GEODETIC SURVEY	NAME	TITLE Director, National Geodetic Information Center, National Geodetic Survey, NOS, NOAA	
	SIGNATURE		DATE

Figure 4. Automatic mailing service agreement

2.5.3 Computer Database

The above reveals a need for a subsequent, more detailed questionnaire sent to a wider range of users, including those in public service (e.g. county engineering departments). This questionnaire did show, however, that with the availability of microcomputers, the average user has the capability of maintaining his own database of survey control data. With the proper software and local support, a user need not make continual requests for data; perhaps one request could be made for data covering a certain area and all of it be stored on one floppy diskette. This database could not only be searched, but could be added to, deleted from, or otherwise updated as needed.

2.5.4 Computational Software

With additional software, certain surveying computations may be performed in conjuction with the database. This could include geodetic computations, coordinate transformations, adjustments, or other geometric calculations. Such software would be integrated into the database so that many operations would be transparent to the user. At the same time, however, the database and its associated retrieval software should be able to operate independently of the computational programs.

2.6 A STATE DISTRIBUTION OFFICE

There are several sources of control data, including, but not limited to, NGS, USGS, Army Corps of Engineers, state highway departments, and city and county governments. Not all these agencies funnel their data through NGS. There is, therefore, no one source of control data for any given area in the state.

A local office can not only maintain NGS control data for their state, but can also collect and disseminate data from many other sources. In addition to serving the user community more efficiently, a state office would relieve the NGS (and other agencies) of individual data requests.

A possible scenario would be one in which NGS distributes its data to each state, which, in turn, becomes responsible for distribution to local users. These state agencies might add their own survey control to the database (such as that obtained through their respective highway departments) and would answer questions and otherwise provide needed support. Figure 5 is an example of a simplified flow of data between various agencies and ultimately to the end-user.

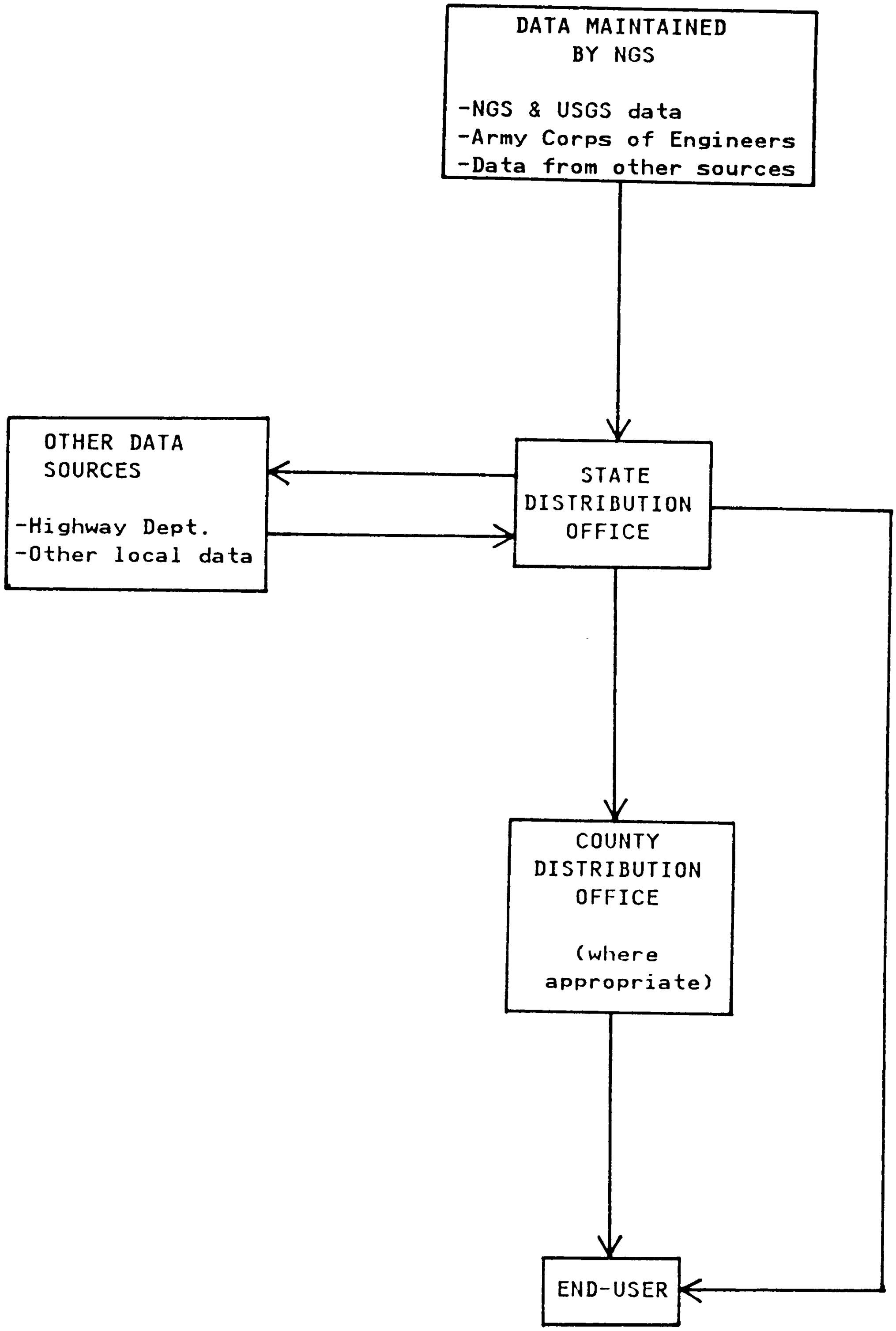

Figure 5. Hierarchy of data distribution

2.6.1 Division of Mapping, Surveying, and Land Information Systems

The Office of State Coordinator for Mapping, Surveying, and Land Information Systems was created in 1987 by the General Assembly of Virginia. The functions of State Coordinator are summarized as follows (State Coordinator, 1986):

1. Provide expert technical advice to local governments Assistance is given to local officials in improving land records, development of mapping specifications, quality control of base maps, etc.

2. Identify and develop needed model data and data quality standards Establishment of new standards and revision, if necessary, of old standards in order to promote a uniformity of data formats and quality standards. This is to ensure that sharing of data in land information systems is done efficiently and effectively.

3. Develop and administer training programs Administer training to non-technicians in the operation and maintenance of modern land information systems.

4. Identify duplication of records and identify needed improvements in state mapping services Assumes responsi-

bility for data verification and overall coordination of existing state mapping agencies.

5. Provide information on the availablity of maps, photography, and other related data Acts as a central depository for mapping and surveying data already collected by federal, state, and local agencies. This function depends on the availablity of certain personnel.

With special assistance, additional services concerning geodetic data and access to federal and state data banks could be provided. NGS currently offers a program which furnishes a geodetic advisor to an interested state by cooperative agreement on a cost-sharing basis. Coordination of this program with the newly-created mapping office would greatly facilitate data distribution in Virginia.

CHAPTER III

CONTROL STATION DATABASE

3.1 DATA CHARACTERISTICS

Survey control data must necessarily be in digital form in order to have access to it through computer software. What media data are stored on and how it is organized must first be known before any database software can be designed. The National Geodetic Survey maintains the largest national repository of geodetic survey data and has recently made its horizontal data available on floppy diskettes. The following discussion, therefore, centers on NGS data and its two basic components: positional and descriptive.

3.1.1 Positional Data

The positional data are mostly numeric, containing the station coordinates, elevation, and other computed values. More specifically, referring back to Figure 2, each computer record is comprised of eleven fields.[1] The first two, the

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[1] NGS has indicated that "customized" formats will be available within the next one to two years as their own mainframe database becomes operational. At that time, a user may be able to specify whatever information he desires on each record (Doyle, 1987).

QIDQSN and station name, are both unique station identifiers. The remaining fields contain the geographic and plane coordinates of the station and other related data.

3.1.1.1 QIDQSN

The QIDQSN is a 12-digit number made up of two different parts which together form a unique identifier for each station. They are the QID, or Quad Identifier, and the QSN, or Quad Station Number (Input Formats, 1980).

Quad Identifier: The primary indexing system adopted by NGS for all horizontal (and vertical) control stations is based on 1 X 1 degree "quads" defined by integer-degree latitude and longitude gridlines, and on the successive quadrantal subdivision of the basic 1 X 1 quads into 30 X 30 minute quads, 15 X 15 minute quads, and 7.5 X 7.5 minute quads accomplished by halving of the gridline interval. The quad identifier, or QID, is an eight-character symbol coded as LLWWWABC and is described in Figure 6.

Quad Station Number: To distinguish among horizontal and vertical control stations which share the same quad identifier, every station is assigned a sequential quad station number (QSN) which is unique within the respective quad. This is a four-digit number starting with 0001 (0001, 0002,

QID = LLWWWABC

LL - Latitude of SE corner of the 1 X 1 degree quad

WWW - West longitude of SE corner of the 1 X 1 quad

A - 30 minute subdivision indicator (1,2,3, or 4)*

B - 15 minute subdivision indicator (1,2,3, or 4)*

C - 7 1/2 minute subdivision indicator (1,2,3, or 4)*

* codes for subquads, where 1=NE, 2=SE, 3=SW, 4=NW

Figure 6. Quad Identifier

0003, etc.) given to each station within the same 7.5 minute quad.

3.1.1.2 Station name

The station name also uniquely identifies a control station. It is a maximum of 30 characters long and sometimes, but not always, indicates a specific area or landmark (e.g."RICHMOND CITY HALL CLOCKTOWER").

3.1.1.3 Latitude/Longitude

These next two fields are the station's geographic coordinates and are comprised of three subfields each: degrees, minutes, and seconds.

3.1.1.4 State Plane Coordinates

The next five fields contain information relating to the plane coordinates that are computed from geographic coordinates. The northing and easting coordinates are given in meters,[2] and the zone indicates the state, and subdivision thereof, within which the coordinates are valid. The con-

---

[2] NAD 83 data is published in meters in an effort to be consistent with the international metric system. Previously, NAD 27 data was published in feet.

vergence (or mapping angle) and scale factor for each station is also given.

3.1.1.5 Elevation/Geoid Height

The elevation is given in meters and is the height of the station above the geoid. These may be approximate or interpolated values; an "SC" as part of this field indicates a scaled elevation as estimated from a topographic map. The geoid height is the height (in meters) of the geoid at that point above or below the reference ellipsoid; these values are usually interpolated from other data.

3.1.2 Descriptive Data

The descriptive data, an example of which was shown in Figure 3, mostly contains the directions to the monument. These detailed descriptions include ties to nearby reference monuments, if any, and also lists the county in which the monument is located. Also included are the station name and QIDQSN, both of which are key fields that link the positional and descriptive files together. Other unrelated information is included, such as date of monument setting and/or recovery, surveyor, and other codes.

The amount and type of information varies for each station. Whatever data are present, however, is organized and coded in such a way that easily permits extraction of any single data element via a computer program (Input Formats, 1980). NGS has written computer programs in PL1 that will reformat descriptive data into an easy-to-read form such as that shown in Figure 1 (Geodetic Software, 1985). Other routines could be written for specific tasks; for example, merging data elements from a descriptive data file with those from a positional data file could be easily performed.

3.2 DATABASE INTERACTION

3.2.1 Database Definition and Requirements

A computer database may be defined as "a collection of interrelated information, usually stored on some form of mass-storage system such as magnetic tape or disk" (Burrough, 1986). Database software must permit data entry, extraction, and editing with minimal effort. Data extraction is simply searching the data for desired information and reporting the results to the user.

At a minimum, a positional database system must be able to search for control stations given either a station name or an area within which to look. The user should then have the option to print the descriptions of any or all stations found in the search. The descriptive data would be in a separate database and would normally be searched by QIDQSN or station name.

3.2.1.1 Search by Area

A typical request of a positional database would be to find those control stations which lie in a certain area. There are at least three possible methods to search for points. The first is to identify a quadrangle (rectangular[3] block) within which to look. The user would then specify latitude and longitude values for the lower-right and upper-left corners of this quadrangle. These might be approximate values as obtained from a U.S. Geological Survey topographical map.

A variation on the above would be a "point and radius" method in which all stations within a given circle are located. In this case, the latitude and longitude of a single point, and a radius in miles (or other linear dimension) are the required search parameters.

The third method utilizes the QID portion of the QIDQSN field (the first field in each record - see Figure 2). As described in the previous section, each station is indexed into 7.5 minute square blocks. The QID, then, may be used

[3] It should be noted that intersecting lines of latitude and longitude only approximates a rectangle; for larger areas, this figure approaches the shape of a trapezoid.

as an alternative to the quadrangle method, although it is a more cumbersome scheme to follow. All three methods are shown in Figure 7.

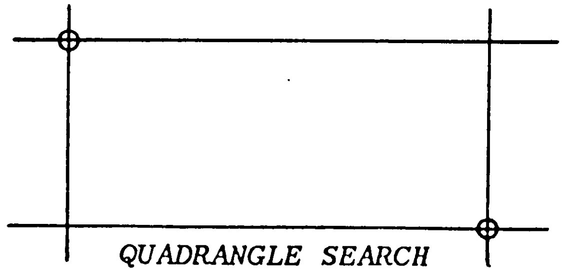
The first two search methods are identical to some of the data retrieval techniques expected of a typical GIS (Dangermond, 1984). "Query generation windows" is a term which relates to the ability of a GIS to generate polygons of various shapes (including squares and circles) from the spatial information contained in a GIS database. One of the functions of these windows is the retrieval of points within polygons. Chapter 5 explores the potential of using a GIS for survey data retrieval and related operations.

3.2.2 Flexibility

Software flexibility as defined here is the capability of not only searching through a large amount of data, but also updating with the user's own control points. Along with this is the option to edit the data in different ways, including adding or deleting records, and changing the fields within records (changing a station name, for example).

A protection flag may be added to data to prevent accidental alteration. Such a flag is important insurance for those stations that are considered fixed and/or external to a specific project. NGS data and other geodetic control are

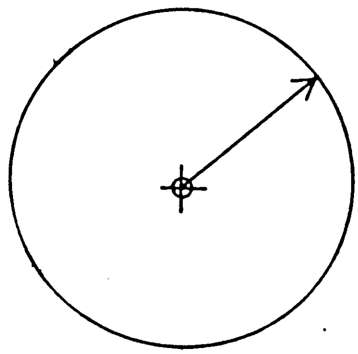
METHOD 1



QUADRANGLE SEARCH

Specify the geographic coordinates of the selected points

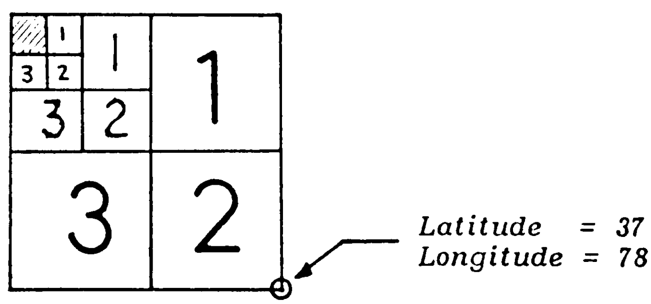
METHOD 2



POINT & RADIUS

Specify geographic coordinates of center point, and radius as a linear dimension (e.g. miles)

METHOD 3



QID

The extreme upper left block (7.5' X 7.5') is coded as follows: **37078444**

Figure 7. Positional database searching by area: Three possible methods of locating control stations

examples of such permanent data, as well as any user-established control that is deemed important.

An extension of individual record protection are the concepts of "master" and "transaction" files. In this situation, the master file contains all original data and/or any other permanent data that will not be changed. Normal data queries are still possible and additional data may be added, but no other editing is permitted. The transaction file, on the other hand, is an editable copy of the master; any data that is in a state of flux or uncertainty will be dealt with here. Only when the data has been certified as "clean" will it be transferred to the master file.

Adding records may be done in batch mode by specifying an input file name, or interactively through the terminal. The batch mode input may be accompanied by routines to reformat and verify data before entry into the database. This can allow for data to be imported from a variety of sources with a minimum of trouble. Interactive input would only be used for entering small amounts of data.

Checking for duplicate records may also be a desired feature: except where comparison of two or more surveys are required (e.g. deformation surveys), all duplications will need to be easily eliminated.

An entire program run by menus, in order to have all editing and updating functions directly at hand, is preferred so that continual reference to an operating manual need not be necessary. At the same time, though, a flexible program could give the user the option of using no menus at all (or limited menus) for those already familiar with the database. This option would be in the form of an interactive prompt at the beginning of the program.

3.2.3 Data Volume

The main drawback to a state-wide database operated exclusively by the end-user is the sheer volume of descriptive data. As mentioned earlier, it takes about 65 diskettes to contain all of Virginia's descriptions. An alternative would be to break down the data into smaller units (such as by county), or continue with the current hardcopy scheme. This problem is reserved for future research as mentioned in Chapter 5, with positional databases being the main focus of this thesis.

3.3 DATABASE SOFTWARE

Software to manipulate the database may be purchased commercially or developed through a programming language such as Fortran. There are advantages and disadvantages of both.

3.3.1 Noncommercial Software: Fortran Programming

Some limited programming was done on an IBM PC using MS Fortran. Several levels of menus were used to search test data based on area and write the results to a file. Figure 8 shows the general scheme of these menus and describes what the various options do.

Additional menus could be used for updating and other functions. This particular program read all values into arrays before any searching was performed. Reading the data was slow, but the searching time was very quick: a few seconds for 1000 records. The obvious limitation here is that the size of the arrays dictates the size of the database. A better program would use a direct access read (instead of sequential access) to process data. Each search would be slower,[4] but the size of the database would be dependent on the capacity of the storage media and not the program itself. Also, updating the data would be much easier using a direct read. To speed up the reading process, the database could be converted to an unformatted or binary file. This conversion has been shown to cut the read-time approximately in half.

---

[4] Informal tests indicated about two minutes of searching time per 1000 records.

```
---------------------------------------------
MAIN MENU - Enter number:

  1. Exit Program
  2. Read in data
  3. Search for points
  4. Write found points to a file
---------------------------------------------

   if "1", program exits
   if "2", program prompts for a file name
   if "3", program prompts with a menu:

         ------------------------------------
         Enter number:

           1. Search by bounding rectangle
           2. Search by point and radius
         ------------------------------------

             if "1", program prompts for latitude, longitude boundaries
             if "2", program prompts for point value and radius (miles)

             --> program reports search results and returns to main menu


   if "4", program prompts with a menu:

         ------------------------------------
         Enter number:

           1. Return to main menu
           2. Write unformatted data (input for GPPC83)
           3. Write formatted data
         ------------------------------------

             if "1", program returns to main menu
             if "2", program writes data to a file in the correct
                     format for a state plane program
             if "3", program writes data to a file in an easy to
                     read format

             --> program automatically returns to the main menu if:
                   data has not been read in yet; or,
                   data has not been searched yet; or,
                   no points were found in the last search.

             --> when writing data, program gives a choice of either:
                   appending to a previously written file; or,
                   writing to a new file.
```

Figure 8. Fortran search program: menu prompts as would appear on screen

Software written at Virginia Tech can be tailor-made to the problem at hand. It can be promptly modified for the better when suggestions and experience warrant it. Source code can also be provided so that a user can alter it for his own purposes. Several versions can even be written: these can range from simple querying of NGS-only data, to a database capable of accepting the user's own points, to one that is fully integrated with computational software. To get the most out of such a Fortran (or other) program, it would need to be written by an experienced programmer familiar with data structures and file management.

3.3.2 Commercial Software: dBase III

The dBase program was investigated as an alternative approach. It has many searching, sorting, and updating functions, and a typical search is performed much quicker than can ordinarily be programmed. It is advertised as a "relational" program where records may be searched using any combination of parameters.[5] For example, locating only those stations within a specified area that are of a certain accuracy (if the data file contained accuracy information) would

---

[5] Or called Boolean logic: this is the use of operators such as AND, OR, etc. in combination with arithmetic operators such as EQUAL TO, LESS THAN, etc. (Burrough, 1986).

be an easy task for dBase to perform. Unless such a search combination is forseen in advance and preprogrammed, Fortran and other conventional languages cannot be used this way.

Initiating a casual search may require a lengthy command. For example, Figure 9 is a query to search for all stations within a given quadrangle. If the command is misspelled, or if additional searches are required, these commands can become very tedious. Fortunately, dBase has its own programming language that can be used to avoid repetitous commands. Figures 10 through 12 illustrates a short program written to search for stations by area or name through a simple menu. In fact, a whole series of programs and menus may be written to aid in various searches and updating. These could be written by someone with average programming experience.

3.3.2.1 dBase Evaluation

There are many features which make dBase a desirable product. Records may be guarded against accidental alteration using a special protection function, and printed reports may be generated in a user-designed format. Search times are quicker: a test file of 1000 records took slightly less than a minute to search through, about half that required for a similar Fortran search. Data may be edited, added to, sorted, or otherwise manipulated in various ways, most of which can be programmed for quick use. However, this

```
DISPLAY NAME, LATDEG, LATMIN, LONDEG, LONMIN FOR;

((LATDEG+(latmin/100)+(latsec/10000)) >= 37.0000;

.and.(LATDEG+(latmin/100)+(latsec/10000)) <= 38.0000);

.and.((LONDEG+(lonmin/100)+(lonsec/10000)) >= 77.0000;

.and.(LONDEG+(lonmin/100)+(lonsec/10000)) <= 78.0000)
```

This will display all points between 37 and 38 degrees of latitude, and between 77 and 78 degrees of longitude.

The station names of all found points are displayed along with their respective degrees and minutes of latitude and longitude (LATDEG, LATMIN, LONDEG, LONMIN are the names of these fields in the database).

Figure 9. dBase search commands: An example illustrating a search for stations within a quadrangle defined by latitude, longitude values

MENU

```
? '    '
? '    '
? '      1.  SEARCH BY AREA'
? '      2.  SEARCH BY NAME'
? '      3.  QUIT'
? '    '
? '    '
? '      Pick a number...'
WAIT ' ' TO CHOICE
DO CASE
   CASE CHOICE = '1'
     DO AREA
   CASE CHOICE = '2'
     DO NAME
   CASE CHOICE = '3'
     CLEAR
     EXIT
ENDCASE CHOICE
```

AREA SEARCH PROGRAM

```
? 'Enter values as DD.mmss (deg, min, sec)...'
?  '    '
?  '    '
INPUT "Enter lower right latitude: " TO lat1
INPUT "Enter lower right longitude: " TO lon1
INPUT "Enter upper left latitude: " TO lat2
INPUT "Enter upper left longitude: " TO lon2
DISPLAY NAME, LATDEG, LATMIN, LONDEG, LONMIN FOR;
((LATDEG+(latmin/100)+(latsec/10000)) >= lat1;
.and.(LATDEG+(latmin/100)+(latsec/10000)) <= lat2);
.and.((LONDEG+(lonmin/100)+(lonsec/10000)) >= lon1;
.and.(LONDEG+(lonmin/100)+(lonsec/10000)) <= lon2)
```

NAME SEARCH PROGRAM

```
INPUT "Enter name (must be in 'quotes'): " TO NME
DISPLAY NAME, LATDEG, LATMIN, LONDEG, LONMIN FOR;
 NME $ UPPER(NAME)
```

Figure 10. Programmed dBase search: Short program written to minimize the effort to do a quadrangle search

```
--------------------------
      1.  SEARCH BY AREA
      2.  SEARCH BY NAME
      3.  QUIT
--------------------------

            if "1", then program prompts with:

                    ---------------------------------------------
                      Enter values as DD.mmss (deg, min, sec)...

                      Enter lower right latitude:
                      Enter lower right longitude:
                      Enter upper left latitude:
                      Enter upper left longitude:
                    ---------------------------------------------

                             if any are found, then the station name,
                             latitude and longitude are displayed (degrees
                             and minutes)

            if "2", then program prompts with:

                    ---------------------------------------------
                      Enter name (must be in 'quotes'):
                    ---------------------------------------------

                             if found, then the station name, latitude,
                             and longitude are displayed (degrees and
                             minutes

            if "3", then program exits program and returns to normal
                    dBase enviroment
```

Figure 11. Programmed dBase search (continued): Program prompts as seen on the screen

```
     1.  SEARCH BY AREA
     2.  SEARCH BY NAME
     3.  QUIT

     Pick a number...1

Enter values as DD.mmss (deg, min, sec)...


Enter lower right latitude: 36.3200
Enter lower right longitude: 75.5200
Enter upper left latitude: 36.3500
Enter upper left longitude: 75.5900

Record#  NAME                            LATDEG LATMIN LONDEG LONMIN
      3  CAPE D 1922                         36     32     75     52
      4  OLD CG STA 166 CUPOLA               36     32     75     52
      5  OLD CG STA 166 FLAGPOLE             36     32     75     52
      6  OLD CG STA 166 MON NE COR 1922      36     32     75     52
      8  BOUNDARY MONUMENT 1 1934            36     33     75     52
      9  BOUNDARY MONUMENT 2 1934            36     33     75     55
     10  CALVIN 1934                         36     33     75     55
     16  COREYS LOOKOUT TOWER                36     32     75     57
     22  NORTH END 2 1934                    36     34     75     55
```

```
     1.  SEARCH BY AREA
     2.  SEARCH BY NAME
     3.  QUIT

     Pick a number...2

Enter name (must be in 'quotes'): 'OLD'

Record#  NAME                            LATDEG LATMIN LONDEG LONMIN
      4  OLD CG STA 166 CUPOLA               36     32     75     52
      5  OLD CG STA 166 FLAGPOLE             36     32     75     52
      6  OLD CG STA 166 MON NE COR 1922      36     32     75     52
     74  VIRGINIA BEACH OLD WIRELESS TR      36     50     75     58
     95  CAPE HENRY LIGHTHOUSE OLD           36     55     76      0
    159  OLD HOUSE CHIMNEY                   36     49     76     12
    287  OLD 1931                            36     33     76      5
    424  OLD PT COMFORT FORT WOOL FLAG       36     59     76     18
```

Notice that in the name search, only a portion of the correct name may be specified, and all stations containing that specific "character string" are listed.

Note: Due to limited space, only the degrees and minutes are listed

Figure 12. Programmed dBase search (continued): Example area and name search

programming language has its limits and not every dBase command can be programmed (or programmed as desired). An experienced dBase programmer can probably find ways around most problems, but may make the resulting program harder to follow than one written entirely in a familiar language such as Fortran. This is a common disadvantage of most commercial software: desired features must be built around what is essentially a fixed system.

Cost is another issue. Database software written at Virginia Tech would become public domain property and would be available at a nominal price. dBase III, on the other hand, currently retails for several hundred dollars. With many potential users being small firms who use national control data only occasionally, this investment is not justified. Even those who already possess dBase for other uses (business records, for example) may find it inconvenient to continually move the program diskette from department to department: dBase is one of many copy-protected programs that prevents back-up copies from being made.

3.4 OPTIONAL HARDWARE: CD ROM TECHNOLOGY

The recent technology of compact laser disks (CD ROMs) holds promise for storing and retrieving large amounts of data. Currently, a single compact disk can hold about 600 Mb of data (equal to about 1500 floppies), more than enough space for all the positional and descriptive information for the state of Virginia. A drawback of this system is that it is essentially a read-only medium, and the user cannot store his own files on the disk; only a few sources produce CD ROMs and these are in the form of ready-to-use software such as encyclopedias and telephone directories (Reed, 1987). However, disks called "WORM" (write-once, read many times) drives enable users to write their own files.

Software can be written for compact disks, and some commercial programs will work on them as well. The Computer Science Department at Virginia Tech is now undergoing research of CD ROMs with large data files in conjuction with the Geodetic Engineering Division. Positional data for the entire state of Virginia and a portion of descriptive data is being written on compact disks for evaluation in later studies.

A system using CD ROMs, then, might be more applicable to a state or county agency who, in turn, would distribute either printouts of data or floppy diskettes to individual users. Such an agency might receive periodic updates (perhaps yearly) from NGS and other sources for them to encode on their WORM disks.

CHAPTER IV

INTEGRATED SOFTWARE SYSTEM

In addition to database management, an ideal software system might have several surveying computational programs interfaced with it. Any program that utilizes coordinates, either as input or output, may be linked to the database. Such automated data flow would, in many cases, be quicker and easier to use, and would also reduce transcribing errors.

For example, Figure 13 shows a flowchart in which a simple plane inverse might be accomplished. Note that either station names or record numbers may be used to find the correct coordinates. Record numbers could be included as part of the information found during a previous database search. Figure 14 illustrates how a program which outputs coordinates (a traverse) might store those values into the database.

Programs which use coordinates as input may operate either with batch input, where the station names or record numbers of needed coordinates are in a file, or interactively through screen prompts. Programs that output coordinates may have codes, dates, or other information attached to them before insertion into the database. For example, a code may be attached to traverse data to signify raw, unadjusted coordinates. A routine could also be added to search for duplicate station names and write over those records if desired. Du-

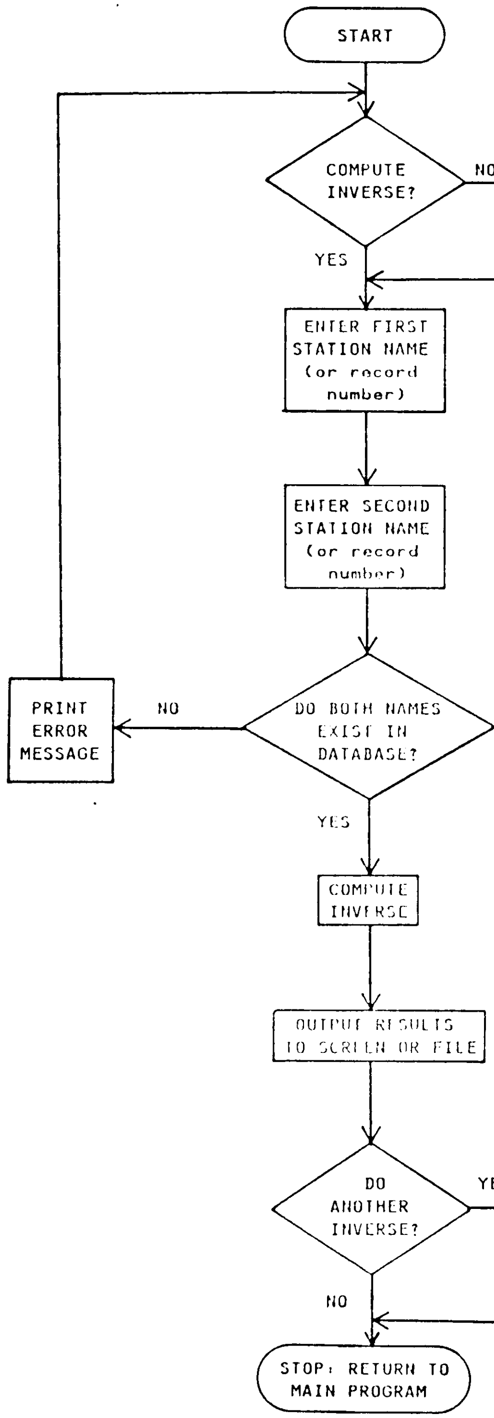


Figure 13. Plane inverse flowchart: An example illustrating an interactive program that utilizes the database for input values

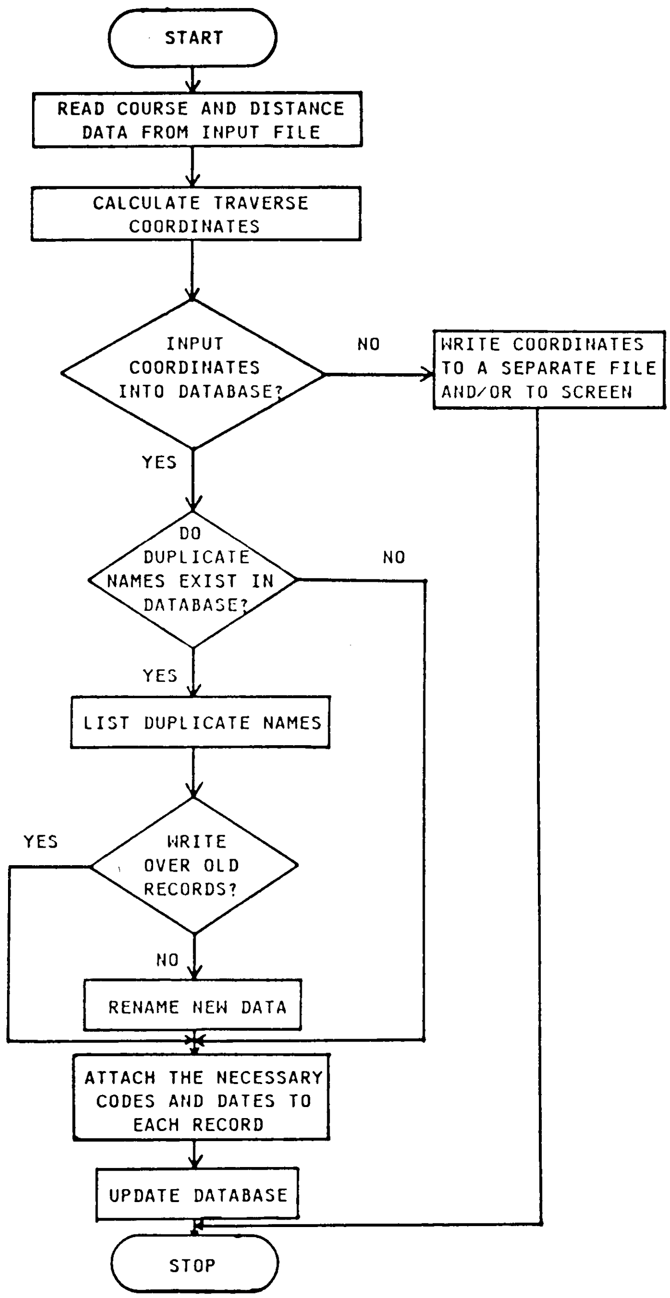


Figure 14. Traverse flowchart: An example illustrating a program updating the database with output coordinates

plicate records could also be retained in special instances such as deformation surveys. In this case, dates or additional codes may distinguish one station from another.

A package of survey routines could be linked to the database and accessed through menus and other prompts. NGS now has, or is in the process of, writing geodetic software that will operate on the North American Datum of 1983 (NAD 83). These are state plane coordinate and UTM conversions, and forward and inverse ellipsoid routines. In addition, ADJUST, a horizontal least squares program, will be available for microcomputers in the near future. Virginia Tech also has a variety of software including coordinate transformations, an adjustment program, plotting routines, and several photogrammetric programs. Some of these are currently on the IBM mainframe, but with minor modification can be made microcomputer ready. Table 1 summarizes available software and their current status.

Table 1 (Part 1 of 3). Software summary

Program	**Description**	**Source**
GPPCGP	Computes state plane coordinates from geodetic positions or vice versa. Utilizes NAD 27 data (Clarke 1866 ellipsoid). **Mainframe**	NGS
DIRECT	Computes the geodetic position of a station given the azimuth and distance from another station. Utilizes NAD 27 data. **Mainframe**	NGS
INVERS	Computes the distance between two stations and the forward and back azimuths, given the geodetic positions of both stations. Utilizes NAD 27 data. **Mainframe**	NGS
UTMDIR/ UTMINV	Equivalent to GPPCGP, except it is for the Universal Tranvserse Mercator (UTM) system. UTMDIR: geodetic to plane. UTMINV: plane to geodetic. Utilizes NAD 27 data. **Mainframe**	NGS
GPPC83	Geodetic to state plane. Utilizes NAD 83 data (GRS 80 ellipsoid). **Microcomputer**	NGS
FORWARD/ INVERSE	Equivalent to DIRECT and INVERS, except runs on IBM PC. Uses International, Clarke 1866, WGS 72, GRS 80 ellipsoids. **Microcomputer**	NGS

Table 1 (Part 2 of 3). Software summary

Program	Description	Source
LEFTI	Least squares transformation package to convert NAD 27 data to NAD 83 (see Chapter 5). **Mainframe and microcomputer.**	NGS
ADJUST	Adjustment. Adjusts classical survey networks and/or GPS observations. **Mainframe and microcomputer.**	NGS
CTRANS	Performs affine, two-dimensional, and three-dimensional least squares coordinate transformations. **Mainframe.**	VA Tech
TRANSCOR	Several routines to transform between geographic coordinates, geocentric space coordinates, and local space coordinates. Uses Clarke 1866 ellipsoid parameters. **Mainframe**	VA Tech
MTEN	Checks and formats field survey data. Documents observational and descriptive data into a format acceptable by NGS. **Microcomputer**	NGS
HPA	Adjustment. Adjusts typical survey networks and generates AUTOCAD plot files. **Mainframe and microcomputer.**	VA Tech

Table 1 (Part 3 of 3). Software summary

Program	**Description**	**Source**
MTENHPA	Formats MTEN output into a form ready for direct input into HPA. **Mainframe**	VA Tech
Under development	State plane to geodetic for NAD 83. **Mainframe and microcomputer.**	NGS
Under development	UTM software for processing data relative to NAD 83. **Mainframe and microcomputer.**	NGS

Driver Program For simplification, a driver routine can be written to handle program execution and interfacing input/output to the database. Figure 15 illustrates possible user interaction through menus.

This driver routine may be invoked either as part of the database retrieval software, or by itself. This flexibility offers several ways to execute and manipulate the input or output.

4.1 USING DBASE

Such an integrated software system must be written from the ground up in order to be fully functional. A system using dBase can probably be used only if formatting and other transitional routines are written to aid the flow of data between dBase and other programs. "Batch" files could be used here: these files contain one or more DOS commands that are executed one at a time; these can therefore execute computational programs in any prearranged order. This mixing of incompatible software, though, may result in a cluttered and confusing system. In general, using dBase in conjuction with computational software may be a poor choice.

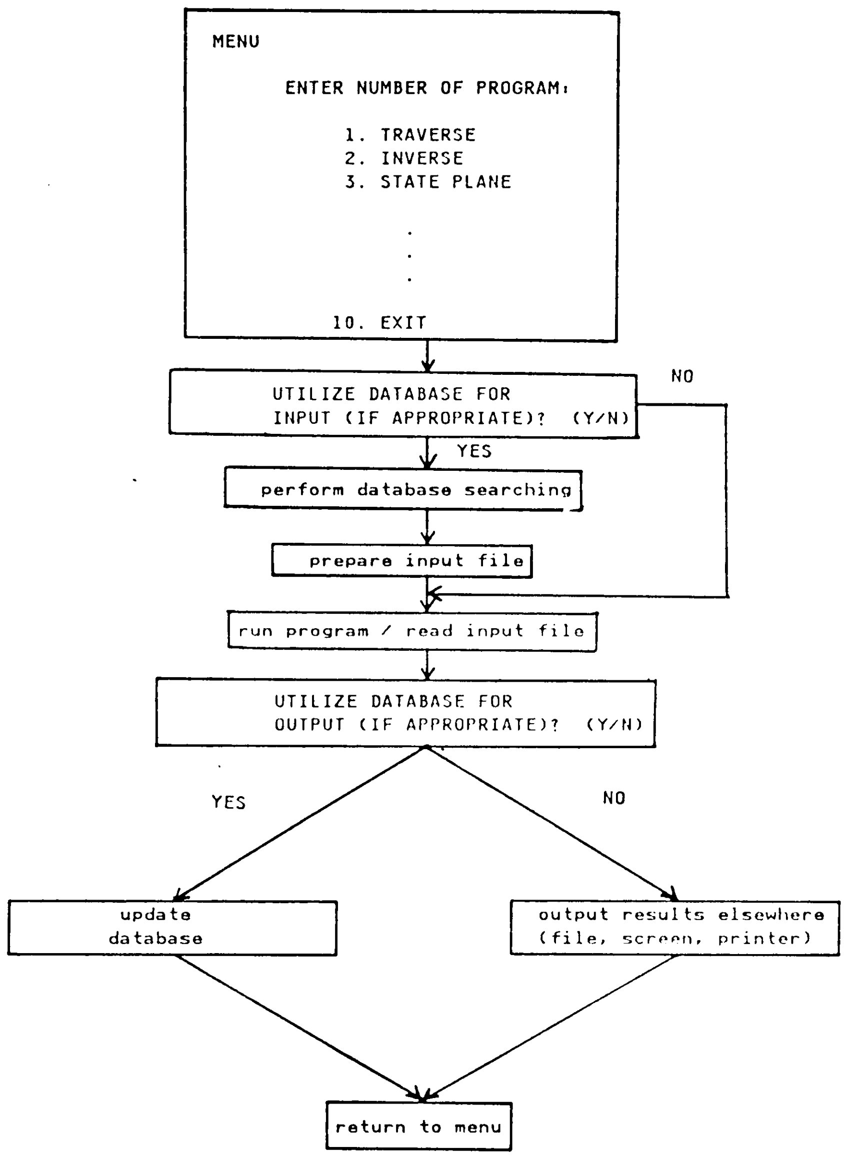


Figure 15. Driver program: An example illustrating how several programs can be handled through a single routine

CHAPTER V

PROPOSED GEODETIC DATABASE AND SOFTWARE SYSTEM

A totally integrated database management system, linked with computational software, is envisioned as the end result of this research. The concept of all software being dependent on a geodetic database is illustrated in Figure 16.

Many issues need further study before any firm conclusions can be formed and software developed. The discussion of these issues are grouped into four categories: software and hardware needs; data types and formats; administrative considerations; and a brief examination of geographic information systems.

5.1 SOFTWARE/HARDWARE

5.1.1 Software

The main priority should be development of software. In addition to database management, the merits of different programming languages need to be looked into, such as Fortran, Basic, Pascal, and "C". An emphasis must be placed on making the software as machine-independent as possible, at least in the early stages of development.

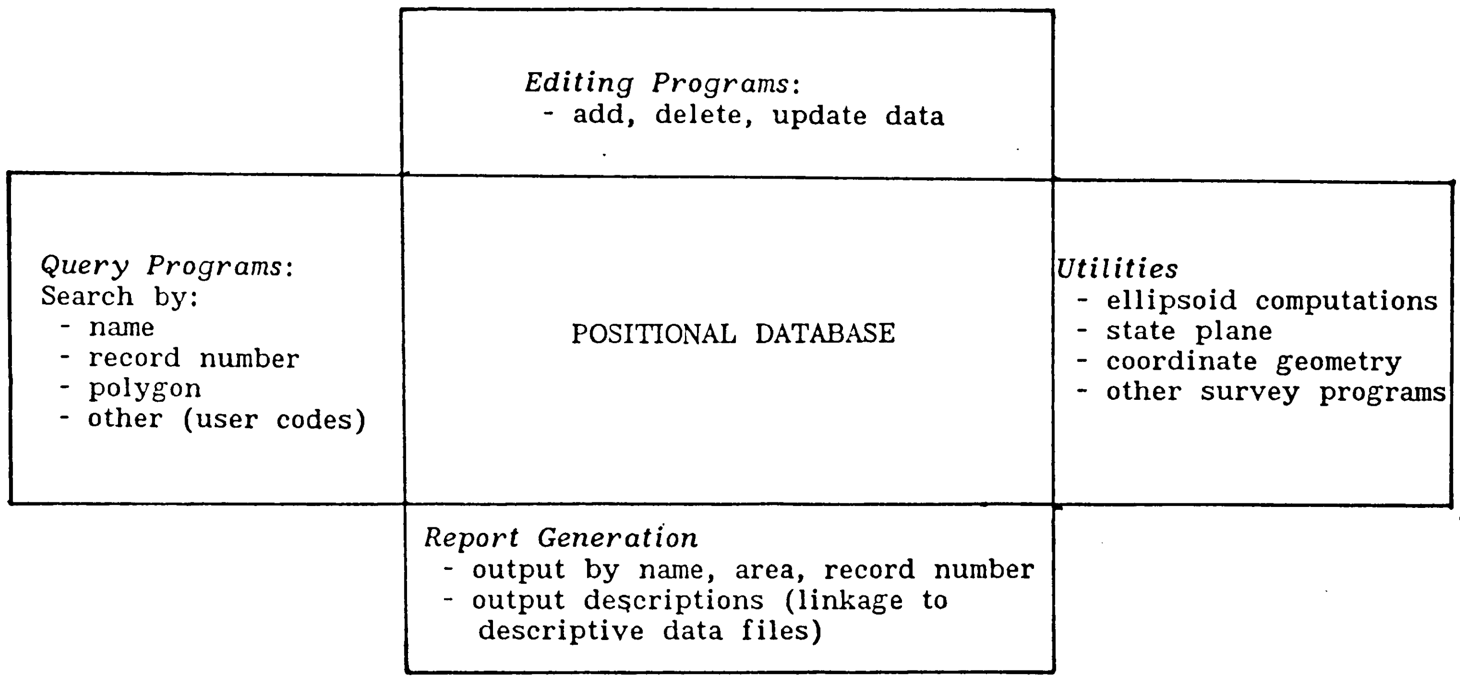


Figure 16 Integrated database model: A conceptual model with various software acting on the database

Programs to handle a database containing descriptive information must be written. This software must necessarily be linked to the retrieval programs that operate on the positional data: after locating stations in the positional database, a user will want the corresponding descriptions in order to locate or further identify them.

A more in-depth review of dBase or other commercial database program is necessary, if only to gain ideas for writing software, or to altogether discard these packages as not applicable to our needs.

Extensive testing of software on large databases and in actual working conditions will be needed to verify and correct any problems or oversights. Feedback from those in industry is vital in order to form a useful model. Questionnaires and limited distribution of test programs can accomplish this.

5.1.2 Hardware

The important hardware issue is storage. The 5.25 inch (360 Kb) floppy diskette is by far the most common computer media. Other storage devices, such as 1.2 Mb floppies and various hard disks may warrant further study, although machines that readily accept these may not be used much at present. Increasingly, however, many microcomputers are now becoming available with 3.5 inch disk drives. These have a storage capacity of about 720 Kb, twice that of a conventional 5.25 inch floppy.

An emerging technology, as mentioned earlier, are compact disks for information management. Advantages include increased access speed and storage capacity. Another possible benefit is data security, because once information is written on a CD, it cannot be changed or erased. It is this permanent nature, then, that might make this system more applicable to a distribution agency rather than the end-user. In this case, such an agency could still send out floppy diskettes of data, since copying from compact disks is not a limitation.

5.1.3 Data Access

The ultimate goal of a functional distribution system is to get control data to the user in a timely and organized manner. There are several ways to accomplish this.

5.1.3.1 Hardcopy Distribution

NGS' automatic mailing service provides geodetic data distribution to those wishing to have the data in hardcopy form. Data is ordered in 30 minute quadrangles, and any updates or revisions for these areas are sent to the users without further correspondence.

A similar system on the state level could distribute local geodetic control in addition to NGS data. Substantial computer and personnel support would be needed, though, in order to be as effective as NGS is at the federal level.

5.1.3.2 Dial-up Access

A direct dial-up link to the NGS database (on their mainframe) is currently under development at that agency. It is hoped that a functional system will be operational within the next year or two (Doyle, 1987). A dial-up system for the state of Virginia may also merit further investigation. In this case, a database of state-wide control (not just NGS data) could be made available by a direct link.

A user with a microcomputer and modem could easily access not only data, but related software and other information as well. Many such computer "bulletin boards" are in use across the country, and a similar system could be adapted to survey databases.

There are potentially numerous logistic problems to solve in developing a direct link. For example, there is the question of how many people could be searching the data at any one time; many simultaneous requests on a large database could quickly bog it down and render it useless. One alternative might be to limit such systems to county offices; this would fix the maximum number of queries at any one time to a manageable number.

5.1.3.3 Individual Distribution of Data and Software

Availablity of microcomputers has made it possible for an end-user to maintain and manage his own survey database. Floppy diskettes can hold thousands of survey coordinates and software to manage it can either be purchased commercially or developed with a familiar computer language. One or two diskettes most likely would contain all the control data a user would ever normally need.

Description Data: A distinct disadvantage is the sheer volume of NGS descriptive data for Virginia. A single 360 Kb diskette holds only a little over a hundred station descriptions. With several diskettes, though, a user should still have enough information at hand for any particular project. It does become a problem for those needing data for most or all of the state. 65 diskettes are required to contain all descriptive data for Virginia; this also includes some overlap into bordering states. One partial solution may be to segregate the data, prior to distribution, into more manageable and practical units. Partitioning by counties would be a natural choice. An efficient program could then, with the data organized this way, prompt the user to load the appropriate diskette containing descriptive data for a particular county. Users could maintain a library of diskettes for the entire state, or merely order county data as their working area expands.

A second solution is for users to maintain only a positional database and send for hardcopy descriptions when needed. This is less desirable, since it defeats the purpose of having an autonomous database.

Data Updates: A lesser disadvantage is keeping updated with new or changing control data in a specific area. Unless there are massive changes, it would be inconvenient to send for a new set of data diskettes every time a station is added to the network. A simple solution is to receive updates either by hardcopy (for very few points), or by diskette (for batch mode input). How fast and effective these updates are depend on the organization of the distributing agency, either at the state or federal level.

5.2 DATA TYPES AND FORMATS

5.2.1 Other Data Sources

In addition to data from NGS, a state would want to make available other data as well. Possible sources for survey information may include the highway department, public utility companies, private engineering firms, and others that make survey information available to the public. Programs to correctly format this data would have to be written; certain codes may be attached to relay information about a station, such as agency source, monument status, dates, etc.

This consolidation and dissemination of state-wide survey data would be the responsibility of a state agency set up for that task. All geodetic control for the state that is publicly accessible should be sent to one state agency for verification and standardization (State Coordinator, 1986). Just as NGS organizes their data into a uniform format, so also would this need to be done at the state level for its local survey data. Also for the sake of standardization, local data preferrably would emulate NGS' data format.

5.2.2 Vertical Data

A database containing elevations may be managed much the same way as horizontal data; NGS currently publishes latitude and longitude values along with the benchmark name, QIDQSN, elevation, county code, and other information. Thus, with minor alterations, the same type of database software that works on horizontal data can operate effectively on vertical data as well. Vertical data from other sources may also be in the database, but since these do not normally include any horizontal information, they will have to be searched by other parameters, such as by job number or other identifier.

5.2.3 Data Search by County

Currently, NGS horizontal positional data has no county identifier; instead, it is included in the descriptive data. Since database searching by county would be very useful, attaching a county code to the data prior to distribution is desirable. There are two possible methods to do this. The first is to write a searching routine to match the station names (or QIDQSN) found in both the descriptive and positional files, extract the county identifier from the former, and attach it as an added field to the latter. This involves massive files and is probably best suited for mainframe work. The second method makes use of a "point-in-polygon" routine that would find which county a point lies in (Nordbeck and Rystedt, 1967). The Geography Department at Virginia Tech possesses both the digitized outlines of all Virginia counties and a point-in-polygon program. Again, this is more appropriate for mainframe usage. One potential problem with this method is the accuracy of the digitized county outlines: points close to a boundary are in a "fuzzy" zone and may actually lie in the adjacent county (Blakemore, 1984). A solution would be to include an extra field to indicate when there may be alternate counties.

5.3 ADMINISTRATIVE CONSIDERATIONS

Deciding which agency would be responsible for state-wide distribution of geodetic data has not been investigated in detail. The newly-created Division of Mapping, Surveying, and Land Information Systems is a likely candidate, however. The Geodetic Division at Virginia Tech may assist in software development, offer technical advice, or otherwise provide support to users. The two could work together, or perhaps the university might take full responsibility for data distribution. Because of the facilities and resources available, Tech is in an ideal position for continuing research and development. Whatever agency distributes data, though, would need to act as a clearing house of surveying information, able to collect and disseminate data from a variety of sources.

Additional agencies that could distribute data are county engineering departments. They might maintain and distribute data for their respective counties and leave the technical support to the state level or other agency.

In summary, the question of who distributes data, who is responsible for software development, and who provides necessary support are issues that need further study. State and county governments creating similar systems also need to be contacted for advice and ideas before making any final decisions.

5.4 GIS APPLICATIONS

5.4.1 GIS Definition

A geographic information system (GIS) is defined as any sequence of interrelated functions that achieves the entry, storage, processing, display, and subsequent generation of spatial information (Burrough, 1986).

5.4.2 Data Characteristics

Geographic information is commonly thought of as having two basic characteristics: spatial information, or locational data; and non-locational descriptive data, or attributes (Dangermond, 1984).

5.4.2.1 Spatial Information

Spatial information is further broken down into two components: The measured coordinates of geographic features (points, lines, and polygons); and its topological location, which defines the location of geographic features relative to one another.

Topological location is usually achieved either by coded network maps, in which adjacency information is stored in linked files, or by coding of geographic features onto a grid. The method of implementation is dependent on software design and hardware limitations.

5.4.2.2 Attribute Information

Attribute information describes the various features of the spatial data. It consists of names, values, classes, variables, and anything else that describes the nature of spatial data. A single spatial feature can potentially have an unlimited number of attributes.

5.4.3 Survey Control Data

A database of positional and descriptive survey information is a prime example of spatial and attribute data, respectively. The positional data are considered point data, and can be located by either latitude and longitude, or by state plane coordinates. The descriptive information and the remaining positional data can be considered station attributes, since they describe the physical location, numerical values, and other (mostly) qualitative information. The QIDQSN (or station name) provide the necessary key field between the spatial and attribute data.

5.4.4 Integration with other Data

Within an automated GIS and merged with other spatial information, a database of survey control data becomes open to a wide range of queries and manipulations.

The location of county boundaries, roads, highways, streams, and elevation data in addition to survey points can also be entered into a GIS database. With these various "layers" of data at hand, map overlay techniques can be used to derive useful information not obtainable through conventional database systems. Output devices, such as plotters and video display units, can generate maps, reports, or other information as the end-result of various kinds of searches.

A detailed discussion of the different GIS functions is beyond the scope of this report, but the following list highlights some of the typical GIS data analysis and spatial modeling operations (Burrough, 1986) that might be applicable to users of geodetic control:

- Viewshed analysis   If a digital elevation model is available, then this function can determine what areas can and cannot be seen from any selected point. This can aid in the design of a survey, since intervisibilty between survey points is always necessary.

- Point in polygon With digitized boundaries in the database, a user can determine whether certain stations lie within a polygon (county or national forest, for example).

- Buffer generation This can create polygons within which a search for survey points can be performed. A circular or square buffer can be created about any selected point. This is identical to the area searches mentioned earlier. Buffers can also be created around linear features such as highways and rivers. This can be valuable for those planning route surveys, for example, and who wish to find all available geodetic control along a strip of specified width.

- Searching This encompasses a wide range of searching operations, including those mentioned above.

5.4.5 Summary

This is only a small sample of the kind of functions a GIS can provide to surveyors and other users of control data. The Map Analysis Package (Tomlin, 1986), a microcomputer-based system, can perform the above procedures along with many other functions. The Geography Department has this software package in its Spatial Analysis Laboratory. This and similar systems may merit further study.

For the problem at hand, however, it should be observed that a GIS is perhaps at a level of sophistication beyond what is considered to be practical (at present) for our applications. It should, therefore, be reserved for future research, since it is likely that survey data will ultimately end up in a GIS as technology evolves and land information data are increasingly being automated.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

It has been established that a need exists for a state distribution office and that survey data distributed on electronic media is anticipated to be far more useful than conventional hard-copy methods. The following conclusions relate to the actual development of a microcomputer database:

1. Development priorities In order to deliver a workable database system to users in a timely and effective manner, data organization and software development must take place in the following order:

   a. Organization of state survey data onto floppy diskettes: this makes data immediately available to users without having to wait for software to be developed. Just as NGS control data is already available on diskettes, so also must state-wide data be consolidated onto floppies. These data must be organized into one standard format (Conclusion #2) so that an existing database program (e.g. dBase) may be used.

b. Database software: only after data are organized into a logical format can serious development of retrieval programs begin. A useful database must be able to be queried, edited, and linked to descriptive data (Conclusion #3).

c. Computational software: integration of a library of survey programs with the database is the next necessary step. These programs already exist, but they must be modified both for microcomputer use, and for ease of execution within the database.

Note: not all microcomputers will be able to accept data types and software designed on a single system. Attention must therefore be given to developing a standard that is acceptable (or easily modified) for use in a majority of machines.

2. <u>Data format</u> There must be certain items in the database for it to be minimally functional:

a. Station name (to uniquely identify each survey point).

b. Latitude & longitude and/or state plane coordinates.

c. State plane coordinate zone.

d. QID (search parameter; can be calculated if not provided).

e. Pointer to corresponding station descriptions (the station name is the key field; a shorter, fixed-length code can also be devised).

Additional items are not essential, but may be useful to specific users. The more important of these are:

a. County code (another search parameter).

b. Elevation.

c. Precision information.

d. Neighboring state plane coordinate zones.

e. Establishing agency.

3. <u>Separate descriptive data file</u> For database efficiency, the descriptive data files must be external to the positional data; these files will only need to be searched by the key field (station name) which links both data

files. Although the files are separate, station descriptions are still vital to the user and must be included in the overall database design.

6.2 RECOMMENDATIONS

1. Questionnaire A more extensive poll is needed of private firms and public agencies. Groups that especially need targeting are those that currently use geodetic data frequently. This can be an aid in our overall design process.

   Also, a detailed questionnaire must be formulated for those agencies that establish state and local control. It must be determined exactly what data are available and in what format so that the process of data consolidation can begin.

2. Future research issues Application to geographic information systems deserves further investigation. A GIS to manage survey data alone would not be justified, but, used in conjunction with other data layers, such a system can be very versatile.

   CD ROMS, because of their storage capacity and security (read-only) feature, also merits a deeper look. The Computer Science Department is currently doing research in this area.

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APPENDIX A

QUESTIONNAIRE

If your agency or firm is a past, present, or future user of geodetic control data, please answer the following:

---

1. Type of company ____________________
(Public agency/private firm)

Location ____________________
(city, county, urban/rural)

Firm name & address (optional) ____________________

____

2. What is your current source of data?

In what form do you request needed control (e.g. by area, such as county)?

3. In what format is control data received (printout, diskette)?

Is this satisfactory? Please comment:

How would you prefer geodetic control data to be distributed?

4. Which coordinate datums do you use (state plane, lat/long, UTM, other)?

5. Do you currently maintain a computerized data base of survey point information?

6. Describe your current personal computer hardware:

7. Other comments:

APPENDIX B

DGSCIC BENCHMARK DATA BASE

In 1982, the Delaware Geological Survey Cartographic Information Center (DGSCIC) BENCHMARK Data Base became operational. This database resides on an IBM mainframe at the University of Delaware in Newark, and is a state-wide repository of benchmarks established by several different agencies.

Users requesting data must complete a questionnaire and send it to the DGSCIC. Although not a microcomputer-based system, the sample questionnaire on the following page illustrates the versatility of the querying program.

DELAWARE GEOLOGICAL SURVEY
CARTOGRAPHIC INFORMATION CENTER

University of Delaware
Newark, Delaware 19716
(302) 451-8262

DGSCIC_BENCHMARK_Data_Base

The Delaware Geological Survey Cartographic Information Center houses a benchmark data base for federal vertical control data. A computer search of this data will reveal information about the location and the current elevation of various benchmarks throughout Delaware. This is accomplished through the use of key words such as: **station**, **agency**, **city**, **county**, **topographic quadrangle**, **NGS quadrangle**, **USGS quadrangle**, and **line number**. The key words help to define the specific benchmark or the area in which you are interested in locating the existing vertical benchmarks. For example, if you wanted to do a survey in the Dover area, a listing of all of the federal benchmarks within a 1 mile radius of the city of Dover can be obtained by using the key word **city** = Dover.

Upon completion of a computer search, the DGSCIC will provide a computer printout of the appropriate data and a copy of the corresponding USGS topographic map showing the exact locations of the benchmarks listed in that printout.

If you are interested in obtaining a benchmark search, please fill out the questionnaire below.

(tear along dotted line)

Please conduct a BENCHMARK computer search for the benchmarks or areas described below:

Name:_______________________________

Address:_______________________________

____

Phone:_____________________

(Please provide as much information as possible so that a concise search can be made)

Station Name(s):____

Agency(s):____
(NGS-National Geodetic Survey; USGS-U.S. Geological Survey ACE-Army Corps of Engineers; FEMA-Federal Emergency Management Agency)

City(s):____

Area(s):____

County(s):____

Topo quad(s):____

NGS vertical quad(s): 380751, 380752, 380753, 380754
(circle quads wanted) 390751, 390752, 390753, 390754

USGS vertical quad(s):_____________________________________
(quads 1 to 20)

Line number(s):____
(NGS or USGS)

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