SURVEY FIELD PROCEDURES MANUAL

Prepared By

THE DIVISION OF PLATS AND SURVEYS
MARYLAND STATE HIGHWAY ADMINISTRATION

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SECTION 1-01 INTRODUCTION

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A. DEFINITION OF SURVEYING

In general, surveying is performed to determine the relative location or positioning of points on or near the earth's surface. More specifically, surveying is the science of making measurements, relative to known or assumed datum’s and standards, and applying the principles of mathematics to such measurements to determine existing or future horizontal and vertical position, from area, magnitude, boundaries, and extent of land parcels and topographical features.

Surveying encompasses the following categories:

1. Geodetic Surveys - Surveys, which establish control networks on a mathematical datum so that measurements will reflect the curved (ellipsoidal) shape of the earth.

2. Land Surveys - Surveys which include retracement of existing land ownership boundaries or the creation of new boundaries.

3. Engineering Surveys - Surveys performed for the location, design, construction, maintenance and operation of engineering projects.

4. Construction Surveys - Surveys which establish stakes in the ground, and other like reference points, at known horizontal and vertical positions to define location and size of each component of the facility to be constructed, enable inspection of contract items, and serve as a basis of payment for work.

5. Cartographic Surveys - Map making from original surveys.

B. IMPORTANCE OF SURVEYING

1. The Basic Engineering Discipline - Surveying is basic to all civil engineering works. In transportation engineering, surveying provides the foundation and continuity for route location, design, land acquisition, and all other preliminary engineering.

Surveys also set a basic "framework" of stakes, which is used by contractors and engineers in building and inspecting transportation projects.

2. The Thread of Continuity - Surveying is the single engineering function which links all the phases of a project including conception, planning design, land acquisition, construction and final monumentation.

3. Basis for Efficiency - To a great degree, the acceptability and cost-effectiveness of planning, land acquisition, design, and construction are dependent upon properly performed surveys.

C. PURPOSE OF MANUAL

1. Primary Objectives - The principal purposes of this MANUAL are to:

   a. Secure an optimum degree of Statewide uniformity in surveying.

   b. Establish and maintain survey standards.

   c. Improve the overall efficiency of the Division's survey function.

   d. Provide a single reference source for Division-wide surveying policies, procedures, and information. (The inclusion of regularly used formulas and tables in the "Appendix" will enable the MANUAL user to reduce his library of reference material.)

2. Secondary Objectives - Secondary aims are to provide:

   a. A comprehensive reference for new employee orientation.

   b. Source material for training.

   c. Help employees in other offices gain a better understanding of surveying and its proper relationship to other Administration activities.

D. SCOPE OF MANUAL

This MANUAL, in general, covers Division-wide surveying policies and procedures and appropriate reference material. It is not a textbook or a contract document. Nor is it a substitute for surveying knowledge, experience or judgment.

Although portions include textbook material, this MANUAL does not attempt to completely cover any facet of surveying.

For Division of Plats and Surveys employees, this MANUAL is policy. As such, it supersedes previously issued Policy and Procedure Memorandums, which deal with the topics covered herein.

CHAPTER 1-00 - GENERAL

SECTION 1-02 ORGANIZATION

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A. PLATS AND SURVEYS DIVISION

Working under the direction of the Deputy Chief Engineer - Office of Highway Development, the Division of Plats and Surveys is organized into three distinct sections.

Basically, the Plat Section is responsible for the creation of right-of-way plats, the Survey Section is responsible for Administration-wide engineering surveys, and the CADD, Mapping, and Control section is responsible for CADD and computer support, processing data collection surveys, and performing Geodetic control surveys. Figure 1-02-A is an organization chart of the Plats and Survey Division.

B. DUTIES AND RESPONSIBILITIES

1. Chief, Division of Plats and Surveys - the Chief, Plats and Surveys Division has the Responsibility to:

   a. Develop and recommend programs, policies, procedures and standards for surveying functions within the Administration.

   b. Provide guidance and assistance to the Engineering Districts and other Divisions on all matters related to surveying.

   c. Maintain liaison with other public agencies, the private sector, and professional societies on surveying activities.

   d. Develop Division survey training programs.

   e. Coordinate survey requirements and related policies with other Administration functions.

   f. Research and evaluate new survey equipment and techniques.

   g. Administer contracts for consulting services and maintenance of traffic.

PLATS, SURVEYS AND MAPPING DIVISION

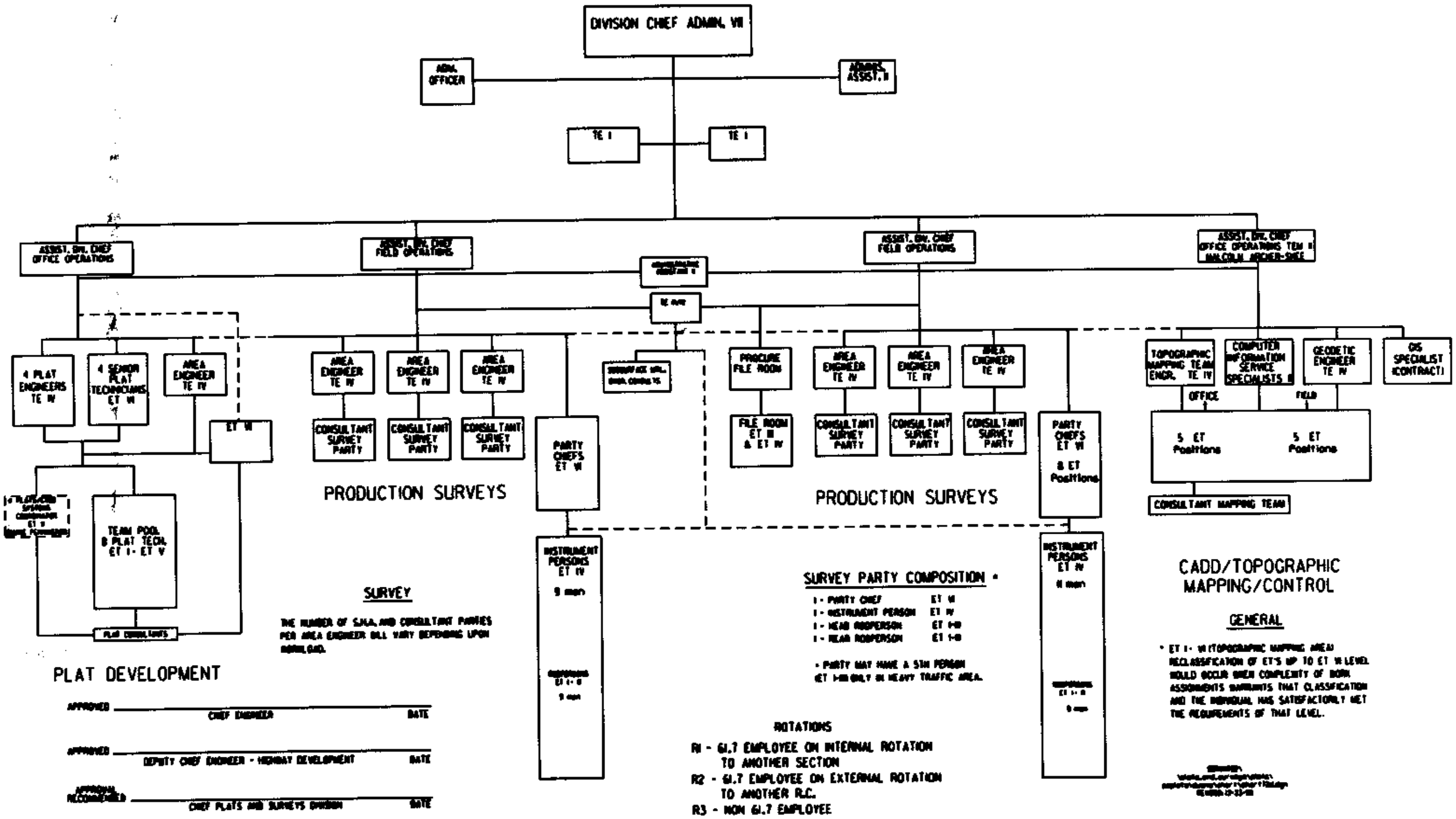

Figure I-02-A Organization Chart - Survey Section

h. Coordinate the establishment, maintenance and application of an effective survey management system.

i. Provide program coordination and review of Basic Control Survey projects and liaison with the National Geodetic Survey.

j. Prepare budget and staffing requirements for the survey function and keeping records of survey costs.

k. Administer personnel rules regarding the hiring, termination, and promotion of Division employees.

l. Review and sign right-of-way plats.

2. Assistant Division Chief - CADD, Mapping and Control Section - Manages and directs the engineering and administrative operations of the Control, Topographic Mapping and CADD Systems Teams within the Division of Plats and Surveys.

   a. Oversees the functions of the Topographic Mapping Team.

   b. Oversees and programs geodetic control survey projects.

   c. Develops and maintains CADD data storage and retrieval systems.

   d. Manages and supervises the CADD Systems Team.

   e. Manages, assesses, and makes recommendations to the Division Chief on acquisition of computer hardware and software needs of the Division.

   f. Develops and manages the Division's CADD programming and training needs, and CADD support consultant contracts.

   g. Develops policies and procedures for geodetic control and topographic mapping.

   h. Represents the Division Chief at meetings within SHA, and with other federal, state and local agencies.

i. Provide administrative functions and support for the Topographic Mapping Team, the Geodetic Control Team and the CADD Systems Team.

3. Assistant Division Chief - Production - Supervises and coordinates the engineering and administrative operations of the Production Survey Section and has the responsibility to:

   a. Assure that a dynamic, effective training and the Surveys Section pursues safety program.

   b. Review requests, plan, and schedule field surveys in cooperation with other Divisions. See Figure 1-02-B.

   c. Oversee all field survey work for planning and design surveys, metes and bounds surveys and construction surveys.

   d. Prepare time and cost estimates for field surveys.

   e. Review and approve employees' expense statements, time reports, mileage reports and efficiency ratings.

   f. Review and approve consultant invoices.

4. Area Engineer - First-line supervisors of the survey crews employed by the State Highway Administration and have the responsibility to:

   a. Solve field survey problems, as well as determine the most expeditious and cost effective manner to perform the survey work.

   b. Meet with other Divisions and agencies to study the scope, details and important aspects of requested field surveys.

   c. Assemble information and develop data necessary to perform field surveys.

   d. Process, coordinate, and evaluate consultant field surveys.

   e. Notify property owners of the Administration's intent to enter upon their property to perform field surveys.

   f. Edit manuscripts for photogrammetric mapping.

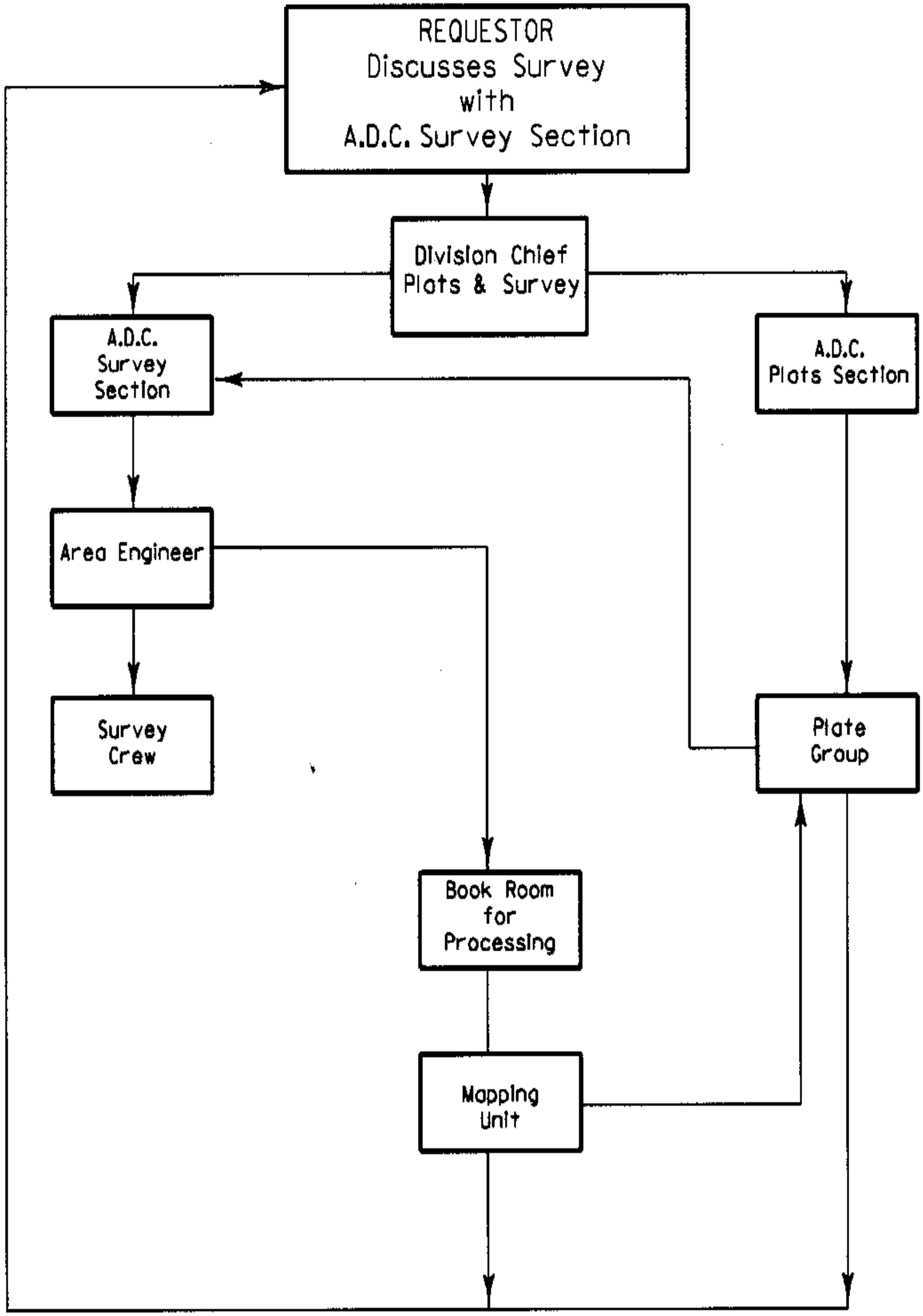

Figure I-02-B Organization Chart - Survey Section

5. Technical Assistant - This position performs technical duties in support of the Assistant Division Chiefs and has the responsibility to:

a. Assist in the review of survey requests submitted by various Divisions, agencies, and districts.

b. Assist in the assembling of all available project data to be furnished to field personnel.

c. Assist in review and calculation of geometric ties to right-of-way lines and lines of division from base lines of survey.

d. Investigate new survey methods and equipment and determine their practical application and adaptability to State survey units.

e. Maintain database files for monument geodetic control points established by the Division of Plats and Surveys and Federal Agencies.

6. Party Chief - This position supervises and directs a survey party conducting field surveys and has the responsibility to:

a. Determine field methods and procedures that produce not only an economical survey but also a final product that meets the engineering needs of that specific project.

b. Monitor his party's deportment during working hours to ensure that adverse reflection is not cast on the Administration.

c. Assure that all survey equipment is properly maintained and that equipment is used for its intended purpose.

d. Ensure that safety is given top priority in the planning and execution of all surveys.

e. Obtain lodging for the crew and to reimburse party members for meal expenses when on travel status.

f. Train party personnel in all phases of surveying as practiced by the Division.

7. Instrument Man - The Instrument Man is the secondary supervisor on a survey party and has the responsibility to:

a. Operate angular, electronic distance measuring, leveling and GPS instruments in field survey operations.

b. Supervise the survey party in the absence of the Party Chief.

c. Maintain and check the survey instruments to ensure proper operating condition and accuracy.

d. Record notes pertaining to the measurements taken by the various survey instruments and other miscellaneous notes as the Party Chief may direct.

e. Assist the Party Chief in the computation of survey data.

f. Assist the Party Chief in the review of project data prior to the beginning of field surveys.

g. Review the survey notes recorded by the Party Chief at the completion of a project.

h. Train lower level party members in the operation of surveying instruments.

8. Rodmen - The Rodmen on a survey crew has the responsibility to:

   a. Operate supporting electronic distance measuring equipment such as prisms, tribrachs, and prism poles during field surveys.

   b. Obtain precise measurements by using steel tapes.

   c. Clear lines of sight.

   d. Maintain and clean survey equipment such as tapes, rods, sighting equipment, hand tools, etc.

   e. Perform other duties as directed by the Party Chief and Instrument Man.

CHAPTER 1-00 - GENERAL

SECTION 1-03 PUBLIC AND INTERNAL RELATIONS

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A. GENERAL

1. Importance - Public relations is one of the more important duties of the surveyor. This is especially true for surveyors who "enter" private property. The wide variety of situations encountered by the surveyor requires a constant awareness of the rights and needs of others. The ability to adjust to these needs is also required.

2. Basic Rules - Common sense and common courtesy are the best rules in any form of public relations. Be prepared, and try to create a good impression when meeting the public. First impressions, whether good or bad, are often lasting. Maintain a pleasant, businesslike attitude at all times and be informed about your job. The impression you create thereby will be a credit to you, your profession, and the Department of Transportation.

3. Use of Business Cards - To help in creating good relations with others, Party Chiefs shall use business cards. A Party Chief contacts many individuals: property owners, other surveyors, park rangers, etc. Often it is necessary to leave an address and telephone number with these people. At other times, the business card can simply be a means of introduction or of creating goodwill.

B. RELATIONS WITH THE PUBLIC

1. All Representatives - All employees and consultant personnel are representatives of the Department of Transportation. All are responsible for developing and maintaining public goodwill. The Department as a public service organization is judged by our behavior as well as by our work.

2. Conduct - The outdoor nature of surveying keeps surveyors in the "public eye" much of the time. Work must be accomplished efficiently and with a minimum of idle time. Good-natured kidding among party members helps morale. But, when around the public, you must be prudent in oral and sign communications.

Excessive kidding and horseplay can create negative impressions, which damage the Department's image.

3. Direct Contact - All direct contact with the public should be pleasant, courteous, and businesslike. This includes answering questions, listening to criticism (justified or not), and listening to suggestions.

4. Answering Questions - In the field, refer questions concerning the work to the Party Chief. He should answer each question for which he knows the facts. If any doubt exists, he should refer the person asking the question to his Area Engineer or an Assistant Division Chief. Probabilities, conjectures, or statements, which might be misunderstood or misinterpreted, should be left unsaid.

C. RELATIONS WITH PROPERTY OWNERS

1. General - Dealing with property owners is a most vital phase of public relations. The property owner is the one who will be directly affected by the survey and, possibly, by subsequent construction. He will naturally take a close interest in any intrusion on his property, no matter what the purpose.

   Good relations developed by conscientious surveyor's carry over in the owner's attitude toward other State Highway Administration employees.

2. Entry on Private Property

   a. Right of Entry - Real Property Article 21, Sub-Section 12-111, gives the State the right to enter private property to make surveys and also provides protection to the property owner by requiring prior contact. For detailed procedures, see Maryland State Highway Directive 5652.1.1.

   b. Pre-Entry Contacts - To promote good relations, a diligent effort to contact the property owner or tenant will be made prior to entering the property.

      1) Objectives - The purpose of the contact shall be to explain:

         a) That entry is required.

         b) The survey activities to be performed and their duration.

c) Any effect the surveys might have on the property.

2) Direct Personal Contact - If possible, acquire verbal approval for entry at the time of the contact.

a) Departmental Representative - The contact should be made either by the Area Engineer or by some other person designated by the Division.

b) Answering Questions - The contact person should know the facts and be prepared to answer questions courteously and promptly. If unanswerable questions arise, the contact person should obtain the answers and personally relay them to the property owner or tenant.

c) Documentation - All verbal contacts should be recorded.

3) Direct Mail Contact - Contacts may be by mail if personal contact is impractical. Include in such letters the same information as that which would be given during a personal contact.

c. Objection to Entry - When a property owner or tenant objects to entry - DO NOT ENTER!

If a property owner claims actual or anticipated damage or interference after a survey has begun, immediately leave the property. The appropriate Assistant Division Chief must be immediately notified so that action is taken as detailed in Directive 5652.1.1.

d. Party Conduct:

1) Conduct operations in a manner that will not create ill feelings with property owners or tenants.

2) Guard against any cause for complaint.

3) Tone down oral communications in populated areas.

e. Property Care:

1) Survey Method - Choose the survey method, which will have the least effect on the land.

2) Stake Location - Place stakes and other markers where there is little likelihood of creating a hazard.

3) Property Rehabilitation - As much as possible, leave the property in the condition that existed prior to the survey. Repair any damage, fill any holes, and restore the property to its original condition. If you must temporarily leave a hazard created by your work, protect people and animals by use of protective devices, such as cones, barricades, and portable fencing.

4) Removal of Hazards - Remove all temporary and hazardous survey stakes and other potentially hazardous items from the work area after their usefulness has ended. The Party Chief is responsible for determining which items to remove and when. However, each party member should call to the Party Chief's attention any possible hazards.

   Examples of items to be removed are: stakes across fields which are to be mowed, stakes in pedestrian areas, back-sights and foresights, and photogrammetry ground control materials. Farm animals tend to be indiscriminate in what they eat, particularly if the item tastes salty to them. This tendency causes them to eat plastic flagging, paper targets, and clothe pre-marks.

5) Concern for Children - Consider hazards to children when setting or leaving survey stakes. Articles such as lathes make excellent swords and spears. Some of the paint we use is toxic if ingested. Nails and spikes can be dangerous in the hands of children.

6) Litter Removal - DO NOT LITTER. Paper, stake fragments, and other trash shall be placed in litter cans in State or consultant vehicles. Litter shall not be left on private or on public property.

f. Law Enforcement Agencies - When a survey requires work around sensitive areas or night work, notify local law enforcement agencies and private security agents. This enables them to be aware of the source and reason for the appearance of "unusual" lights and activity.

D. INTERNAL RELATIONS

1. Survey Party - Proper relationships within a survey party are necessary if individuals are to function as a team.

   Party Chiefs can help maintain good party relationships by keeping party members well informed about individual and party roles and their duties for each job.

2. Office

   a. Party Chief and other supervisors must be kept informed of important developments. They should not be put in the embarrassing positions of learning important information from outside sources.

   b. Good relations among office personnel can be maintained through good communications and a clear understanding of responsibility.

   c. Relations and contacts with other Divisions should be courteous and businesslike. When in doubt about the requirements of a survey request, phone the requester for a clarification.

CHAPTER 1-00 - GENERAL

SECTION 1-04 SAFETY

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A. INTRODUCTION

Maryland State Highway Administration employees survey in many different hazardous environments. Rugged terrains, high-speed traffic, hand and power tools, and construction equipment are some of the elements that typify survey hazards.

Most people have one thing in common with many who have experienced an accident--they believe it could not happen to them. A meaningful safety program requires that each employee acknowledge that "It can happen to me." Each must also ask, "What is my responsibility and what can I do to keep it from happening?"

B. SAFETY MANUAL

1. Each field employee shall have ready access to the "Safety Manual for Field Survey Personnel"

2. No survey operation shall be considered as either so important or so urgent that the Safety Manual or any safe practice will be compromised.

C. RESPONSIBILITIES

1. Individuals

    a. All field personnel shall have a practical working knowledge of the Safety Manual.

    b. Each employee will do everything reasonably necessary to protect life, safety, and health of everyone and comply with all occupational safety and health regulations that are applicable to his job.

    c. Each employee shall report to work each day in an alert, agile and capable condition. You should be:

        1) Healthy - If you are ill, do not report to work. If you become ill on the job, do not continue to work. Report to your supervisor and then get aid.

2) Rested and Nourished - Each surveyor must report for work prepared to perform an alert, accident-free, full shift of work. For most individuals this dictates 7 to 8 hours of sleep and a nourishing breakfast.

3) Free From Influence of Drugs or Alcohol -

a) Drugs - Whenever a physician gives you a prescription, inquire if the drug might impair your safe functioning. If any impairment might result, ask the doctor what you can and cannot do while taking the medication. Notify your supervisor.

Do not report for work if you are under the influence of non-prescribed narcotics. Also do not report for work if you have been taking any drugs, prescribed or otherwise, which diminish your alertness and your ability to react quickly and make sound judgments.

b) Alcohol - Do not report for work if you are under the influence of intoxicants. Also, do not report for work if any lingering effects from drinking intoxicants (such as a "hangover") would diminish your alertness and keep you from reacting quickly or would impair your judgement.

2. Area Engineers - The Area Engineers are responsible for:

a. Monitoring safety conditions and performance of survey crews working on their projects.

b. Reviewing with the Party Chief the planning of all surveys. Planning shall include:

1) The safest time of day that the survey can be accomplished.

2) The optimum number of personnel to do the job.

3) The assignment of trained and qualified personnel for the more hazardous jobs.

3. Party Chiefs - Each Party Chief is responsible for the work methods and safety practices of his party.

The Party Chief is in the best position to see that all safety rules and procedures are followed and that all work is performed safely. Do not attempt to delegate this responsibility. The Party Chief must ensure the use of the one best SAFE method for each operation.

a. Safe Surveying Practices

1) See that a copy of the Safety Manual is always available to members of your party.

2) Enforce all elements of the Safety Manual.

3) Monitor employees for drug and alcohol abuse.

b. Job Planning

1) Give safety first priority in planning each survey.

2) As required for each job, develop additional safety practices.

3) Request enough personnel for safe surveying: for buddies, lookouts, flagman, etc.

4) Insofar as possible, plan around hazards, especially life-threatening hazards such as traffic.

5) Avoid assigning party members to solo-type tasks that isolate them from other party personnel. Try to have each member working with a buddy. (This is especially important in high hazard areas, such as along roads and mountain areas.)

c. Personal Equipment - See that each subordinate possesses or has available required personal safety equipment. You must see that employees use this equipment as required. If an employee refuses to use required equipment, do not allow him to work. Dismiss him, without pay, for the rest of the day. Refer the matter to your supervisor.

d. Party Equipment - See that equipment and supplies are safe to use.

e. New Employees

1) Show the employee where the Safety Manual, first aid kit, fire extinguisher, safety flares, etc. is stored.

2) Adequately orient and begin training the new employee in required work tasks before allowing him to work alone at individual tasks.

3) Appraise the driving abilities of each new employee before allowing the employee to operate a State vehicle.

   NOTE: The appropriate Assistant Division Chief is to notify the Party Chief if the new employee has any driving restrictions.

CHAPTER 1-00 - GENERAL

SECTION 1-05 ACCIDENT/INJURY REPORTS

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A. GENERAL

1. Responsibilities - Accidents, injuries, and work-related illnesses shall be promptly and properly reported.

   a. Party Members - Each employee must report any accident to his supervisor.

   b. Party Chief - Each supervisor must see that reports are correctly prepared and promptly submitted. (If any injured employee cannot prepare required reports, his supervisor shall ensure submittal on the employee's behalf.)

2. Submittal of Originals - Report all required accident data on the original. A combination of original material and carbon copies of other material, which together comprises one report, is not acceptable.

3. Clarity and Completeness - Make an accident report a full and frank statement of all facts in the case. Do not conceal or minimize essential facts. Consider taking photographs and drawing detailed sketches to clarify any facts. Make reports as complete and precise as possible.

4. Routing of Reports - Distribution of accident reports is sometimes indicated on the various forms. However, survey personnel shall submit reports directly to the Division of Plats and Surveys Office.

B. WORK RELATED INJURIES AND ILLNESS

1. Medical Treatment - If injury or work-related illness occurs and medical attention is needed:

   a. Routine Treatment - Take or send the employee to any doctor on the approved physicians list. (A copy of this list should be posted in each survey vehicle.)

   b. Emergency Treatment - when an injury requires emergency treatment, use the nearest medical facility, regardless of the "list".

c. Employee Refusal - If the employee refuses to see an "approved" doctor in non-emergency cases, advise him that he will be required to pay his own medical expenses.

d. Information to Give - The attending physician shall be informed that:

1) He will be paid for his services.

2) The injured is an employee of the Maryland State Highway Administration.

3) Bills are to be sent to the Maryland State Accident Fund.

2. Industrial Injury Reports

Three different forms are used in reporting personal injuries. The three forms to use are:

a. Department of Transportation Form D.PER-033(1-82), Report of Accident/Incident.

b. Employer's First Report of Injury Form No. C-1.

c. Earnings Report to the Maryland State Accident Fund.

C. MOTOR VEHICLE ACCIDENT

The glove box of each state-owned vehicle contains a "Vehicle Accident Kit". This has instructions on accident reporting and accident report form "ACORD 2(5/86)." (If the Kit or its contents are missing, obtain a replacement from the Division of Maintenance.)

The State is self-insured and the State Treasurer contracts with a claims adjustment company. Prompt handling of accident reports minimizes the chances that the State will be disadvantaged.

If you are injured while operating or riding in a State vehicle, submit personal injury reports in addition to the vehicular accident forms.

CHAPTER 1-00 - GENERAL

SECTION 1-06 VEHICLES

Revised 11/01

A. GENERAL

Vehicle operation and care are joint responsibilities of all survey party members. Some of these responsibilities are:

1. Use of seat belts by all.

2. Use of defensive driving techniques.

3. Observance of all State and local vehicle regulations.

4. Operation within the physical and mechanical limitations of the vehicle.

5. Prevention of vehicle abuse.

In addition to the above, the Party Chief is responsible for appointing capable and qualified drivers and training party members in safe vehicle operation.

Promptly report all accidents, work damage, and traffic citations to your Party Chief. The Party Chief will then forward the information to his supervisor.

B. SAFETY

If you drive State vehicles you must learn and heed the vehicular safety instructions in Chapter VII of the Safety Manual.

A survey truck driver has added responsibilities and has a harder job than the driver of sedans or pickups. He must control a larger vehicle under conditions of all-around visibility.

C. MISUSE

Misuse of a State owned vehicle includes the following:

1. When driven or used otherwise than in the conduct of State business.

2. Carrying in the vehicle any persons other than those directly involved with official State business, except with approval of the employee's immediate supervisor for each trip.

3. The State Highway Administration also regards the following as misuse of state-owned vehicles:

   a. Noncompliance with traffic laws.

   b. Unsafe driving practices, including failure to use seat belts.

   c. Failure to comply with Administrative procedures.

   d. Improper parking or storage of State vehicles.

   e. Failure to take necessary safeguards to protect State equipment stored in vehicles.

   f. The improper operations of the vehicle or failure to provide appropriate service procedures, causing damage to or premature failure of equipment components.

4. Additional Guidelines - The drivers of State vehicles are subject to critical public observation. Avoid the slightest appearance of misuse and be exemplary in all vehicle operations.

   As a guide, avoid:

   a. Parking State vehicles overnight on streets.

   b. Parking on private lots without permission.

   c. Carrying passengers who are not on official business.

   d. Exceeding posted speed limits.

   e. Displaying signs, posters, pictures, stickers, decals, or messages, which are not approved by the Department or required by law.

   f. Dirty and disorderly vehicles.

D. SECURITY

As an operator or user of State vehicles, you are responsible for the security of the vehicle and its contents when parking it overnight.

The following security precautions will help:

1. Park off the street whenever possible.

2. Leave vehicle in "low" or "reverse" in manual transmissions, or "park" in automatic transmissions and with the hand brake firmly set. If parked on a grade, turn the front wheels into the curb. If the road does not have a curb, turn the front wheels so the vehicle will roll away from the road.

3. Remove ignition keys.

4. Close all windows.

5. Lock total station instrument, level, and radios in metal security box.

6. Conceal attractive and valuable equipment. (All such equipment should be stored out-of-sight.)

7. Lock all doors and compartments.

8. Set burglar alarm system.

E. PURCHASES OF PETROLEUM PRODUCTS, SERVICES AND PARTS

1. Policy - Permissible routine purchases of expendable supplies and services and emergency parts and services shall be made at the lowest possible cost to the State.

    a. Preventive Maintenance - Operators of State vehicles shall follow the practices prescribed in Division of Maintenance Directives. This will minimize the need for emergency purchases from "outside" sources.

    b. State Sources - When accessible, supplies for vehicles shall be acquired from State stock.

        1) Fuel - Bulk-fuel facilities (which are generally located at District Maintenance Shops, District Offices, and most maintenance stations) of the State shall be the first choice for fuels for State vehicles, only. Purchase fuels from commercial vendors only when State bulk fuel is not reasonably available. Before leaving on a trip that might consume a tank-full or more of fuel, see that the fuel tank of a State vehicle is filled at a State bulk-fuel facility.

2) Oil Changes and Lubrications - Whenever possible, arrange for routine maintenance to be performed at a State facility. This will save on the cost of petroleum products and filters. In addition, it will enable the employee doing the work to inspect for vehicle problems or additional preventive maintenance needs.

c. Outside Sources

Fuel - Self-service islands of commercial facilities must be used whenever available.

2. Credit Card Usage - In recent years the State has been using a multi-company credit card. This card provides maximum flexibility for State employees when petroleum products and vehicular parts and services must be obtained from private vendors. When using this credit card observe the following precautions.

a. Checks for Card Acceptance - Among the companies that honor the card are Exxon, Amoco, Texaco, Shell and Chevron. However, an individual station proprietor might not accept the credit card. Check for acceptance before delivery of products or service is begun.

b. Fuels - Gasoline may be purchased without restrictions for State vehicles, as long as a State bulk-fuel facility is not accessible.

c. Employee Responsibilities - Each operator of a State vehicle must help assure proper credit card usage through the following actions:

1) Determine if the vendor accepts the credit card before delivery of supplies and/or services begins.

2) Ensure that the charge ticket shows all pertinent information such as price per gallon, number of gallons, total cost and vehicle license number.

3) Protect the card by returning the card, after each usage, to the proper storage place in the vehicle.

4) Use the credit card only for the particular vehicle that the card is assigned.

3. Cash Purchases

If products or services cannot be obtained through the credit card, the employee may pay cash. Reimbursement is through a "Employee Expense Statement" SHA 30-502-L.

F. PREVENTIVE MAINTENANCE PROGRAM

1. General

The State's preventive maintenance guidelines are to be followed in servicing and maintaining passenger cars, station wagons, vans, pickups, and all other trucks or transportation type vehicles equipped with speedometer or odometer and serviced on a mileage sequence.

2. Purpose

To minimize wear and damage, and to avoid mechanical failure attributed to lack of service and maintenance at proper intervals. To increase performance and production, prolong useful life of equipment, increase availability, improve safety of operation, increase disposal value, improve public image, maintain favorable employee morale, and lower operation ownership cost in final analysis.

It is the duty of all operators of State-owned equipment and their supervisors to make the equipment available to the proper SHA shop when service is required. It is the duty of all shop personnel and their supervisors to perform service operations promptly and properly.

3. Routine Maintenance

The first or initial oil change, oil filter change and inspection on a new vehicle shall be performed at 1,000 miles or 60 days, whichever occurs first.

After initial inspection, the regular inspection period will be every 4,000 miles, or 6 months, whichever occurs first. This inspection will include a complete lubrication along with other services.

Every 12,000 miles a "C" maintenance will be performed on the vehicle. The extent of this service requires that the vehicle is taken to the Southern Avenue garage or Hanover Traffic Shop and a "spare" vehicle be used until the service is completed.

4. Exterior Maintenance - Washing, Polishing, Etc.

The vehicles are to be washed whenever needed, according to appearance weather and road conditions. Flushing with cold water and complete washing is encouraged, as soon as possible after traveling highways treated with chemicals during the winter months.

A new vehicle is not to be polished and/or waxed for at least six months; thereafter, it shall be polished and waxed at least once each year (check the manufacturer's manual - some paint finishes never require polishing).

All rust damage, dents, scratches, etc., are to be repaired a soon as possible. Until repairs are made, vehicles which have chipped paint, must be waxed more frequently to avoid corrosion or spread of rust.

CHAPTER 1-00 - GENERAL

SECTION 1-07 COMMUNICATIONS

Revised 11/01

A. GENERAL

Good communications are essential to efficient and safe operations. Every employee must strive to make his communications as effective as possible. Beside the usual verbal and written communications, PSD may directly or indirectly use the following communications systems:

1. Telephone
2. Mobile Radio
3. FAX Systems
4. Pagers

This section deals only with information regarding the use of the telephone and mobile radio systems. Personnel who need to use the FAX system should obtain specific instructions from the operators of this system.

B. TELEPHONE

Instructions for telephone usage, local and long distance, are found in the State directory. Be especially aware of these guidelines:

1. State telephones are for the conduct of State business.

2. When receiving and placing telephone calls, always identify yourself. For example:

   a. Answer a call thus, "Surveys, Charles Streeter speaking";

   b. Place a call in this manner, "This is Leroy Habersack of the State Highway Administration, may I speak to ..."

3. Do not make any personal toll calls that will be charged to the State.

C. MOBILE RADIO SYSTEM

1. General - The Federal Communications Commission (FCC) has licensed the Administration to operate a short-wave radio system.

This prime system consists of approximately 70 base stations and hundreds of mobile units. Mobile units include radio-equipped vehicles and portable, "Walkie Talkie," radios. It is classified as a mobile radio system. In addition, the Administration operates a statewide microwave system to extend the range of the prime system.

2. Channel Assignments - The Engineering Districts are assigned a single channel (frequency) from a statewide group of five channels. The assignment of channels throughout the State is made so inter-district radio interference is minimized. The channels are assigned as follows:

Channel	Frequency	Assigned To
1	47.32	Headquarters
2	47.26	Bridge Remedial Traffic
3	47.40	District 1
4	47.14	District 2
5	47.20	District 3
6	47.10	District 6
7	47.12	District 7
8	47.02	District 5

All shops and mobiles can be switched to Channel 1 for communications during emergency conditions.

3. Mobile Unit Identification Numbers - A unit identification number will be assigned to each mobile unit (vehicle and portable radios). Affix this identification number to the unit for reference when calling and answering (see Operating Procedures in this topic). All mobile units assigned to PSD are in the 800 series. Listings are issued to each operator whenever changes in radio assignments occur.

4. Operating Procedures

   a. Safety - Radio transmissions can discharge electric blasting caps. Never transmit near blasting operations without first receiving clearance from the foreman in charge.

b. Microphone Technique - Hold the microphone an inch or two from the mouth. Do not let the lips touch the microphone; this causes extraneous noises.

Strive to make each word and syllable distinctly understood. The listener's full attention can then be focused on the meaning of what you say. Choose words that have a clear, definite meaning and speak at a moderate rate. Use the "10-Code" (see paragraph f) to minimize words.

Do not shout into the microphone. This results only in distortion and makes your message more difficult to understand.

c. Calling and Answering - In calling and answering, base stations are identified by their geographical locations while mobile units (vehicle and portable) are identified by their unit identification number.

Whether calling or answering, the identification of the radio should be given first. For example,

SOC calls District 4 thus:
"SOC District 4"
District 4 then answers SOC,
"District 4"

Once the initial contact has been made, further identification is not necessary until sign-off, the FCC requires that each station (unit) identify itself at the end of each contact (at the end of each series of transmissions). The base station must use the call assigned by the FCC to its transmitter, as shown on the license. The mobile unit uses its regular unit identification number such as "806".

d. Message Handling - When transmitting a message, which must be written, allow the other operator time to write. Speak in natural phrases. Use the phonetic alphabet (see paragraph g) for difficult or unusual words.

On a long message pause at thirty-second intervals and ask if the message has been received thus far.

When a portion of a message is missed, do not ask for the entire message to be repeated; ask only for the part you missed.

This can be done by using such phrases as "10-9 word after...", 10-9 word before..., and "10-9 all between...and ...".

e. Courtesy - Develop the habit of listening before you transmit. Do not break into another's transmission. Genuine emergencies are excepted from this rule.

Keep all transmissions as short as possible. This is required by FCC rules, and it is practical because others might be waiting to use the channel. Do not chatter idly or talk about personal matters.

The use of obscene or profane language on the radio is a violation of the Federal Criminal Code.

f. The 10-Code - Use the 10-Code to conserve time and communicate clearly. The following is a list of 10 codes used by the State Highway Administration and the Maryland State Police:

10-1 Unable to copy signal	10-50 Accident (F, PI, PD)
10-2 Receiving well	10-51 Wrecker needed
10-3 Stop transmitting!/Emergency	10-52 Ambulance needed
10-4 Acknowledgement	10-53 Road blocked at ...
10-5 Relay / Relay message	10-54 Livestock on highway
10-6 Busy	10-57 Hit and run
10-7 Out of service	10-58 Direct traffic
10-8 In service	10-59 Convoy or escort
10-9 Repeat	10-61 Personnel in area
10-12 Standby	10-62 Reply to message
10-13 Weather/road conditions	10-63 Prepare to make written
10-17 Meet complainant	10-64 Message for local del.
10-18 Quickly	10-65 Met message assignment
10-19 Return to station	10-66 Message cancellation
10-20 Location	10-67 Clear for network mes.
10-21 Call by telephone	10-68 Dispatch information
10-22 Disregard	10-69 Message received
10-23 Arrived at scene	10-70 Fire alarm
10-24 Assignment completed	10-71 Advise nature of fire
10-25 Report in person	10-72 Report progress of fire
10-30 Unnecessary use of radio	10-73 Smoke report
10-33 Emergency	10-74 Negative
10-36 Correct time	10-75 In contact with
10-37 Suspicious vehicle	10-76 In route
10-39 Urgent use light/siren	10-77 ETA
10-41 Beginning tour of duty	10-78 Need assistance
10-42 Ending tour of duty	10-82 Reserve lodging
10-43 Information	10-84 If meeting advise ET
10-44 Permission to leave	10-85 Delayed due to ...

10-45 Animal carcass at ...	10-86 Officer/operator on duty
10-46 Assist motorist	10-87 Pickup/distribute checks
10-47 Emergency road repair at ...	10-88 Present telephone number
10-48 Traffic standard repair at...	10-92 Improp. parked vehicle
10-49 Traffic light out at ...	10-97 Check (test) signal

g. The Phonetic Alphabet - The phonetic alphabet is designed to aid in the spelling of difficult or unusual words. There are several versions of this alphabet. The one adopted by the Administration is:

Adam	John	Sam
Boy	King	Tom
Charles	Lincoln	Union
David	Mary	Victor
Edward	Nora	William
Frank	Ocean	Xray
George	Paul	Young
Henry	Queen	Zebra
Ida	Robert	

As an example, the word "phonetic" would be spelled as follows:

Paul Henry Ocean Nora Edward Tom Ida Charles

h. Operating Problems - When you have trouble with your radio, promptly report the specifics to your communications technician. But, do not automatically assume that your radio is at fault when you are unable to communicate with a desired station. The other radio, associated control equipment, or repeater station might be defective. Also, the operator at the other radio might be temporarily away from his unit; you could be out of range or in a "dead" spot; or the other radio might be turned off.

i. Operating Range - The prime system operates on the VHF band. At these high frequencies, radio waves act somewhat like light waves. They will not bend around corners, although they sometimes deflect around obstructions. Range is shortened when obstructions are between the radio units or when the units are over the horizon from each other.

In metropolitan areas range is usually shortened because of the shielding effect of buildings. This same effect occurs when inside tunnels or metal bridges. Therefore, operating range varies with operating conditions.

j. Optimum "Pointing" - Radios do not work equally well in all directions. There is a "best" direction for each.

k. Operational Aids - If you are unable to communicate with a desired station (unit), it might help to change location or move to a higher elevation.

CHAPTER 1-00 - GENERAL

SECTIONS 1-08 WORK HOURS AND TRAVEL

Revised 11/01

A. GENERAL

Field personnel of the Plats and Surveys Division, due to their Statewide work responsibilities, frequently find it necessary to travel long distances from their permanent residences.

B. DEFINITIONS

1. Headquarters - The Baltimore Office.
2. Residence of Record - The permanent residence of an individual as on file with the Plats and Surveys Division.
3. Assignment - The geographic location where an individual or surveys party is directed to report for work.
4. Local - The work assignment is less than 60 miles from the Party Chief's residence.
5. Out-of-town - The work assignment is 60 miles or more from the Party Chief's residence.

C. WORK HOURS

1. Local

   Employees shall travel on their own time to and from the work site or designated meeting place. This applies whether state or personal vehicles are used.

   Unless approved by the Division Chief or an Assistant Division Chief, the work hours are from 7:00 AM until 4:00 PM with 1 hour for lunch. If conditions dictate, the Party Chief may deviate from this schedule ONLY WITH THE ASSISTANT DIVISION CHIEF'S OR DIVISION CHIEF'S APPROVAL.

2. Out-of-town

   The work hours for out-of-town shall be the same as noted above except for arrival and departure days as noted below.

This policy supersedes all previously issued written or unwritten direction. This applies to all Survey Section Party Chiefs who are required to secure overnight lodging because of out-of-town status.

INITIAL TRAVEL DAY

Travel Distance from Residence to Job Site	Arrival Time on Job Site
Up to 150 miles	no later than 8:00 a.m.
151 miles to 175 miles	no later than 8:30 a.m.
176 miles to 200 miles	no later than 9:00 a.m.
Any mileage greater than 200 miles, add 30 minutes	per 25 miles

DEPARTURE DAY

Travel Distance from Job Site to Residence	Departure Time from Job Site
Up to 150 miles	no earlier than 3:00 p.m.
151 miles to 175 miles	no earlier than 2:30 p.m.
176 miles to 200 miles	no earlier than 2:00 p.m.
Any mileage greater than 200 miles, subtract 30	minutes per 25 miles

The travel distance and Arrival Time/Departure Time that the Party Chief will use for the Initial and Departure Days will be assigned when the survey crew receives the project assignments. All other assignments shall be carried out between the hours of 7:00 a.m. and 4:00 p.m. except when a change is authorized by the Division Chief or Assistant Division Chief.

D. LODGING

When the job site is 60 miles or more from the Party Chief's residence, the Party Chief will secure lodging and take meal allowances for himself and those members of his crew who reside 60 or more miles from the job site.

Lodging will only be taken at a motel/hotel that is on the Plats and Surveys Division's approved room rate list and also has agreed to bill the State directly for room charges. The Party Chief will pay the individuals their expense money and will file one expense account for the survey crew as an entity.

The Party Chief will follow the following procedures when taking lodging:

1) Ascertain if the establishment is on the approved Plats and Survey Division's approval list and will direct bill the State.

2) Show photo ID and copy of "Letter of Authorization" to desk clerk.

3) Inform the clerk that room charges are the only items that are to be shown on invoices and that the crew prior to checking out will pay all other charges.

4) Direct the clerk to send invoice to:

   Chief, Plats and Surveys Division
   707 North Calvert Street
   Baltimore, MD 21203-0717

5) On a weekly basis forward to the Office a completed "Accommodation Verification" form for comparison to invoices. See Figure 1-08-B for an example of this form.

An employee may stay at a place other than where the crew is lodged (for example - a relative's home). When the employee exercises this option, he will be allowed $20.00 per night for lodging. A signed receipt must be obtained from the provider and given to the party chief.

E. MEAL ALLOWANCE

1. Local

   The cost of breakfast is reimbursable when an employee in travel status has to leave home on official business 2 or more hours before the start time of the employee's shift.

MARYLAND DEPARTMENT OF TRANSPORTATION
EMPLOYEES EXPENSE STATEMENT

Employees Name (Print)	Classification Title	Employee ID	Period Covered	Agency
Kenneth Hook	ET IV	2136078 14 [redacted]	04 24 91 to 05 07 91	SHA

Date Mo.	Date Da.	Destination From	Destination To	Account Charge	P O N	Vehicle Mileage Subsistence	Vehicle Mileage Job	Vehicle Amount	Other Transportation Amount	Breakfast	Lunch	Dinner	Total Meals	Room	Miscellaneous Amount	Miscellaneous Description
04	24	Woodsboro	Rte 26 & Oakland Mill	AW 261-203-377	N	33			7.92							
"	25			Q 508-305-270	N	33			7.92							
"	26			CH 555-301-570	N	33			7.92							
"	29			Q 627-301-270	N	33			7.92							
"	30			"	N	33			7.92							
05	01			"	N	33			7.92							
	03			P 891-301-371	N	33			7.92							
	06			M 248-302-372	P	33			7.92							
				TOTALS		264			63.36							

STATEMENT TOTAL 63.36

DO NOT WRITE BELOW THIS LINE — OFFICE OF FINANCE AND PROGRAM MANAGEMENT USE ONLY

Card Type	Control No.	Employee ID	
10		2136078 14 [redacted]	10

—PUNCH ON ALL CARDS—

Card Type	S/O	P	Subsistence Mileage	Job Mileage	Other Transportation	Meals	Room	Miscellaneous	Statement Total
05	S	R	264						63.36
06									
06									
06									

Card Type	User R.C.	Objective	Account Charge	P O N	Distribution Memo	Amount	CR
07		818	AW 2611-2013	N	518	17.92	
07		818	Q 5081-3015	N	518	17.92	
07		818	CH 5551-3011	N	518	17.92	
07		808	Q 6271-3011	N	518	23.76	
07		818	P 8911-3011	N	521	17.92	
07		818	M 2481-3012	P	521	17.92	
07							
07							

I HEREBY CERTIFY THAT THE ABOVE EXPENSES WERE INCURRED BY ME EXCLUSIVELY IN CONNECTION WITH OFFICIAL BUSINESS OF THE MARYLAND DEPARTMENT OF TRANSPORTATION.

(SEE REVERSE SIDE)

Kenneth Hook
EMPLOYEES SIGNATURE

05-07-91
DATE

667
RESPONSIBILITY CENTER

[signature]
AUTHORIZED APPROVAL

ADDITION CHECKED BY ____

DISTRIBUTED BY ____

AUDITED BY ____

SHA 30-502-L
4-1-88 ORIGINAL-OFFICE OF FINANCE AND PROGRAM MANAGEMENT

EMPLOYEE'S EXPENSE STATEMENT (MILEAGE)

FIGURE 1-08A

The cost of dinner is reimbursable when an employee in travel status arrives at home 2 or more hours after the employee's normal quitting time. In both cases, the 2 hours are in addition to the normal commuting time.

In cases when an employee meets the conditions for both breakfast and dinner reimbursement as listed above and is in travel status for the entire day, or if the employee is required to stay overnight, the employee's lunch also is reimbursable.

2. Out-of-town

The Party Chief will reimburse himself and members of his crew the cost of meals in accordance with the rate schedule in effect. On the first day of the work week, breakfast allowance will not be allowed. On the last day of the workweek, dinner allowance will not be allowed unless the conditions as indicated under Local Meal Allowances (above) are met.

F. MILEAGE

1. Local - Employees using personal vehicles when total round-trip driving distance is less than 120 miles to the job site, Party Chief's residence or designated meeting place whichever is closest will be allowed mileage at the effective rate. Distances will be measured by shortest paved route.

2. Out-of-town - For employees using personal vehicles the maximum mileage allowed will be 120 miles round trip. Only one round trip will be allowed each week.

   Claimed mileage is to be entered on the Employee's Expense Statement as if the round trip occurred on the first day of the workweek.

3. Toll Fee - Personnel required to use Maryland Toll Facilities while commuting or on travel status will be reimbursed for toll fares. Items are to be entered on Employee's Expense Statement and receipts submitted.

4. Reimbursement - Claims for reimbursement must be made on Form SHA 30-502-L, Employees Expense Statement (see Figure 1-08-A). This form is to be submitted every two weeks on a schedule established by the Administration.

Exp Acct # 06
CKs # 256, 258, 259, 260, 261, 263

MARYLAND DEPARTMENT OF TRANSPORTATION
EMPLOYEES EXPENSE STATEMENT

EMPLOYEES NAME (PRINT)	CLASSIFICATION TITLE	EMPLOYEE ID	PERIOD COVERED	AGENCY
JOHN SMITH	E. T. VI	220341481 [redacted]	022791 TO 031291	SHA

DATE MO. DA.	DESTINATION FROM	DESTINATION TO	ACCOUNT CHARGE	P O N	VEHICLE MILEAGE SUBSISTENCE	VEHICLE MILEAGE JOB	VEHICLE AMOUNT	OTHER TRANSPORTATION AMOUNT	BREAKFAST	LUNCH	DINNER	TOTAL MEALS	ROOM	MISCELLANEOUS AMOUNT	MISCELLANEOUS DESCRIPTION
02 27	LANHAM	CLINTON	P 391-201-570	N					16.00	28.00	56.00	100.00	20.00		
" 28	"	"	"	"					16.00	28.00	56.00	100.00	20.00		
03 01	"	GRANTSVILLE	"	"					16.00	28.00		44.00			
" 02	-		644087											10.00	PARKING RENT - MONTH OF FEB 91
" 04	GRANTSVILLE	LANHAM	P 732-502-371	N						28.00	56.00	84.00	20.00		
" 05	LANHAM	LARGO	"	"					16.00	28.00	56.00	100.00	20.00		
" 06	"	"	"	"					16.00	28.00	56.00	100.00	20.00		
" 07	"	"	"	"					16.00	28.00	56.00	100.00	20.00		
" 08	"	GRANTSVILLE	"	"					16.00	28.00		44.00			
" 11	GRANTSVILLE	LANHAM	"	"						28.00	56.00	84.00	20.00		
" 12	LANHAM	LARGO	"	"					16.00	28.00	56.00	100.00	20.00		
			TOTALS									856.00	160.00	10.00	STATEMENT TOTAL 1026.00

DO NOT WRITE BELOW THIS LINE — OFFICE OF FINANCE AND PROGRAM MANAGEMENT USE ONLY

CONTROL NO.	EMPLOYEE ID	22 23
10	2203411481 [redacted]	06

—PUNCH ON ALL CARDS—

CARD TYPE	S/O	P	SUBSISTENCE MILEAGE	JOB MILEAGE	OTHER TRANSPORTATION	MEALS	ROOM	MISCELLANEOUS	STATEMENT TOTAL
05	S	R				856.00	160.00	10.00	1026.00
08									
08									
08									

CARD TYPE	USER R.C.	OBJECTIVE	ACCOUNT CHARGE	P O N	DISTRIBUTION MEMO	AMOUNT	CR
017		88	P 39111-2011	N	SR	284.00	
017		88	P 17321-15021	N	SR	732.00	
017		84	644087		SR	10.00	
017							
017							
017							
017							
017							

I HEREBY CERTIFY THAT THE ABOVE EXPENSES WERE INCURRED BY ME EXCLUSIVELY IN CONNECTION WITH OFFICIAL BUSINESS OF THE MARYLAND DEPARTMENT OF TRANSPORTATION.

(SEE REVERSE SIDE)

John Smith
EMPLOYEES SIGNATURE

03-12-91
DATE

61.7
RESPONSIBILITY CENTER

D. S. Koulder
AUTHORIZED APPROVAL

ADDITION CHECKED BY

DISTRIBUTED BY

AUDITED BY

SHA 30-302-L
4-1-88 ORIGINAL-OFFICE OF FINANCE AND PROGRAM MANAGEMENT

PARTY CHIEF'S EXPENSE STATEMENT

FIGURE 1-08B

CHAPTER 1-00 - GENERAL

SECTION 1-09 REPORTS AND RECORDS

Revised 11/01

A. DAILY REPORT CARD

1. General

   Daily, each Party Chief shall record his party's operations on SHA Form 61-1-144. (Figures 1-09-A and 1-09-B are examples of completed Daily Report Cards.) Every effort should be made to mail these reports to the SHA's Baltimore Office on a daily basis. Errors are much more probable when entries are delayed for one or more days and made from memory.

2. Information to Report

   The Daily Report is mostly self-explanatory as to the information to be reported. The "Party" portion of the card shall contain a listing of the party's assigned personnel, their attendance status, and their Engineering Technician rank. The following letters shall be used to designate the condition of the crew member's attendance:

   P - Present
   V - Vacation
   S - Sick
   L - Personal Leave
   M - Military Leave
   W - Leave Without Pay
   A - Administrative

B. PARTY CHIEF'S DIARY

Each day, the Party Chief shall enter into a diary all the information contained on the Daily Report Card. In addition, he should record details of the following:

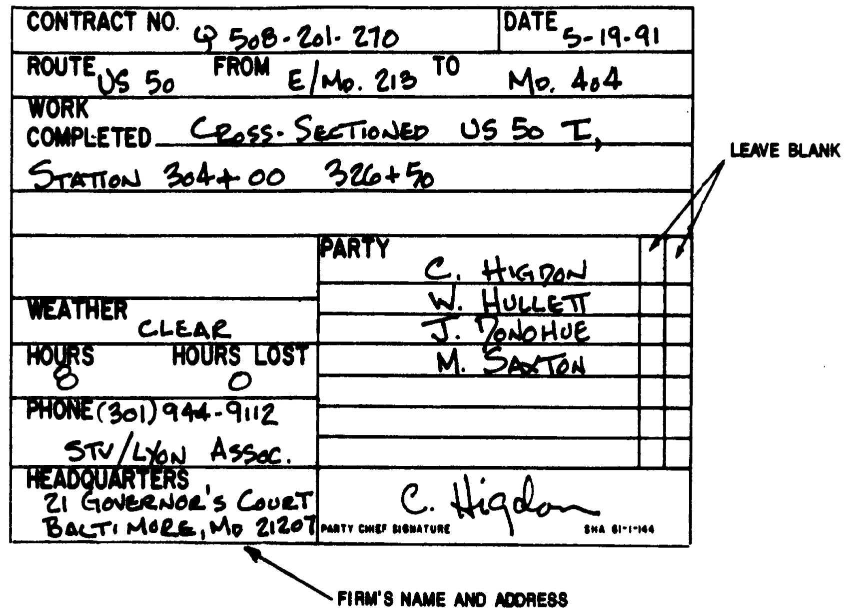
1. Vehicle Mileage

2. Any Vehicle Maintenance (include gas usage)

3. Party Expenses

4. Miscellaneous Expenses

5. Checks written on State Account



CONTRACT NO. Q 508-201-270 | DATE 5-19-91

ROUTE US 50 FROM E/MD. 213 TO MD. 404

WORK COMPLETED Cross-Sectioned US 50 I, Station 304+00 326+50

PARTY C. Higdon, W. Hullett, J. Donohue, M. Saxton

WEATHER Clear

HOURS 8 HOURS LOST 0

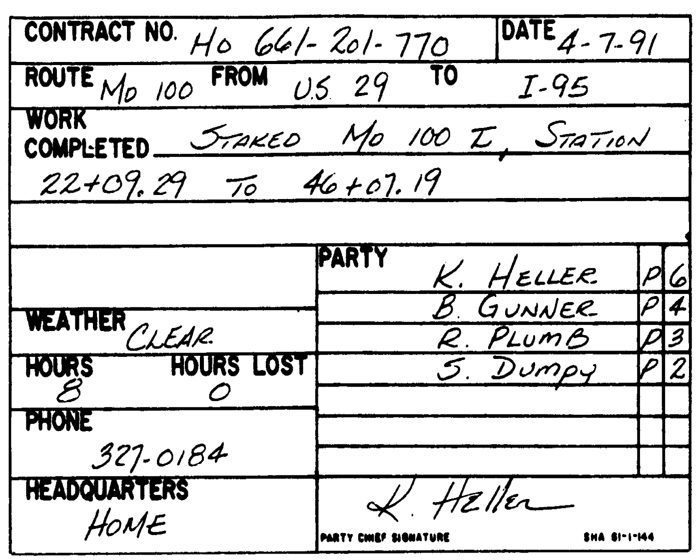
PHONE (301) 944-9112

STV/Lyon Assoc.

HEADQUARTERS 21 Governor's Court Baltimore, MD 21207

C. Higdon
PARTY CHIEF SIGNATURE SHA 61-1-144

FIGURE 1-09-A CONSULTANT'S REPORT CARD



CONTRACT NO. Ho 661-201-770 | DATE 4-7-91

ROUTE MD 100 FROM US 29 TO I-95

WORK COMPLETED Staked MD 100 I, Station 22+09.29 To 46+07.19

PARTY K. Heller P 6, B. Gunner P 4, R. Plumb P 3, S. Dumpy P 2

WEATHER Clear

HOURS 8 HOURS LOST 0

PHONE 327-0184

HEADQUARTERS Home

K. Heller
PARTY CHIEF SIGNATURE SHA 61-1-144

FIGURE 1-09-B STATE PARTY REPORT CARD

6. Conversations with property owners, contractors, Area Engineers, other SHA employees, etc. (Be specific and note proper names and titles.)

7. Personnel problems.

8. Any other matters of importance.

C. PROJECT CARD

1. General

   A Project Card, SHA Form 61.7-5-2, shall be prepared and accompany each survey project. (Figure 1-09-C is an example of a completed Project Card.)

2. Area Engineer

   The Area Engineer in charge of the project will initiate and complete the following parts of the Project Card as shown in Figure 1-09-C:

   1. Road system the survey project is to be performed on.

   2. Area Engineer's initials and date(s) project was set up.

   3. Method of survey request, requester's name and Division. (Note: Copy of Requesting Letter is to accompany job.)

   4. Party Chief's name the project is assigned to.

   5. Contract number that is to be entered on index page of survey books.

   6. Contract number against whose account monies will be charged.

   7. Route number and termini of survey project.

   8. Beginning station and ending station of survey project, if applicable.

   9. Character of work, such as topo, cross-sections, data collection, metes and bounds, etc.

   10. Special instructions.

   11. Type of supplemental material that accompanied survey request.

HO 661-201-770 HOWARD CO.

☑ PRIMARY ①
☐ SECONDARY
☐ INTERSTATE

SET UP ② R.S.W 5/20/91

☑ LETTER
☐ PHONE
☐ VERBAL
③ R. SMITH - HWY DESIGN

CHIEF OF PARTY K. HELLER ④

CONTRACT NO. HO 661-201-770 ⑤ CHARGED TO SAME ⑥ P.N.

PROJECT MD RTE 100 ⑦
US 29 TO I-95

STATIONS 22+09.29 TO 170+99.36 ⑧

CHARACTER OF WORK STAKE TRAVERSE ⑨

☐ CHARGED

REMARKS SET CONTROL POINTS FOR SPURS, BUT DO ⑩
NOT RUN IN AT THIS TIME

☐ PLANS ⑪ — ☒ SURVEY SET UPS OR LAYOUTS ☐ PLATS (R/W OR SUB-DIV.)

BOOK NUMBERS BK 23104 - CONTROL BK 22913 - B.M.s ⑫

NEW BOOK NUMBERS 29818 & 29819 - TRAVERSE STK'T ⑬

SHA FORM NO. 61.7-5-2

(FRONT)

STARTED PROJECT 6/3/91 ⑭

COMPLETED PROJECT 8/14/91 ⑮

WORKING DAYS CHARGED TO PROJECT 29 ⑯

DAYS LOST ON ACCOUNT OF WEATHER 3 ⑰

REMARKS ⑱

(REVERSE)

FIGURE 1-9-C PROJECT CARD

12. Numbers of survey books contained in job package. If none enter "None."

3. Party Chief

After the project has been completed, the Party Chief is to complete the Project Card. Figure 1-9-C shows that the Party Chief is to fill in the following numbered spaces:

13. New Book numbers and their contents.

14. Date when surveys began.

15. Date when surveys were completed.

16. Number of days charged to project.

17. Number of charged days lost to weather.

18. Any remarks about project that cannot prudently be entered into survey books.

CHAPTER 1-00 GENERAL

SECTION 1-10 EMPLOYEE LEAVE

Revised 11/01

A. GENERAL

Leave is an authorized absence from work for a specific time. FAILURE TO OBTAIN AUTHORIZATION FOR AN ABSENCE WILL RESULT IN DISCIPLINARY ACTION.

B. REQUESTING LEAVE

All leave requests must be submitted on Form DTS-31 (Request for Leave) for approval. Written leave requests must be submitted for all leave taken (includes Personal, Sick Leave, etc.), even if the leave request was verbally approved and the leave has been taken. This documentation is needed for the file.

Each employee is responsible for keeping a personal record of his/her annual, personal, sick, and/or compensatory leave use, and to check those records against the quarterly summary issued by the SHA Payroll Section. The employee is to check this record to see if the leave being requested is available before submitting a "Request for Leave" form to the Supervisor for approval.

During certain high leave usage seasons, it is advisable to submit a leave request as soon as possible. Every effort will be made to approve requests for leave; however, manpower and workload will be the determining factor and leave could be denied. It is, therefore, beneficial for the employee to make his/her request as early as feasibly possible.

C. UNSCHEDULED ABSENCES

It is realized that because of illness and other emergencies, it is not always possible to schedule advanced leave. When this occurs, it is absolutely essential that the employee notify their immediate supervisor as soon as possible and no later than 1/2 hour after normal starting time. SUPERVISORS WILL DETERMINE WHETHER OR NOT TO GRANT APPROVAL OF LEAVE.

It is absolutely essential that survey personnel notify their immediate supervisor, and one of the Assistant Division Chiefs or the Field Coordinator as soon as possible and no later than 8 a.m. (work shift begins at 7:30 a.m.) on the day of their absence.

For obvious reasons, field personnel must make every effort to contact their Party Chief prior to his departure for work on that day. The employee will state the reason that they are requesting to be absent and the expected date of their return.

EMPLOYEES WHO FAIL TO GIVE PROMPT NOTICE OR WHO FAIL TO RECEIVE APPROVAL FOR THEIR ABSENCE ARE TO BE CONSIDERED ON UNAUTHORIZED ABSENCE AND ARE SUBJECT TO DISCIPLINARY ACTION.

D. LATENESS

It is the duty and responsibility of every employee to report to work on time. Employees who are late for work and are not on approved leave will not be excused unless a satisfactory explanation is provided to his/her immediate supervisor.

Supervisors have the authority and responsibility for determining whether or not to excuse lateness or to grant leave. Supervisors also have the authority to request verification of the reason for lateness and emergency leave.

If the lateness is excused, the employee has the option of charging the time to vacation or personal leave. If leave is not available or if the lateness is not approved by the supervisor, time will be charged to leave without pay. Chronic lateness will result in disciplinary action being taken.

. ANNUAL LEAVE

Annual Leave is earned per 26 payroll periods, excluding overtime, at a rate depending on years of service.

Full-time employees may carry a maximum of 50 (400 hours) leave days over into the following calendar year. New, permanent employees must work 6 months before they may use Annual Leave, at which time 5 days will be available.

Employees requesting approval of annual leave for up to one day should notify one of the Assistant Division Chiefs or the Field Coordinator, prior to 12 noon of the previous work shift. Employees desiring leave greater than one day should request approval from one of the Assistant Division Chiefs or the Field Coordinator prior to 12 noon on Wednesday of the week preceding the requested leave.

An employee requesting leave must verify its approval. This will be done by the employee informing the Party Chief of the requested leave and having the Party Chief recommend approval by initialing the leave form prior to its submittal to the office.

The Party Chief will then call the office no less than three (3) working days prior to the requested leave to verify the leave has been approved. This will also assure that the employee's written request has been received and approved at the office and appropriate work assignments can be made.

F. PERSONAL LEAVE

All permanent employees are given 6 Personal Leave days which they may use any time during that calendar year, without prior written approval, after proper notification to their supervisor. Proper notification is notifying the immediate supervisor up to 1/2 hour after the normal starting time on the day on which Personal Leave is to be taken.

For Survey Party Staff, proper notification is calling your Party Chief prior to his departure from his residence, or if the Party Chief can not be reached, contact one of the Assistant Division Chiefs or the Field Coordinator no later than 8 a.m.

Personal leave may NOT be carried over into the next calendar year. Unused Personal Leave will be forfeited by the employee and transferred to the Leave Bank. This leave may be transferred to an employee who has a documented medical disability.

An employee who meets all the requirements for Payment of Unused Personal Leave for a full calendar year may be paid for up to three (3) days of unused personal leave.

G. SICK LEAVE

1. General

   Sick Leave is time off with pay when an employee is unable to work because of illness, injury or disability, or for an appointment with a licensed medical provider or because of death of an immediate family member (DIF). Death in the Family leave is not counted against the employee's number of sick leave occurrences.

   Earned sick leave may be used to accompany an immediate family member to a medical appointment, or to provide medical care and treatment in the event of illness, injury, or other disability.

2. Prolonged Illness

Employees on a prolonged illness will be expected to notify their supervisor at least once every two weeks of any changes in their current condition and their anticipated return to work date. A medical certificate (see Medical Documentation) shall be forwarded to the supervisor not less than once a month or as often as every two weeks, if the circumstances justify.

In case of a prolonged sickness and all sick leave has been exhausted, employee may request leave from the: Employee Leave Bank, Employee Leave Donation Program, Advanced Sick Leave, Extended Sick Leave, and/or Approved Leave without pay.

3. Advanced Sick Leave

Advanced Sick Leave may be granted at a rate of 15 days for each year of completed service, up to a maximum of 60 days in any calendar year. In the case of approved Advanced Leave, leave shall be repaid at a rate of 50% of sick leave earnings. (At the 50% pay back rate for each day of leave earned, only one half will be available to the employee for future use.)

ADVANCED SICK LEAVE REQUESTS MUST BE APPROVED BY THE DIVISION CHIEF AND THE APPROPRIATE PERSONNEL OFFICER. IT IS, THEREFORE, NECESSARY THAT THE EMPLOYEE ALLOW SUFFICIENT TIME TO RECEIVE THESE APPROVALS PRIOR TO THE REQUESTED LEAVE DATE.

4. Extended sick leave

An employee may be allotted extended sick leave for a specific illness in an amount equal to the amount of earned sick leave the employee used for that illness or related condition during the preceding two (2) years prior to the last day of work and any other paid leave the employee used for that illness or related condition after the employee's last day of work.

Extended sick leave may not exceed twelve (12) months for a specific illness. The employee must provide medical documentation that the previous earned sick leave used was for the illness or related condition necessitating the request for extended sick leave. An employee must have exhausted all other leave, including advanced sick leave. An employee shall complete an Extended Sick Leave Request Form and submit it to the Appointing Authority.

The Department Medical Advisor shall determine whether extended sick leave is medically necessary and the duration of the extended sick leave. In making this determination, the Department Medical Advisor may require the employee to submit to a medical examination. Any employee that refuses to submit to a medical examination shall have their request for extended sick leave denied.

5. Sick Leave Counseling

Abuse of sick leave will result in appropriate disciplinary action.

A medical certificate authenticating the period of illness (even less than one day) may be required from an employee who has been absent for five or more occurrences in any twelve month period. The Division Chief may implement the requirement of this certification with the approval of the Attendance Control Officer. This One-Day Sick Certificate requirement must be for at least a six-(6) month period. The requirement may be extended in six (6) month intervals.

Whenever, in the opinion of the Attendance Control Officer, the sick leave taken by an employee is of a questionable nature, or indication of a serious medical condition which prevents the employee from properly completing his duties, the appointing authority may refer the employee to a Work Ability Evaluation.

Employees who have four separate, undocumented occurrences of sick leave in ANY twelve month period will be referred to their supervisor or representative to discuss their usage of sick leave and receive counseling as appropriate. A written record of the discussion, including the employee's justification and conclusions agreed upon, would be made for the working files.

Upon the sixth undocumented sick leave occurrence in any twelve-month period, the supervisor will again counsel the employee. Possible courses of action for the supervisor include: referring the employee to EAP, referring employee to the medical advisor, and/or continuing to monitor the situation.

Any further undocumented occurrences of sick leave may subject the employee to appropriate administrative actions in accordance with the policies and regulations of the Department, including disciplinary actions as necessary and appropriate.

H. EMPLOYEE LEAVE BANK / LEAVE DONATION PROGRAM

When an employee exhausts ALL leave and has been out 10 or more consecutive work days due to illness/injury, he/she may receive leave from the Leave Bank as long as they are a member, that is, have donated a minimum of 8 hours leave to the bank. Membership lasts for a two-year period. An employee may receive up to 2080 hours.

I. LEAVE WITHOUT PAY

After using all available leave and an employee wants to take off from work, he/she is required to report to work unless there is an emergency. When he/she calls the supervisor requesting leave without pay, the supervisor may deny that leave if they do not accept the reason for not reporting to work. A supervisor may request appropriate documentation to support granting leave without pay for the emergency. Example: Dr.'s slips for sick leave, car repair slip for car problems, etc. Each case will be evaluated separately.

CHAPTER 2-00 - SURVEY EQUIPMENT

SECTION 2-01 CONTROL

Revised 11/01

A. TECHNICAL SUPERVISOR AND DIVISION PROCUREMENT OFFICER

The Administration-wide control of surveying equipment is the responsibility of the Technical Supervisor and Division Procurement Officer, Plats and Surveys Division. He is responsible for the procurement and maintenance of this equipment as well as maintaining an inventory which shows the location of each piece of equipment and the person or responsibility center to whom it is assigned.

B. PARTY CHIEF

When equipment is assigned to a survey party, the Party Chief is the responsible agent.

C. GPS TECHNICIAN

Each GPS technician is responsible for the GPS receiver, truck and accessories that they work with.

CHAPTER 2-00 - SURVEY EQUIPMENT

SECTION 2-02 CARE OF EQUIPMENT

Revised 11/01

A. GENERAL

Proper care and respect for all equipment should be the hallmark of every survey party. The Party Chief is responsible for his party's equipment. He shall train all members to properly care for this equipment and delegate the responsibilities for such care. The Party Chief shall also see that the equipment is used for its intended purpose. Party members must understand the absolute necessity of using the proper equipment, in the proper condition, for given tasks.

B. TOTAL STATION INSTRUMENTS

The total station instrument is one of the most expensive pieces of equipment used by the survey crew. It should be treated with the same care as any precision instrument.

The name Total Station is applied to instruments that combine an Electronic Distance-Measuring (EDM) instrument and a Theodolite. See Chapter 2, Section 5 for a detailed description of these instruments.

The Total Station has almost completely replaced the Engineer's Transit and the optical-reading Theodolite. Thus, Total Stations are the only type of angle measuring instrument discussed herein.

If handled carefully, total stations will stay in adjustment and produce consistently good results. Some general guidelines for the care of Total Stations are:

1. Vehicular Transport

    a. Transport and store Total Stations in their carrying case in positions that are consistent with their carrying case design.

    b. Protect all instruments from excessive vibrations. If possible, line the inside of the lock box with carpet, foam or other cushioning material to reduce vibration.

2. Casing and Uncasing

a. Before removing an instrument, study the way it is placed and secured in the case. This will help in properly re-casing the instrument.

b. Carefully remove the instrument. Grip it with both hands, but do not grip where pressures will be exerted on tubular or circular level vials, which can be forced out of adjustment.

3. Field Transport

a. Short Distances - Total Station instruments may be moved short distances while still fastened to the tripod but ONLY with the instrument vertical (the tripod legs pointed down). DO NOT "SHOULDER" ANY TOTAL STATION! That is, do not carry a Total Station horizontally while mounted on a tripod. Doing so may damage the instrument beyond repair.

This precaution is necessary because the center spindle (center spigot or the standing axis) of a Total Station is hollow and relatively short. When carried horizontally while on a tripod, the instrument's weight is an excessive load for the hollow centerpiece to bear. Instrument damage can result if this precaution is ignored. Also, the instrument fastener can break, causing the Total Station to fall.

b. Moderate distances - When moving the instrument moderate distances, release the tribrach clamp and carry the instrument by the carrying handle.

c. Long Distances - For long distances or over rough terrain, place the instrument in its carrying case. Take a safe route to all set-up sites.

4. Setups

a. When possible, select instrument stations where operation is not dangerous to the Instrument Man, the party, or the instrument. Select stable ground for the tripod feet. Do not set an instrument near the front or rear of a vehicle or equipment, which is likely to be moved.

b. At the site, firmly plant the tripod with its legs widespread. Push parallel to the legs, not vertically downward. On smooth surfaces, use some type of tripod leg restrainer to keep the legs from sliding outward.

c. Always have the tripod firmly set over the point before removing the instrument from its carrying case. Immediately secure the instrument to the tripod with the instrument fastener. Never leave an instrument or its tribrach on the tripod without securing either to the tripod.

   Moderate pressure on the instrument fastener screw is sufficient. Excessive tightening causes undue pressure on the foot screws and on the tribrach spring plate. This can warp the instrument fastener's shifting arm.

d. Make sure the tribrach screw or clamp is tight or in the "lock position". This precaution is especially important when traversing and using tribrachs for "forced-centering" of sights and the Total Station.

5. Routine Care

   a. Daily Inspection - before making the first set-up of the day, visually inspect the instrument for cracks, bumps, and dents. Check the machined surfaces and the polished faces of the lenses and mirrors. Try the clamps and motions for smooth operation (i.e., absence of binding or gritty sounds).

   b. Cleaning - Frequently clean the instrument externally. Any accumulation of dirt and dust can scratch the machined or polished surfaces and cause friction and sticking in the motions.

      1) First, remove all dust with a camel's-hair brush.

      2) Clean soiled non-optical parts with a soft cloth or with a clean chamois.

      3) Clean the external surfaces of lenses with a fine lens brush. Then, if necessary, use a lens tissue. Do not use silicone treated tissues: they can damage coated optics. Also do not use liquids. If required, fog the lenses or their coatings. DO NOT loosen or attempt to clean the internal surfaces of any lenses.

   c. Cover an instrument whenever it is uncased and not being used.

d. Dry a wet instrument as completely as possible before casing. After work uncase the instrument in a clean room and dry it thoroughly. (If the instrument is left in the case, an increase in temperature can condense moisture inside the instrument.) Circulating air around the instrument will speed drying.

e. NEVER leave an instrument unattended. If you must leave it, have another party member watch it for you. Protect the instrument from people, animals, equipment, rain, sand, dust, wind, traffic and other hazards.

f. Never point the instrument directly at the sun. Sunlight shining directly into the instrument can damage receiving elements.

g. Protect Total Stations from excessive heat. Heat can cause erratic readings and deterioration of components. Do not leave instruments in closed vehicles, which are parked in the sunlight.

h. Keep batteries well charged. Low batteries can cause erratic readings.

i. When not in use, keep reflectors in their containers.

j. Keep reflectors clean to ensure maximum light return. Clean with a camel's-hair brush and lens tissue.

6. Adjustments - Keep instruments in good adjustment. But, only make adjustments when results are poor or excessive manipulation is required. Test frequently.

   a. Check optical plummets every three months or before calibration on the EDM range. They can and do go out of adjustment from bumps or jars.

   b. Frequently check the condition and adjustment of tripods because they directly affect accuracy.

   c. Only attempt those adjustments, which are listed in Section 2-05. DO NOT "field strip" (dismantle) Total Stations.

C. AUTOMATIC LEVELS (SELF-LEVELING)

Automatic levels are the standard leveling instrument used on MD SHA survey parties.

These levels are fast, accurate, and easy to maintain. Proper care is required to ensure continuous service and required precision. DO NOT disassemble them in the field. Only attempt those adjustments set forth in Section 2-04.

Review the previously stated guidelines for care of total stations. These guidelines are also generally true for the proper care of pendulum levels (except that levels may be shouldered). Additional guidelines are:

1. Do NOT spin automatic levels; this can adversely affect the compensatory.

2. Protect the level from dust. Dust or foreign matter inside the scope can cause the compensator's damping device to hang-up.

3. Frequently check the adjustment of the bullseye bubble. Adjust the bulls-eye to the center, not almost to the center. Make certain it is adjusted along the line of sight and transversely, as well. Proper adjustment reduces the possibility of compensator hang-up.

4. Do NOT tap the instrument or the tripod to check for compensator hang-up: check by turning a foot screw back and forth. If the compensator is malfunctioning, send the instrument in for servicing. Do not attempt compensator servicing in the field.

D. TRIPODS

A stable tripod is required for precision in measuring angles. Therefore, a tripod should not have any loose joints or parts, which might cause instability. Some suggestions for proper tripod care are:

1. Maintain a firm snugness in all metal fittings, but never tighten them to the point where they will unduly compress or injure the wood, strip threads, or twist off bolts or screws. (This includes leg clamps.)

2. Tighten leg hinges only enough for each leg to just sustain its own weight (when spread out in its normal working position).

3. Keep metal tripod shoes clean and free from dirt. They should also be tight.

4. Keep all tripods well painted or varnished to reduce moisture absorption and swelling or drying out and subsequent shrinking.

(A bright yellow color has been adopted as the standard color for the Department's tripods.)

5. Replace top caps on tripod heads when the tripods are not in use.

6. Regularly check the shifting-arm pivot-screw for tightness. The degree of tightness does not affect the free pivoting of the shifting arm.

   Total stations and automatic levels are secured to the tripod by an instrument fastener screw. This 5/8" x 11 screw fits in and slides along a "shifting-arm" which is fastened at one point under the tripod head by a shifting-arm pivot-screw.

E. LEVEL RODS

1. General - Maintain level rods as you do other precise equipment. Accurate leveling is as dependent on the condition of rods as on the condition of levels. Reserve an old rod for rough work, such as measuring mud depths. San Francisco "Frisco", geodetic, and 25-foot fiberglass rods are the types most often used. The care requirements, common to all of them, are:

   a. Protect from moisture, dirt, dust, and abrasion.

   b. Clean graduated faces with a damp clothe and wipe dry.

   c. Touch graduated faces only when necessary.

   d. Avoid laying a rod on matter or material where soiling might result.

   e. Do not set a rod where it might fall or be knocked over.

   f. If the rod must be laid down, place the rod face up.

   g. Do not abuse a rod by throwing, dropping, or dragging it or by using it as a vaulting pole.

   h. Refrain from using the metal "shoe", or "foot", for scraping foreign matter off a bench or other survey points.

   i. If possible, leave a wet rod uncovered and extended until it dries.

j. When not in use, store rods in protective cases and in a dry place. Do not store rods where other equipment can hit or abrade them.

k. Store the rods either vertically or horizontally with at least 3-point support.

l. Periodically check all screws and hardware for snugness and for operation.

2. Frisco Rod - These rods are sturdy, but abuse and lack of care will take a toll in lost time and accuracy. Protective practices for a Frisco include:

   a. When the rod is being extended fully, gradually ease the two sections apart until the stops are engaged, not until they "collide".

   b. Only tighten the knurled knob clamp to a snug condition.

   c. Carry an extended rod with a wooden side down to minimize "whip". When walking adjacent to traffic lanes be careful to carry a rod parallel with the roadway. Do not swing a rod into a traffic lane.

   d. As needed, clean and re-coat the tape face with clear polyurethane.

3. Geodetic Rod - These of rods are precisely made and standardized. Extra care is required to retain this precision.

   a. Store, by "matched" pairs, in a dust-tight, water-tight box with full rod support on all sides and at the ends.

   b. Do not use in rain or dust.

   c. Carry parallel with the ground. Also, alternately carry it "face-up" and "face-down" to equalize weight stresses.

   d. Avoid laying rod on the ground.

   e. If foreign matter has "fouled" a rod, carefully disassemble and clean. The invar face must slide freely in the recessed guides as the outer part expands or contracts.

   f. If a rod is refinished, be sure the guides do not become clogged.

4. 25-Foot Fiberglass Rod - Though these rods are made of strong, resilient fiberglass, specific care is required.

   a. Grit and sand can "freeze" the locking system of the slip joints. The close fit of these joints will not tolerate foreign matter. Do not lay a fiber glass rod in sand, dust, or loose granular material.

   b. "Lower" the sections as the rod is being collapsed; do not let them "drop". Dowels through the bottom of a section keep the section above from falling inside that section. "Dropping" sections during collapsing can loosen the dowels and jam the telescoping. Dropping can also shatter the fiberglass around the dowel holes.

   c. Remove the rubber boot each day and shake out any grit.

   d. Store in a carrying case.

   e. When a slip joint goes bad, promptly remove the rod from service for repair.

   f. Lubricate the rod with oil-free silicone spray or with talcum.

F. TAPES

A reliable, properly standardized tape is vital to a party's operations. Routine care extends tape life and helps prevent errors and blunders. Some guidelines to follow are:

1. After the day's work, clean and dry tapes, which are soiled. In wet weather lightly oil, then dry before storing. Avoid storing in damp places.

2. Clean rusty tapes with a damp cloth or and cleaning solvent. Use soap and water when a tape is dirty or muddy. To prevent rust after cleaning, lightly oil the tape, then dry.

3. Do not place a tape where it can be stepped on or run over by a vehicle. Otherwise, it might kink, bend, or break.

4. Avoid pulling a tape around poles or other objects: a hard pull can stretch or break the tape.

5. Do not wind tapes overly tight on their reels. This tends to exert unwanted stresses. However, "normal" winding of a tape onto a reel does NOT harm the tape.

G. MISCELLANEOUS EQUIPMENT AND TOOLS

Each employee is responsible for keeping his miscellaneous tools and equipment in good condition. To prevent loss of small equipment and tools, avoid laying them on the ground, on vehicles or on equipment, which might be moved. When not in use, carry them in scabbards and pouches on a chaining belt.

1. Hand Levels - Keep them clean and in good adjustment.

2. Cutting Tools

   a. Maintain sharp cutting edges. A dull tool will often deflect, instead of biting into the wood, and cause injury.

   b. Sharpen with a 12-inch flat or curved bastard file, which has a guarded handle. Avoid "bluing" or burning the edges when sharpening: this destroys the temper.

   c. Store in protective cases and in safe positions. Do not store them in the passenger areas of vehicles.

3. Driving Tools - Replace or repair a driving tool, which is burred or fractured on any part of the driving or striking face. Many surveyors have been injured by "shrapnel" from gads and sledges, which had ragged edges.

4. Tool Handles - Keep all handles firmly secured in or to all cutting and driving tools. Crooked or warped handles can cause injury as well as mis-hitting and damage to the tool. Promptly replace such handles and those that are cracked or broken. Only install handles that are made for each particular type of tool. When installing make certain the handle is symmetrical with the head or the bit of the tool.

H. EQUIPMENT STORAGE IN VEHICLES

The care, organization, and general housekeeping of a vehicle, generally, are good indications of the attitude of the entire party. Keep the cab and passenger compartments free of unnecessary clutter and equipment. Store all equipment in designated places in compartments.

Any equipment or material stored in the passenger compartment should be neatly and firmly secured. A good rule to follow is - "A place for everything and everything in its place."

Loose equipment and tools and general clutter are safety hazards. The Occupational Safety and Health Act requires that survey vehicles, "be kept clean and orderly and in a sanitary condition".

CHAPTER 2-00 - SURVEY EQUIPMENT

SECTION 2-03 SURVEY PARTY EQUIPMENT

Revised 11/01

A. GENERAL

This section lists the equipment tools and material required for a basic 4-Man survey party. The list may be modified when a party performs different phases of surveying, different jobs, or is away from a source of supply.

B. ROUTINE NEEDS

1. Equipment

   a. Instruments

      1 - total station instrument
      1 - automatic level
      3 - optical plummet tribrachs
      1 - electronic data collector
      1 - floppy disk drive
      1 - printer
      1 - calculator
      1 - voltmeter
      1 - barometer
      1 - thermometer
      1 - magnetic locator
      1 - compass
      1 - right angle prism

   b. EDM reflectors

      3 - standard reflectors
      2 - mini "peanut" reflectors
      1 - standard reflector holder

   c. Range poles

      2 - telescoping prism poles
      6 - standard 8 foot range poles

   d. Level Rods

      1 - San Francisco (Frisco) rod
      1 - fiberglass, 25-ft.

e. Tapes

1 - 200' steel tape
1 - 100' steel tape
2 - 100' fiberglass (cloth) tape
1 - 12' pocket tape, engineers
1 - 6' folding rule, engineers

f. Radios

1 - vehicle radio
3 - portable radios

g. Miscellaneous Equipment

3 - tripod, extension leg
5 - plumb bob with sheath
5 - lock level with sheath
6 - batteries, portable radio
5 - canvas pouches
1 - stake bag
1 - water cooler
4 pr. - hip boots

h. Cutting Tools

2 - axes, single bit
1 - hatchet
5 - brush hooks
2 - files

i. Digging Tools

1 - shovel
1 - pick

j. Driving Tools

1 - maul 8/10-lb.
1 - hammer, engineers

2. Expendable Supplies

a. Miscellaneous

Plumb bob points
Plumb bob cord
Keel
Spray paint
Can paint
Plastic flagging - blue, orange, red, yellow, and "wetlands"

b. Survey Points and Markers

1x2x18 Flat Stakes
2x2x(12 & 18) hubs
Wire Flags - Blue, Orange, Red, and Yellow
Rebars - 5/8"
Rebar Caps
Spikes, Railroad
Spikes, Boat
Nails, Chaining
Nails, P.K.
Nails, Masonry
Nails, Roofing
Tacks, Stake (cup)
Shiners

3. Stationary Equipment and Supplies

a. Pencils and Marking Pens
Pencils, 0.3 mm and .5 mm
Lead Holders
Markers, felt tip
Colored pencils
Fiber tip pens

b. Leads
0.3 & 0.5 mm - HB, H, and 2H
Lead Holder Leads - HB, H, and 2H

c. Erasing Supplies

Eraser - Clic or Staedtler
Eraser Refill - Clic or Staedtler
Eraser Shield

d. Miscellaneous

French Curves
Protractors
Engineer's Scale - 6"
Triangles
Templates
Lead Pointer
Peg Books
Clip Board
Stapler

4. Safety Equipment

1 - Fire Extinguisher
1 - First Aid Kit
6 - Flares, 30-Minute

12 - Traffic Cones - 28"
8 - flags, vinyl
2 - "Slow-Stop" paddles
4 - Sign Holder - Windmaster or similar
4 - Sign - "Survey Party", 48" x 48"
1 - Hard Hats, per person
6 - Safety Vests
1 - Goggles, per person
1 - Gloves, Steel w/inserts

5. Publications

1 - "Survey Manual"
1 - "Safety Manual"
1 - "Route Location and Design" - Hickerson
1 - "Directory of Medical Facilities"

6. Forms

a. Attendance Forms

Employee Leave Request, Form SHA-22.0.1
Daily Report Card, Form SHA 61-1-144

b. Expense Forms

Employees Expense Statement, Form SHA 30-502-L
Accommodation Verification
Checking Account Log

c. Vehicle Accident Forms

Motor Vehicle Accident Investigation Guide, Form 71.0-FS-1
Driver's Report of Accident, Form 71.0-74
Automobile Loss Notice, Form ACORD 2(2/88)

d. Vehicle Usage

Operator's Report A, Form DBFP-FM-MFOMS
Equipment Usage Report, Form SHA 30.0-590-0

e. Industrial Injury Forms

Report of Accident/Incident, Form D-PER-033
Employer's First Report of Injury, Form c-1

f. Miscellaneous Forms

Project Card, Form SHA 61.7-5-2
Equipment Request, Form SHA 61.7-S-3
EDM Calibration Record

C. INTERMITTENT NEEDS

A survey party should have the following equipment and supplies available as the need arises:

1. Miscellaneous Instruments and Equipment

   Altimeter, Surveying
   Measuring Wheel
   Precise Rods, Yard
   Brass Disks

2. Power Tools

   Chain Saw
   Power Post Hole Digger

3. Hand Tools

   Number and Alphabetical Die Set
   Post Hole Digger
   Tape Repair Kit

4. Safety Equipment and Supplies

   Hearing Protectors
   Safety Harnesses or Belts
   Safety Ropes, Manila or Nylon

5. Sounding Equipment

   Sounding Line w/Weight
   Fathometer

CHAPTER 2-00 - SURVEY EQUIPMENT

SECTION 2-04 LEVELING INSTRUMENTS AND RODS

Revised 11/01

A. POLICY

All survey parties shall be equipped with an automatic level. Use of dumpy levels shall be limited to times when wind or heavy equipment causes oscillation of an automatic level's compensator. Additionally, where first or second-order vertical control is sparse, the use of specialized, precise levels may be necessary.

B. AUTOMATIC LEVELS (SELF-LEVELING)

The Division's Inventory of automatic levels includes Topcon AFT-2, Leitz B-1 and Zeiss NI-2 with micrometer. The principle of operation is essentially the same in all makes.

The line of sight is maintained perpendicular to the direction of gravity through a system of prisms called a compensator. This compensator maintains a horizontal line of sight when the instrument is approximately leveled.

Automatic levels have three leveling screws and a circular bubble whose upper inner surface is spherical and has etched a bull's eye on it. This bull's eye generally defines the limits within which the compensator will maintain a horizontal line of sight.

1. Adjustments - Adjust an instrument only if testing shows the need. If adjustment is necessary, it is made by estimation. Therefore, the test must be repeated after each adjustment until the required tolerance is met. After all adjustments are made, repeat each tests to be sure each adjustment has held through subsequent adjustments.

   With the exception of parallax elimination, which is performed each time an instrument is used, check the adjustments described below at intervals of 90 days. Check more often if significant discrepancies appear in a level circuit. If the instrument has not been used for a long time or a long circuit with few checks is to be run, test the level before starting. When running three-wire or other high-order levels, check the adjustments at the start of each day's run or more often, if required.

Adjust level bubbles with the instrument in the shade. Most adjustments are more valid, and easier, if the temperature is constant. Field adjustment procedures are detailed below. When possible, consult the manufacturer's instructions for specifics. Only the adjustments listed below should be made in the field. Other adjustments should not be attempted. Do not attempt adjustments that require dismantling any part of the instrument.

a. Parallax

When working with any instrument telescope, an observer simultaneously views two images. One is the object focused on by the telescope, and the second is the cross hairs image. Both must come to focus on a single plane in order to be seen clearly. If this condition is not met, parallax exists.

1) To test - the telescope should be focused on some distant well-defined object with the cross hairs appearing sharply focused. While viewing the object, the observer's eye is shifted slightly horizontally and vertically to check for any movement of the cross hair relative to the object. If the cross hairs do not oscillate over the object then adjustment is not necessary. If the cross hairs do appear to move on the object, parallax exists and must be corrected.

2) To Adjust - to eliminate parallax, turn the reticle focus slightly until no movement of the cross hairs relative to the object is detected. Re-adjust the telescope focus and check for parallax again. Repeat the procedure as necessary until parallax is eliminated.

b. Circular Bubble

1) To Test:

a) Carefully level the instrument, making sure the "bulls-eye" is exactly centered.

b) Rotate the telescope 180☜ and check the bubble.

2) To Adjust:

a) If it is not centered, bring the bubble halfway to the center by using the adjusting screws beneath the knurled ring around the bubble.

b) Re-level the instrument, rotate it 180☜, and repeat the adjustment, if necessary, until the bubble remains centered.

When adjustment is complete all adjusting screws should be snug but not strained. The bubble should remain exactly centered in the ring when the telescope is turned in any direction.

c. Horizontal Cross Hair (Two-Peg Test) - This test checks the collimation of the line of sight (as defined by the horizontal cross hair) with true level (as defined by the instrument's leveling apparatus).

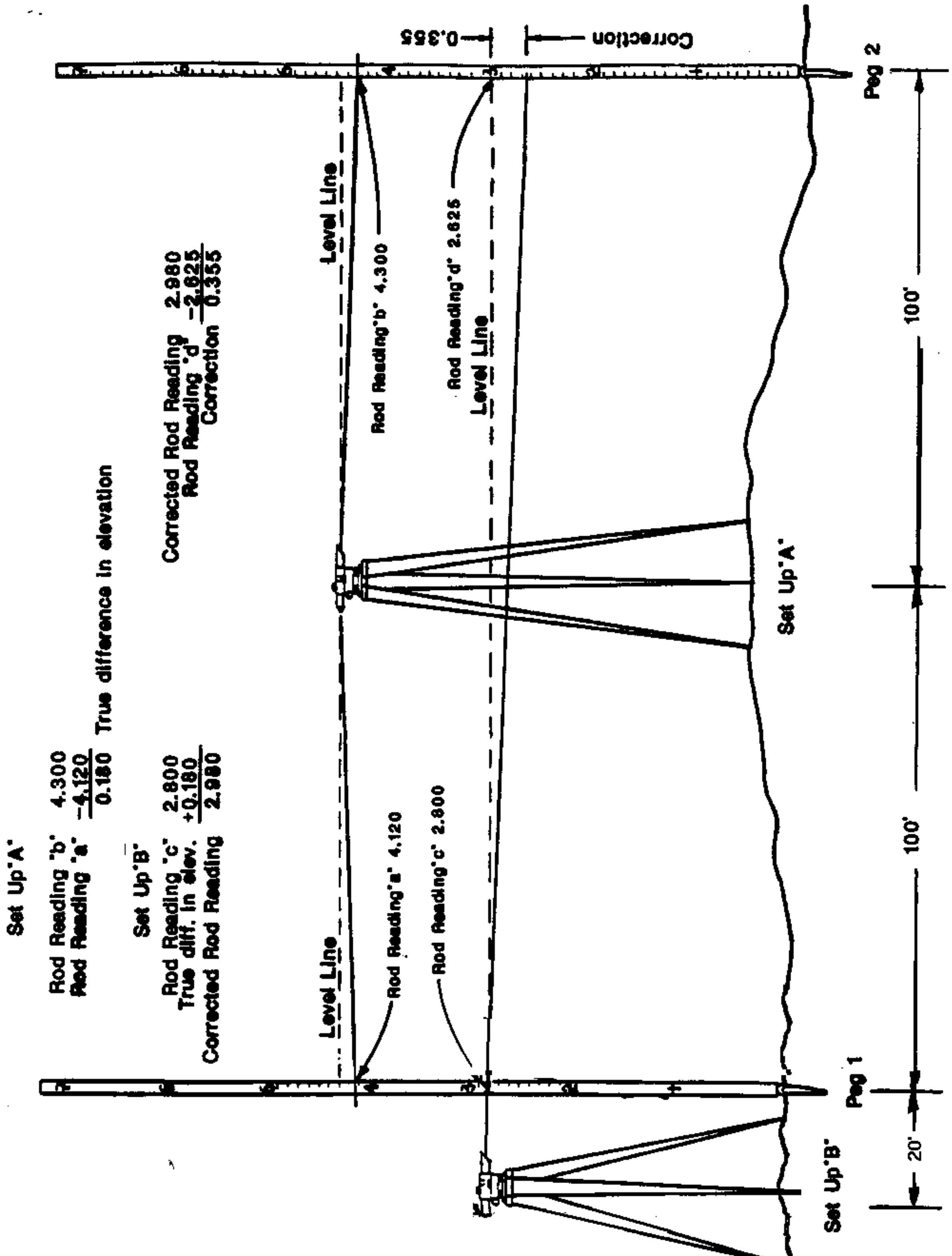
1) To Test:

a) Set two stable points (with a well-defined, high point on each) on level ground, 200 feet apart as shown in Figure 2-04-A. The pegging course should be on stable ground, free from vibrations caused by traffic or heavy equipment.

b) Set up the instrument at "A", exactly midway between the two-peg points. Read the same rod on both points. Read to the nearest thousandth of a foot. Note which point has the greatest (lowest) reading.

c) To assure good results, repeat these readings with the level at a different height of instrument (HI).

d) Compute the average difference in elevation from the two sets of readings. This is the "true" difference between the pegs: the balanced sights eliminate any horizontal cross hair error.



TWO-PEG TEST

FIGURE 2-04A

)The level is then moved to the point 20 feet outside of point A. Read the rod on point A first. If point B is lower than point A, add the difference in elevation as determined in the first set-up to the reading on point A. This should be the reading on point B ✂ .005 ft.

2) To Adjust:

a) Unscrew the reticle cover. (This is a circular cap at the eyepiece end of the telescope barrel.) A small capstan-head screw will be exposed just above the eyepiece. This raises and lowers the cross hair reticle against a spring loading. (See note below.)

b) Adjust the horizontal cross hair to the corrected reading on the far rod.

c) Replace the cap and check the rod readings on both points. The difference in readings should approximate, within required tolerance, the "true" difference in elevation of the points. If so, this completes the adjustment.

Note: Some instruments have two capstan-head adjusting screws one atop the reticle and one below. The two-screw adjustment requires a corresponding loosening of one screw and tightening of the other. The adjustment is made in gradual, successive sets of "loosen one and tighten the other". When adjustment is completed both screws should be snug but unstrained.

2. Accessory Equipment - Parallel Plate Micrometers are available for most automatic levels. This accessory consists of a drum micrometer that is linked to an optically ground, plano-parallel lens. The surfaces of a plano-parallel lens are exactly parallel. When the lens is rotated, it offsets the line of sight exactly parallel to the true line of sight.

When a rod is read, the micrometer knob is turned until the cross hair appears to coincide with the lowest possible whole graduation on the rod.

This "offset" reading on the rod plus the direct reading from the micrometer drum equals the actual rod reading to thousandths. By use of this accessory the estimation of thousandths is eliminated.

C. DUMPY LEVELS

The dumpy level was at one time used extensively on all engineering works. Although automatic levels have to a great degree, replaced this simple instrument, a few remain in the Division's inventory.

1. Adjustments - Due to its simple construction, dumpy levels have only two principal adjustments.

    a. Bubble Tube

        1) To Test - Set up the instrument so the bubble tube is directly over two opposite leveling screws, and carefully enter the bubble. Rotate the instrument 90☜ to place the bubble tube over the remaining pair of leveling screws and again center the bubble. Rotate the instrument 180☜ to reverse the tube's position. If the bubble runs off center, an adjustment is necessary.

        2) To Adjust - The distance the bubble moves represents twice the error present. To correct, bring the bubble back halfway by turning the adjusting nuts at one end of the bubble tube. Re-center the bubble using the two level screws in line with the tube. Rotate the instrument 90☜ and center the bubble using the other pair of leveling screws. Provided the adjustment was done correctly, the bubble will remain centered as the instrument is rotated. If the bubble runs again, repeat the adjustment until it stays centered.

    b. Horizontal Cross Hair - Adjust the reticle in the same manor as described for automatic levels.

D. LEVEL RODS

1. San Francisco Rod - This type rod is the standard for routine differential leveling.

a. Rod Construction - This rod consists of three sliding wooden staffs with replaceable metal scale faces. The scales are graduated in 100ths of a foot by unique marking which are designed to prevent reading errors.

b. Adjustments - The positions of the metal scales on the two top staffs should be checked with a steel tape while rod is fully extended and locked. Adjust the two upper scales by loosening their retaining screws and indexing the tapes at the exact distance from the bottom of the rod.

c. Advantages

1) The rod is sturdy and will take considerable abuse.

2) Each of the three metal scales is replaceable.

3) The notes kept for leveling with this type of rod provide a record, which can be checked in the office.

2. Invar-Tape Rod - This type rod is used for precise geodetic leveling.

a. Rod Construction - This type of rod consists of an aluminum staff, 3 meters long, which "carries" an invar tape.

The invar tape is precisely graduated in either half-centimeters, centimeters or special bar coding. The bottom of the tape is secured to a hardened steel shoe at the base of the rod. The upper end of the tape is held at an established tension by a strong spring. This method of "suspending" the invar tape in the tape guides allows the tape to remain at a constant length even when the staff expands or contracts.

b. Checking and Maintenance - Precise rods are used in matched pairs. Periodically check the rods to verify that the index difference between them remains constant. Index is checked by comparing high and low readings made on each rod on the same point. If index has changed, either the tape guides are fouled or the rod has been damaged.

When a tape is badly damaged, replace the rod. Tape replacements are not available.

If the tape guides are fouled, carefully disassemble and clean the guides.

3. 25-Foot Fiberglass Rod

a. Rod Construction - This rod consists of five tubular sections, which telescope from 5 to 25 feet. It has San Francisco-type graduations. Later models have spring biased locking buttons, whereas the sections of older models were held in place by slotted twist-type retainers which were bonded to the sections.

b. Advantages and Uses - The fiber glass rod is very useful where relatively low accuracy is sufficient and where large differences in elevation are encountered. With this rod, twice as much relief can be covered from one setup than when using a Frisco rod. It is a time-saver on work where difference in elevation, rather than distance, determines the frequency of turns. This is especially true where vegetation is a factor. Fiberglass has another significant advantage: it is nonconductive. When dry, it may be used around electrical installations with caution.

c. Precautions - Be alert for slippage of the sections when the rod is extended, especially with a well-worn rod. Maneuvering the fully extended rod is awkward, and it is particularly cumbersome in high winds. Do not use this rod if consistent accuracy to hundredths of a foot is required.

CHAPTER 2-00 - SURVEY EQUIPMENT

SECTION 2-05 ANGLE AND DISTANCE MEASURING INSTRUMENTS

Revised 11/01

A. GENERAL

Transits and theodolites are instruments designed to measure horizontal and vertical angles. Angle measuring instruments were originally theodolites. As the design and manufacture of optical instruments progressed, the original very long theodolite telescope became shortened to the point that the telescope could be revolved 360 degrees about its horizontal axis. This act of turning the telescope over, called "transiting" the telescope, speeded up alignment work and permitted the averaging-out of sighting and instrumental errors. These instruments became known as transiting theodolites, and, in time, simply as transits.

Further improvements in instrument design resulted in three-screw leveling bases, with optical scales as opposed to the older design, which was characterized by four-screw leveling bases, together with open-faced, silvered (later aluminum and glass) scales read with the aid of attached vernier scales. To differentiate between the old-style instruments and the newer instruments, surveyors began to call the new instruments theodolites.

The vernier transits have been largely replaced with optical scale theodolites, optical micrometer theodolites, and electronic theodolites. Many colleges and universities, however, still introduce their students to angle measurement techniques by using vernier transits; the simple, open design permits the students to readily understand the mechanics and geometric principles of these instruments.

Transits are often graduated to one minute of arc; some transits are graduated to twenty seconds of arc. Optical scale theodolites are also graduated to one minute of arc, whereas optical micrometer theodolites can be graduated to 20, 10, 6, 1 and .2 seconds of arc. Electronic theodolites may read to one second of arc, but the actual precision can be from 10 seconds to a fraction of a second, depending on the design.

Electronic Distance Measurement instruments (EDMI) are the result of advances in electronics technology. Distances are now measured by light waves including laser and infrared. Use of EDMI has almost entirely eliminated the taping of distances. The Total Station instrument is the name applied to instruments that combine an Electronic Distance Measuring instrument and a theodolite. These instruments have replaced the "stand alone" theodolites and EDMI on all of the Division's Survey Crews.

B. THEODOLITES

1. Definition - In this Manual the term "theodolite" refers to a tribrach-mounted, closed, optical-reading, angle-measuring instrument with an optical plummet. That is, a theodolite is secured to a tripod by its separate base, the tribrach; the circles are read through a microscope and prism system; and it can be plumbed over a point without using a plumb bob. (The term "transit" is limited to an instrument that has open circles and verniers that must be read directly with the naked eye or with the aid of a hand-held magnifier.)

2. Tribrachs - A tribrach is the base of an instrument and it contains the leveling screws and the 5/8" X 11 female thread that accepts the tripod's instrument fastener screw.

3. Vertical Circle and Telescope Orientation - Theodolites used by the Division have vertical circles that are zenith oriented (telescope pointed overhead) at zero degrees. When the telescope is horizontal and the vertical circle is to the left of the line of sight, the vertical circle "reads" 90 degrees. This attitude of the theodolite is called "circle left", "face I" or the "direct" position. In the "reverse" position ("face II" or circle right") the vertical circle is to the right of the line of sight. In this attitude the vertical circle "reads" 270 degrees when the telescope is horizontal. In this MANUAL the terms "direct" and "reverse" are used.

4. Basic Types - Two basic types of theodolites are manufactured.

   a. Repeating Theodolites - These instruments can be used to measure a horizontal angle by repeating (or accumulating) the angle. The horizontal circle can be turned independently about the vertical axis or it can be turned with the alidade. A measured angle, either horizontal or vertical, is read internally at one point on the circle through the reading microscope.

      Repeating theodolites are generally graduated to 20 seconds or one minute; however, 10- second and

30-second models are manufactured. Most one-minute repeating theodolites marketed in the United States have horizontal circles, which are graduated clockwise and counterclockwise. Other repeating theodolites, and some one-minute instruments, are numbered only in one direction - clockwise or to the right. Certain makes of one-minute theodolites are available with either type of graduation.

Repeating theodolites are used primarily on design surveys and on construction staking. They are not to be used for precise control surveys.

b. Direction Theodolites - In these instruments the horizontal circle cannot be moved by rotating the alidade; it is moved by a "circle drive knob". After initial pointing the horizontal circle remains fixed during a set of observations. Angles cannot be accumulated or repeated.

The horizontal circle is single-numbered, clockwise-graduated and read through a reading microscope. A single microscope reading is a mean of readings on two diametrically opposite points on the circle. Thus, errors of circle eccentricity are eliminated.

5. Accuracies to Expect - From testing, manufacturer's technical data, and conservative assumptions, probable accuracies calculated for horizontal angles (measured by an experienced Instrument Man under good conditions) are, for a One-Second Theodolite, a maximum error of:

a) One Position (1D, 1R) - 4 seconds
b) Two Positions - 3 seconds
c) Four Positions - 2 seconds

C. ELECTRONIC DISTANCE MEASURING INSTRUMENTS (EDMI)

1. General - The development of Electronic Distance Measuring Instruments (EDMI) is the most noteworthy recent advancement in surveying. Linear measurements, in any practical range, can be made speedily and precisely due to the development of short, medium, and long-range EDMI. To realize the many benefits of EDMI, each surveyor should become familiar with the application, operation, and maintenance of EDMI.

2. Principles of Operation

a. Definitions

1) Amplitude - The departure of a wave from its average value. Amplitude indicates the amount of energy contained in a wave. For a light wave, the amplitude corresponds to the intensity or brightness of the light.

2) Phase - The position of a wave in relation to some standard position. Phase is expressed as an angle and is usually measured in radians.

3) Modulation - The varying by external means of the amplitude, phase, or frequency of a wave. Amplitude modulation of light causes pulsation in the brightness of the light.

4) Photocell or Photo-Diode - A type of tube or diode in which light-sensitive plates are used. When light strikes these plates, electrons are dislodged and caused to flow.

5) Sine Wave - A wave form, which is similar in appearance to the graph of the trigonometric sine function. The amplitude of the wave is proportional to the phase angle.

6) Heterodyne - The mixing of two different frequencies. This produces beats or pulsations of a third, lower frequency.

7) Frequency - The number of complete wave oscillations produced per second.

8) Phase-Detector - A device which detects and indicates the phase difference between two signals, usually a received signal and a reference signal.

9) Carrier Wave - A very high frequency beam, such as a light beam, which is used to transmit some type of modulated signal. The carrier is not measured, but the modulated signal is.

10) Resolver - A device which varies a phase-detector until some specified phase relationship is obtained. The resolver has a calibrated readout so the amount of movement needed to produce the specified phase relationship can be determined.

b. Description - All EDMI used by the Division operate essentially on the same principles. The sequence of events that occurs in a measurement process is:

1) Signal Generation - One "generator" produces two amplitude modulated signals. One signal is transmitted externally as a beam of light and the other remains internal.

2) Signal Transmission

   a) External Signal - The external signal (light) is transmitted from the instrument to a "remote" reflector and back to the EDMI.

   b) Internal Signal - The internal signal, the reference signal, travels a known path within the EDM. It serves as a zero point for measurement of the phase shift (see Item 5), below) of the external light.

3) Signal Reception and Conversion - The reflected external signal returns to the instrument and is converted into an electrical signal by the photocell.

4) Heterodyning - Before phase comparison is made, both signals, external and reference, are converted to a lower frequency by heterodyning. The resulting lower frequency has the effect of averaging a large number of high frequency wavelengths. This reduces the effect of atmospheric disturbances on the measurement.

   Note: The angular phase shift for the lower frequency is the same as for the higher frequency.

5) Phase "Shift" Measurement - The angular difference between the reference signal's phase and the returned signal's phase is called "shift". Shift is a function of the distance being measured. It is measured by the phase-detector and the resolver. This determines the length of the last partial wavelength entering the instrument. The number of whole wavelengths required to span the remainder of the distance is determined by measuring at two or more frequencies and

observing the relationship between the frequencies. In other words, partial wavelengths are determined for several frequencies.

6) Distance Determination - By mathematically comparing the partial wavelengths of several frequencies, unambiguous distances can be determined. The principle is illustrated by the example in Item c, below. Remember, it is the phase "shift" of the external signal which is measured. Neither the travel time of the light nor the frequency of the light is measured. The light beam acts only as a "carrier" for the modulated signal.

c. Example - Assume that the same distance is measured with three tapes of different lengths: tape "A" - 100.00 feet, tape "B" - 99.00 feet, and tape "C" - 90.00 feet. (The tapes correspond to the frequencies in an EDM.) Only the last partial tape length is recorded for each tape. (The partial tape lengths correspond to the partial wavelengths in electronic measurements.) The partial tape lengths (remainders) are:

Tape "A" - - - 1.00'
Tape "B" - - - 2.00'
Tape "C" - - - 11.00'

Tapes "A" and "C" have a lowest common denominator (LCD) of 900. This means that tapes "A" and "C" would repeat the above remainders at only 101', 1,001', 1,901', ...100,901', ...200,801', ... (The first length is determined by trial and error; each following length is computed by adding the LCD to the preceding length.)

Tapes "A" and "B" have a LCD of 99,900. The listed remainders for tapes "A" and "B" would occur at 1,001', 100,901' 200,801'....

From the possible remainders calculated for tapes "A" and "C" and those for tapes "A" and "B", the distance measured must be 1,001.00', or 200,801.00' or ... because these are the only lengths that will give the matching remainders shown.

With EDMI the second largest possible length is normally beyond the range of the instrument. Or, the differences between the various possibilities are usually so great that the correct length can be easily selected by estimation.

D. TOTAL STATION INSTRUMENTS

1. General

The name Total Station is applied to instruments that combine and EDMI and a theodolite. Because of different operations that must be performed on different types of this configuration there is a need to define and name three separate types. They are:

a. Manual Total Station - Both distance measuring and angle measuring make use of the same Telescope Optics (coaxial). Slope reduction of distances is done by optically reading the vertical angle (or Zenith angle) and keying it into an on-board calculator or any pocket calculator. Horizontal angles are read optically.

b. Semi-Automatic Total Station - Contains a vertical angle sensor for automatic reduction of distances (without keying in a slope angle). Horizontal angles are read optically.

c. Automatic Total Station - Both horizontal and vertical are read electronically for use with slope distances in a data collector or internal computer. These are the only types used by Plats and Surveys Division.

2. Total Station - Theodolite Part

a. Angle measuring - Electronic Theodolites employ an incremental method of angle measurement. These instruments have multi-layered glass circles that are graduated into unnumbered gratings. The number of gratings involved in a measurement is determined from whole circle electronic scanning by light emitting diodes which are positioned above and below the glass plates.

Circle imperfections are thus compensated for, permitting higher precision with only one circle setting. The measured distance of activated arc is then decoded and displayed as degrees, minutes and seconds.

b. Accuracy - Most models in the Division's inventory have an accuracy (standard deviation of a direction, direct and reversed) of 3".

c. Adjustments - Total Stations and theodolites are high precision instruments. Unlike high-precision laboratory Instruments, they are used outdoors, under all types of atmospheric conditions. They are transported in trucks and vans, over all types or terrain, and expected to function perfectly every time they are attached to a tripod.

Fortunately, surveying instruments have adjustment screws that allow the user to make field adjustments, when necessary. Details of instrument construction vary with manufacturers, and with different models from the same manufacturer, but the desired features are the same. The following is a list of conditions that must be fulfilled.

1) The vertical axis must be perpendicular to the bubble axis so as to have the vertical axis truly vertical when the bubble is centered.

2) The line-of-sight must be perpendicular to the horizontal axis so that the line-of-sight revolves in a vertical plane rather than along a conical surface.

3) The horizontal axis must be perpendicular to the vertical axis so that the horizontal axis is parallel with the bubble axis and the line-of-sight passes through a vertical plane rather than an inclined one when the telescope is rotated about the horizontal axis.

4) The vertical cross-hair should be vertical and the horizontal cross-hair should be horizontal when the instrument is leveled.

5) The vertical axis, horizontal axis, and line-of-sight should intersect at one point.

6) The vertical axis should pass through the center of the horizontal circle.

7) The optical plummet axis should be coincident with the vertical axis and perpendicular to the plate bubble axis.

With very few exceptions, an out-of-adjustment angular measuring instrument will give the correct results if direct and reverse circle readings are taken and the mean values used. The problems that survey parties encounter are the result of single-face measurements.

The one error that is not corrected by direct and reverse readings is Item 1) in the above list. If the bubble axis is not perpendicular to the vertical axis, the bubble will move when the instrument is pointed in different directions. Re-centering the bubble does not bring the vertical axis into the vertical plane; the result is the horizontal circle is not rotating in a horizontal plane.

The correct observing procedure is to mount the instrument on the tripod, and level the plate vial as you normally would. With the bubble centered, rotate the instrument 180☜. If the bubble remains centered, the instrument is in adjustment, with the vertical axis truly vertical.

If the bubble moves off-center, the vertical axis is not vertical, and the amount the bubble moves is an indication of the amount of inclination. If the number of divisions the bubble moved is counted, it can be moved back half the number using the leveling screws, making the vertical axis vertical. If the bubble is kept in this same off-center position when pointing the telescope in any direction, the vertical axis will remain vertical and the horizontal circle horizontal.

In summary, Field adjustments to the angle measuring function of a Total Station instrument are usually confined to:

1) Plate Level
2) Circular Level
3) Reticle Adjustments
4) Coincidence of the Distance Measuring Axis with the Reticle
5) Optical Plummet

THESE ADJUSTMENTS SHOULD BE MADE BY FOLLOWING THE INSTRUCTION MANUAL SUPPLIED WITH EACH INSTRUMENT.

3. Total Station - EDMI Part

a. Principles of Operation - See previous C.2. of this section.

b. Atmospheric Correction

The velocity of light through air is affected by the atmospheric temperature and pressure. If the velocity of the EDM's light beam is slowed, the distance displayed will be longer than the true distance. If it is faster, the displayed distance will be shorter than the true distance.

The affect on the distance is computed in Parts Per Million (PPM). One PPM is equal to 1 mm per km or .001 ft. per 1000 ft. If the computed correction is +30 PPM, the distance will be affected by 30 mm per km or .03 ft. per 1000 ft. If one failed to correct for this, a 2 mile traverse would be in error by 0.30 ft. due to atmospheric conditions alone.

EDMI have three methods for applying the correction:

1) The correction is obtained from a chart based on the temperature and pressure.

2) The temperature and pressure are keyed into the EDMI and the machine computes and applies the correction.

3) The EDMI itself measures the temperature and pressure and applies the appropriate correction.

Refer the EDMI's manual to determine which type it is.

c. EDMI Precision

The statement of precision for an EDMI is a two-part number, such as (5 mm + 5ppm). The first number, 5 mm (0.016 feet), means that at any distance, the EDMI can have a spread, in distance measured, of as much as 5 mm from the mean distance. If the EDMI is calibrated to a National Geodetic Survey (NGS) baseline, this mean distance will be the true distance.

The second number, 5ppm, is equivalent to 5 mm per km or .005 ft. per 1000 ft. This is especially important when using the EDM to measure long distances. At 800 meters (2625 feet), 5 ppm is only 4 mm (0.013 feet). At 1400 meters (4593 feet), 5 ppm is 7 mm (0.023 feet). Therefore, an EDMI used to measure a distance of 4593 feet could show a measured distance that could vary as much as 5 mm + 7 mm or 0.039 feet.

d. EDMI test and calibration

To determine the accuracy of an EDMI, a comparison of distances measured to known distances must be made. This can be performed at calibrated baselines established in the State by the NGS.

Prior to going to a test range, check all tribrachs and optical plummets to make sure they are in good adjustment. If the EDMI or total station requires a screwdriver or special tool to make offset changes, make sure you have this tool available. Read the paragraph in the instrument instruction manual that describes the process of changing offsets. The prism(s) that will be used to calibrate the instrument should be the same prisms that will be used with this instrument on a daily basis.

The calibration procedures should be as follows:

Step 1 - Position the Total Station instrument directly over the "150" monument of the calibrated baseline. Carefully level the instrument.

Step 2 - Position a prism directly over the 0 meter and 430 meter monuments.

Step 3 - Determine the atmospheric temperature and pressure and set the corresponding PPM correction in the EDMI. Switch the EDMI to the metric measuring mode and the readout for horizontal distances.

Step 4 - Measure the distance to the 0 meter monument ten times and compute the mean.

Step 5 - Measure the distance to the 430 meter monument ten times and compute the mean.

Step 6 - Add the two mean distances together. Subtract the published distance from this value. The result is twice the offset error.

Step 7 - If necessary, change the instrument constant and repeat steps 1 through 6 to check.

Step 8 - Move 430 meter setup to the 1400 meter monument and measure this distance ten times.

Step 9 - Move the instrument to the 430 meter monument and measure the distance to the 0 meter point ten times.

Step 10 - Measure the distance to the 1400 meter monument ten times.

Step 11 - Move the instrument to the 1400 meter monument and measure the distance to the 0 meter monument ten times.

Evaluate all of the measurements taken to see if they agree with the published distance within the stated accuracy of the instrument.

CHAPTER 2-00 - SURVEY EQUIPMENT

SECTION 2-06 TAPES

Revised 11/01

A. GENERAL

Surveyor's tapes are available in various lengths of different materials, and with numerous methods of graduation. This manual deals only with the types commonly used by the Division.

B. STEEL TAPES

The Division uses both standard and metric steel tapes. Standard tapes are 50 ft., 100 ft. and 200 ft. and are graduated in feet, tenths and hundredths throughout their length.

Metric tapes are 30 meters in length and are graduated in meters, decimeters, centimeters and millimeters throughout their length.

C. NON-METALLIC TAPES

Non-metallic cloth tapes are made from synthetic fibers, coated with a flexible, durable plastic. Markings are impressed into the fibers and protected by a final coat of clear plastic. Standard Non-metallic cloth tapes are graduated to 0.05 foot throughout their length. They are available in 100-foot lengths without cases. Metric tapes are 30 meters long and graduated in meters and centimeters.

Non-metallic cloth tapes are subject to stretching and shrinking and should never be used for precise measurements.

CHAPTER 2-00 - SURVEY EQUIPMENT

SECTION 2-07 OTHER SURVEY EQUIPMENT

Revised 11/01

A. HAND-HELD COMPUTERS/CALCULATORS

1. General

Electronic calculators are highly adaptable to fieldwork. Calculators programmed for trigonometrical functions have almost totally eliminated the need for field tables. Further, errors from table usage are also eliminated. Some electronic calculators used by the Division are programmable. That is, these calculators have the capacity to store and run programs involving many mathematical steps.

2. Sharp - Model EL 5500 III

The Sharp EL 5500 III has been issued to all Party Chiefs. The hand-held computer has an alphanumeric keyboard, 8 KB RAM, 26 memories, 85 programmed scientific functions and a 24-digit Dot Matrix display.

A modified COGO program using Sharp Basic Language has been written and loaded into these machines. The routines included in this program allow the survey crew to perform many tasks that heretofore would have been prohibitive because of the complex mathematics involved.

Some examples of this are:

a. While performing a metes and bounds survey, two pipes that are thought to constitute a deed line are located by angle and distance from a traverse station. The two pipes are not intervisible because of obstructions and the distance between them cannot be checked for comparison to the deed distance. Using the Sharp calculator it is possible to rapidly compute this distance by:

   1) Assume, if need be, coordinates on the occupied station.

   2) Locate the first pipe by the "Locate Bearing Routine" (LBR) using an assumed bearing and the measured distance.

3) Locate the second pipe by the "Locate Angle Routine" (LAN). Use the angle difference between the first pipe and the second pipe and the measured distance.

4) Inverse between the two pipes using the "Inverse Bearing Routine" (IBR). If the inverted distance is close to the deed distance it can be assumed that the correct pipes have been located and the survey may be resumed. If the invades distance is not close to the deed distance the inverse distance can be used to facilitate further search for another pipe or corner.

b. A right-of-way (R/W) stakeout is being performed on a project where the baseline and R/W breaks have coordinate values assigned. It is necessary to place R/W stakes along a line where the R/W breaks are separated by a long distance that runs through many obstructions. The location of points along this line can be calculated by:

1) Store the coordinates of the occupied baseline station and the baseline station sighted on. Store the coordinates of the R/W breaks. Note the assigned number of these points.

2) Turn and record angles that fall between the obstructions and that are on clear lines of sight.

3) Using the recorded angles and an assumed distance of say 500 feet, by the "Locate Angle Routine" (LAN) set a series of points. Note the assigned numbers of these points.

4) Assess the "Points Intersect Routine" (PIT). Use the point numbers that define the R/W line as Line 1. Use the number assigned to the occupied point in combination with the points established in Step 3) to define Line 2. Intersect and note assigned intersection numbers.

5) Inverse between the occupied station and the intersection points established in Step 4) using the "Inverse Bearing Routine" (IBR). Note distances between occupied station and intersection points.

6) Use recorded angles from Step 2) and inverse distances from Step 5) to set R/W stakes.

B. COMPASSES

1. Features - The essential features of compasses used by surveyors are:

   a. A compass box with a circle graduated from zero degrees to 90☜ in both directions from the north and south points.

   b. A line of sight along the south-north points of the compass box.

   c. A magnetic needle.

   When the line of sight is pointed in a given direction, the compass needle gives the magnetic bearing.

2. Type

   The pocket compass is the type issued to Division crews. This is generally held in the hand and bearings observed. It is used on Metes and Bounds surveys to trace property lines and on Global Positioning Systems (GPS) reconnaissance surveys where the bearing and distance to all obstructions extending 20 degrees above the horizon must be noted. It should also be used to place an approximate bearing on baselines used in borrow-pit surveys.

C. HAND LEVEL

A basic instrument used on survey crews is the hand (Locke) level. It consists of a spirit bubble and sighting horizontal wire held in a telescope having zero or 2x magnification.

Low-cost hand levels generally have a sighting chamber with no optics and only a horizontal cross hair and mirror to show the bubble image on the wire. Sights are considered level when the bubble is centered on the wire. Low-powered optics are often introduced in the hand level to extend the distance of operation. Generally, unaided sights are used up to 30 feet and optic assisted sights to 70 feet.

These instruments are usually used in cross-section and taping operations. Hand levels should be tested periodically and adjusted when necessary.

D. TRIPODS

Standardization by instrument manufacturers has created a need for only two types of surveyor's tripods: European and American.

1. European - This tripod has a 5/8" (diameter) X 11 (threads per inch) instrument fastener, which secures the instrument to the tripod head. The centering range of the fastener is approximately 1-1/2 inches. European tripods have a wide-frame design. In this design the leg dowels for each leg are attached to the tripod head at a spacing of approximately four inches. This gives greater stability. The European tripod is the standard tripod for Division instruments.

2. American - The American tripod has a threaded head for fastening instruments. The head is 3-1/2 inches in diameter with eight threads per inch. Most of these tripods are now supplied in the wide-frame style. The American tripod is used with American-made engineers transits and dumpy levels.

   Both types are available with either fixed legs or extension legs. The extension-leg tripod is much preferred. It is easier to store and is more flexible and easier to use.

   The stability of a tripod can be maintained by periodically checking the fittings for excessive "play" and keeping all screws and bolts snug. Moving parts should operate smoothly and freely.

E. METAL DETECTORS

Electronic metal detectors have replaced the old dip needle instruments that were previously used. The electronic detectors will sense ferrous metal (iron and steel) at considerable depths. They operate on the fluxgate-magnetometer principle, which means they locate the magnetic field found around any ferrous object. The detection of a magnetic field activates an audio signal, which is transmitted through a loudspeaker or an attached headset.

Electronic metal detectors are used extensively on metes and bounds and recover surveys. Better quality electronic detectors are expensive but economically practical investments.

F. ABNEY LEVEL (CLINOMETER)

This instrument is suitable for both direct leveling and for measuring slope angles. For direct leveling, the index of the graduated arc is set at zero. When it is used as a clinometer, the level tube is rotated about the axis of the vertical arc until the cross wire bisects the bubble as the object is sighted. Either the slope angle or the slope percentage is then read on the vertical arc. The Abney level can be used to acquire approximate heights of structures and overhead wires. Its primary use is for mapping the horizon on GPS reconnaissance surveys.

CHAPTER 2-00 - SURVEY EQUIPMENT

SECTION 2-08 PARAVANT DATA COLLECTOR AND PERIPHERALS

A. DISK OPERATING SYSTEM (DOS)

1. General - This section covers some of hardware that makes up the system as well as some of the most frequently used commands for copying, printing, listing, deleting and manipulating files.

2. Disk Drives - The paravant has 4 disk drives when the portable disk drive is connected. These are lettered A: through D:.

   a. The A: drive refers to the 1 Megabyte external drive, which is a removable random access memory (RAM) card. All executable programs (.EXE) files, batch (.BAT) files, parameter (.PAR) files, back-up (.BAK, .TBK, .XBK) files, and text (.TXT) files must reside on this drive.

   b. The B: drive is the normal working drive and refers to either an internal drive on the older units or to the 512 RAM drive on the newer units. This drive normally contains the field (.FLD) files, the traverse (.TRA) files, the cross-section (.XCT) files, as well as copies of the .TXT and .PAR files.

   c. The C: drive is an internal drive, which contains the programs that make up the operating system of the paravant. This drive is write-protected so that it cannot be altered.

   d. The D: drive is the portable disk drive. This drive is connecting to the unit via a RS232 serial port and cable. It is used for creating disks for sending into the office and for storing back-up copies of programs and data.

3. System Files - Although these files are on the C: drive, customized versions of them must be on the A: drive for the paravant to operate properly.

   a. COMMAND.COM - This file contains instructions for performing various functions. It is a "binary" file and cannot be printed or viewed.

   b. CONFIG.SYS - This file contains settings for general operation of the unit. It is an ASCII file and can be viewed and printed.

c. AUTOEXEC.BAT - This file is a batch file that runs automatically whenever the unit is re-booted. It is an ASCII file.

4. DOS Commands - These commands can be issued with drive letters and switches. A switch alters the way the command works.

   a. DIR - This command will display a directory listing of files. DIR A: will list the files on the A: drive. DIR/W will display a wide listing.

   b. COPY - This command copies files from one place to another. COPY JUNK.FLD D: will copy the JUNK.FLD file to the portable disk drive. COPY D:JUNK.FLD copies the JUNK.FLD file from the D: drive.

   c. RENAME - This command changes the name of a file. RENAME JUNK.FLD SAMPLE.FLD changes the name of the JUNK.FLD file to SAMPLE.FLD.

   d. DEL - This command deletes a file. Once the file is deleted, it cannot be brought back! DEL JUNK.FLD deletes the JUNK.FLD file.

   e. TYPE - This command displays the contents of an ASCII file. TYPE JUNK.FLD will list all of the data stored in the JUNK.FLD file to the screen.

   f. PRINT - This command will cause a file to be printed out on the printer if attached. PRINT JUNK.FLD will cause the JUNK.FLD file to be printed out.

   g. PATH - This command tells the paravant where to look for programs if they don't exist on the current drive. The AUTOEXEC.BAT file has a PATH command set to A:\;B:\;C:\

B. SPECIAL FUNCTIONS OF THE PARAVANT

1. Display screen - Various lighting conditions will effect the screen display. The screen display can be changed by holding down the FUNCT key and pressing the UP arrow to increase contrast or the DOWN arrow to decrease contrast. Press the ALT key and the UP or DOWN arrows to increase or decrease brightness.

2. Power on/off - Press the FUNCT key and POWER keys

simultaneously to turn the computer on and off.

3. Extra characters - Press the FUNCT key and the appropriate letter key to enter special characters not marked on the keyboard:

<table>
<tr><th>KEY</th><th>CHAR</th><th>KEY</th><th>CHAR</th><th>KEY</th><th>CHAR</th></tr>
<tr><td>A</td><td>'</td><td>I</td><td>&</td><td>Q</td><td>}</td></tr>
<tr><td>B</td><td>~</td><td>J</td><td>(</td><td>R</td><td>|</td></tr>
<tr><td>C</td><td>!</td><td>K</td><td>)</td><td>S</td><td>;</td></tr>
<tr><td>D</td><td>@</td><td>L</td><td>_</td><td>T</td><td>"</td></tr>
<tr><td>E</td><td>#</td><td>M</td><td>=</td><td>U</td><td><</td></tr>
<tr><td>F</td><td>$</td><td>N</td><td>[</td><td>V</td><td>></td></tr>
<tr><td>G</td><td>%</td><td>O</td><td>]</td><td></td><td></td></tr>
<tr><td>H</td><td>^</td><td>P</td><td>{</td><td></td><td></td></tr>
</table>

4. Rebooting - The collector can be re-booted by entering an "R" while in DOS or by pressing the reset switch located in the battery compartment next to the battery. Avoid rebooting the computer while in a program as this may corrupt data files in use by a program. Always exit the program normally if possible.

   The reset switch normally performs a "soft" reset of the computer and boots (starts-up) MS-DOS. This will have no effect on the internal memory, configuration settings or the real time clock.

   The reboot will restart the Paravant screen. Proceed as normal.

   NOTE: If you rebooted during the ETSC program, be aware, you will have to re-enter the next point and figure numbers because the default will display Pt.# 301 and Fig. # 1.

C. PARAVANT CONFIGURATION - (If unsure, call the office to see which configuration your Paravant uses.

1. RHC-44 3512 RAM card in A: drive:

   a. From the C: prompt Key-in CONFIG and press Enter.

   b. Select F2 - Low Power/Event Wait Configuration.

   c. Set up as follows:

      Automatic Power Down Timeout - 10
      Power Down = > Wait Keyboard - YES
      Power Down = > Poll Keyboard :
      Activate: NO Location: DOS
      Enable Serial Port - YES
      Install Low Power Handler - YES
      Low Power Message Interval - 120

   d. Press Escape and save changes.
   e. Select F1 - Memory Mapping

   f. Set up as follows:

Program Memory	Disk Memory
Bank 0 - 00	Disk 1 Start 80
Bank 1 - 01	Disk 1 Stop 83
Bank 2 - 02	
Bank 3 - 03	Disk 2 Start 04
Bank 4 -	Disk 2 Stop 07
	Disk 3 Start 40
	Disk 3 Stop 41

      Important: Bank 4 must be left BLANK. The default setting is 04 for bank 4. To change this setting you must enter a -1 at the prompt. This will create a blank space for this bank. If the memory banks are not set correctly, you will get an error message "Program/Disk Memory Conflict".

      Be sure to save the changes when you EXIT.

      If you get ERROR reading drive B: - Go to c:\ and key-in FORMAT B: to fix the problem.

2. RHC-44 MF3513 RAM card in the A: drive

a. From the C: prompt Key-in CONFIG and press Enter.

b. Select F2 - Low Power/Event Wait Configuration

c. Set up as follows:

```
Automatic Power Down Timeout   -   10
Power Down = > Wait Keyboard   -   YES
Power Down = > Poll Keyboard :
Activate:   NO         Location:  DOS
Enable Serial Port -    YES
Install Low Power Handler - YES
Low Power Message Interval - 120
```

d. Press Escape and save changes.

e. Select F1 - Memory Mapping

f. Set up as follows:

Program Memory	Disk Memory
Bank 0 - 00	Disk 1 Start C0
Bank 1 - 01	Disk 1 Stop C3
Bank 2 - 02	
Bank 3 - 03	Disk 2 Start 04
Bank 4 -	Disk 2 Stop 07
	Disk 3 Start 40
	Disk 3 Stop 41

Important: Bank 4 must be left BLANK. The default setting is 04 for bank 4. To change this setting you must enter a -1 at the prompt. This will create a blank space for this bank. If the memory banks are not set correctly, you will get an error message "Program/Disk Memory Conflict".

Be sure to save the changes when you EXIT.

If you get ERROR reading drive B: - Go to c:\ and key-in FORMAT B: to fix the problem.

3. RHC-44 with 1MB RAM card in A:

a. From the C: prompt Key-in CONFIG and press Enter.

b. Select F2 - Low Power/Event Wait Configuration

c. Set up as follows:

```
Automatic Power Down Timeout   -   10
Power Down = > Wait Keyboard   -   YES
Power Down = > Poll Keyboard :
Activate:   NO          Location:  DOS
Enable Serial Port -    YES
Install Low Power Handler - YES
Low Power Message Interval - 120
```

d. Press Escape and save changes.

e. Select F1 - Memory Mapping

f. Set up as follows:

Program Memory	Disk Memory
Bank 0 - 00	Disk 1 Start C0
Bank 1 - 01	Disk 1 Stop C7
Bank 2 - 02	
Bank 3 - 03	Disk 2 Start 04
Bank 4 -	Disk 2 Stop 07
	Disk 3 Start 40
	Disk 3 Stop 41

Important: Bank 4 must be left BLANK. The default setting is 04 for bank 4. To change this setting you must enter a -1 at the prompt. This will create a blank space for this bank. If the memory banks are not set correctly, you will get an error message "Program/Disk Memory Conflict".

Be sure to save the changes when you exit.

4. RHC-44 with 1MB RAM card in A: and 3512 RAM card in B:

   a. From the C: prompt Key-in CONFIG and press Enter.

   b. Select F2 - Low Power/Event Wait Configuration

   c. Set up as follows:

      Automatic Power Down Timeout - 10
      Power Down = > Wait Keyboard - YES
      Power Down = > Poll Keyboard :
      Activate: NO Location: DOS
      Enable Serial Port - YES
      Install Low Power Handler - YES
      Low Power Message Interval - 120

      d. Press Escape and save changes.

      e. Select F1 - Memory Mapping

      f. Set up as follows:

Program Memory	Disk Memory
Bank 0 - 00	Disk 1 Start C0
Bank 1 - 01	Disk 1 Stop C7
Bank 2 - 02	
Bank 3 - 03	Disk 2 Start 80
Bank 4 - 04	Disk 2 Stop 83
	Disk 3 Start 40
	Disk 3 Stop 41

Important: If the memory banks are not set correctly, you will get an error message "Program/Disk Memory Conflict".

Be sure to save the changes when you exit.

5. RHC-44 with 1 - 2MB RAM card for A: drive:

   a. From the C: prompt Key-in CONFIG and press Enter.

   b. Select F2 - Low Power/Event Wait Configuration

   c. Set up as follows:

      Automatic Power Down Timeout - 10
      Power Down = > Wait Keyboard - YES
      Power Down = > Poll Keyboard :
      Activate: NO Location: DOS
      Enable Serial Port - YES
      Install Low Power Handler - YES
      Low Power Message Interval - 120

      d. Press Escape and save changes.

      e. Select F1 - Memory Mapping

      f. Set up as follows:

Program Memory	Disk Memory
Bank 0 - 00	Disk 1 Start C0
Bank 1 - 01	Disk 1 Stop CF
Bank 2 - 02	
Bank 3 - 03	Disk 2 Start 04
Bank 4 -	Disk 2 Stop 07
	Disk 3 Start 40
	Disk 3 Stop 41

Important: Bank 4 must be left BLANK. The default setting is 04 for bank 4. To change this setting, you must enter a -1 at the prompt. This will create a blank space for this bank. If the memory banks are not set correctly, you will get an error message "Program/Disk Memory Conflict".

Be sure to save the changes when you exit.

If you get ERROR reading drive B: - Go to c:\ and key-in FORMAT B: to fix the problem.

D. RHC-44E COMMANDS

1. To obtain a directory listing of the files on a floppy disk that is installed in a CMT disk drive, type CDIR at the B:> prompt and press enter.

2. To obtain a directory listing of the files on the Paravant, type PDIR at the prompt that you want to read (A: or B:) and press enter.

3. To copy files from the Paravant to the CMT disk drive type FOUT FILENAME (where FILENAME is the name of the file you wish to copy) at the prompt you want to copy from (A: or B:) and press enter.

4. To copy files from the CMT disk drive to the Paravant type FIN FILENAME at the prompt that you want to copy to (A: or B:) and press enter.

5. To print files type PFILE FILENAME at the prompt that you want to print from (A: or B:) and press enter.

6. When you hook up the Paravant to be charged, you will not hear a beep as you did with the previous model. If you turn on the Paravant RHC-44E while in the charging mode, 1 of 3 things will happen:

   a. A message "Fast Charging" will appear if the power is low.

   b. A message "Trickle Charging" will appear if the power is close to full.

   c. A normal screen will appear if power is full.

E. DICONIX 180si PRINTER

1. Charging - The 180si printer is capable of recharging its own batteries; all five batteries must be recharged at the same time. The Power indicator will begin to flash when battery power is low. Generally, you can print two or more pages before all power is depleted.

   a. Connect the AC adapter to your printer.

   b. Turn on the printer while holding down the Font (Recharge) button.

   The recharging operation takes ten hours to complete. During this time, the font indicator lights will flash in varying combinations during the ten-hour charge time, indicating the length of time remaining for the complete charging operation. When 25% of charging has been completed, the Gothic light will blink:

```
+))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))),
*$ Power     +))))))))),+))))))))),+))))))))),              *
*" Add Paper *" On Line**LF/FF   **Font    * $ Prestige 10 *
*            *         **        **" Draft * # Prestige 12 *
*            .)))))))))-.))))))))-.))))))))- $ Helva      *
* !"####!    $$$$$$$$$$ $$$$$$$$$ $$$$$$$$$  * Gothic     *
.)))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))-
```

When 50% of charging has been completed, the Gothic and Helva lights will blink:

```
+))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))),
*$ Power     +))))))))),+))))))))),+))))))))),              *
*" Add Paper *" On Line**LF/FF   **Font    * $ Prestige 10 *
*            *         **        **" Draft * # Prestige 12 *
*            .)))))))))-.))))))))-.))))))))- * Helva      *
* !"####!    $$$$$$$$$$ $$$$$$$$$ $$$$$$$$$  * Gothic     *
.)))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))-
```

When 75% of charging has been completed, the Gothic, Helva and Prestige 12 lights will blink:

```
+))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))),
*$ Power     +))))))))),+))))))))),+))))))))),              *
*" Add Paper *" On Line**LF/FF   **Font    * $ Prestige 10 *
*            *         **        **" Draft * * Prestige 12 *
*            .)))))))))-.))))))))-.))))))))- * Helva      *
* !"####!    $$$$$$$$$$ $$$$$$$$$ $$$$$$$$$  * Gothic     *
.)))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))-
```

When 100% of charging has been completed, the Gothic, Helva, Prestige 12 and Prestige 10 lights will blink:

```
+))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))),
*$ Power     +))))))))),+))))))))),+))))))))),              *
*" Add Paper *" On Line**LF/FF   **Font    * * Prestige 10 *
*            *         **        **" Draft * * Prestige 12 *
*            .)))))))))-.))))))))-.))))))))- * Helva      *
* !"####!    $$$$$$$$$$ $$$$$$$$$ $$$$$$$$$  * Gothic     *
.)))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))-
```

At the end of the recharging operation, all indicators will stop blinking and the Power indicator light will illuminate (steady, not blinking). The batteries are now fully charged.

Once the batteries are fully charged, the printer will operate continuously for a minimum of 50 minutes in the print mode or 12 hours in the stand-by mode.

2. Printing While Recharging - You can send data from your computer to the printer during the recharge operation. When the 180si printer receives this data, it stops the recharging process and prints. If you need to print while the battery is charging:

a. Press the On-Line button to bring the printer on line.

b. Insert paper if necessary.

c. Print.

A short time after the job is finished, the printer automatically resumes the recharging process from the point where you left off, provided AC power to the printer has not been interrupted.

3. Power interruptions - If the AC power is interrupted during recharging, the recharging operation will not automatically restart when power is restored. Continue to operate the printer until the batteries are low (Power Indicator flashes) and then begin the recharging process.
Make sure to use the appropriate charger for the printer. The charger is labeled INK JET PRINTER and Model # AD187. It is also larger than the Paravant charger.

F. THE CMT DISK DRIVE

1. General - The CMT Disk Drive is an exceptionally rugged portable battery-operated floppy disk drive designed for use with RS-232 compatible devices. It is waterproof, dust proof and vibration resistant.

One special feature of the CMT Disk Drive is its hinged water-tight front cover. While working in a hostile environment, you can screw on the cover to protect the disk drive and the front panel. Under normal operating conditions, swing the cover under the CMT to prop it up slightly.

2. Recharging the CMT Disk Drive - The CMT Disk Drive has built-in rechargeable batteries. Before using it for the first time, fully recharge your CMT by connecting it to a plugged-in Paravant charger for 10 hours.

You may keep the recharger plugged into a wall outlet while operating the CMT. However, if the batteries are very low, the unit will not operate properly, even if it is connected to the wall outlet.

G. RAMCARD BATTERIES

1. General - The lithium battery used on a RamCard cannot be recharged; it must be replaced. It will provide enough power to assure data retention for 8 months to 3

years, depending on the memory capacity of the RamCard. However, if the Ramcard is inserted into your computer while it is turned on, the RamCard is powered by the RHC-44 main battery; this will extend the life of the lithium battery.

The computer will periodically scan the RamCard slots to determine if one of them contains a RamCard with a low battery. You will then have the option either of continuing to receive the message, or of turning the message off.

2. Replacement - If you insert the RamCard into the computer with the system ON so the main battery provides power to the RamCard, it is possible to replace the lithium battery without losing data stored on the RamCard. However, it is advisable to have a good backup of your data before attempting to change the battery.

   If the lithium battery is completely dead, you will have to format the RamCard just as you would a brand new one and recover any files from a suitable backup copy. Send the RamCard to the office if it needs to be formatted.

   Obtain a new battery of the same type as the original. Use the screw driver provided with the RamCard to loosen the battery retaining screw approximately 5 millimeters. Hold the RamCard firmly and pull the battery holder from the card. Remove the old battery from the battery holder and insert the new battery in its place. Place the battery holder back into the card and tighten the retaining screw.

H. TROUBLE SHOOTING

1. Paravant Batteries

   A. Main Battery - The most frequent problem encountered with the Paravant data collector is low main battery voltage. If you suspect the battery is to blame, check the voltage of the main battery. A fully charged battery will register about 6.4 volts DC. If the battery is below 5.5 volts, the Paravant will not operate properly.

      Nicad batteries often develop problems when they get about 2 years old under normal use. Return the battery to the office for replacement. When possible, print and download files with the data collector while the unit is being charged.

B. Internal Back-up Battery - If the Paravant loses data or its configuration when you swap the main battery, the internal battery voltage may be low. It can only be charged when the Paravant is plugged into the AC charger (the output of the charger can be checked with the voltmeter). If the main battery charges but the internal does not, the Data Collector must be returned to the office for servicing.

2. Cables - The next most frequent problem encountered in the field is cables. If, during collection, you receive a "com port error" message, either the instrument is not set correctly, the wrong instrument is selected, or there is a loose connection in the cable connecting the Collector with the total station. Swap cables and try again. If you still get the same error message, check the battery of the total station. If this is okay, there may be a problem with the total station itself. NEVER USE THE TOTAL STATION IN THE RAIN! This can damage the electronics resulting in costly repairs.

3. Paravant configuration - Some problems can be traced to improper configuration or lost configuration. Reconfigure the unit if necessary. Be sure to reset the time if needed.

4. Two many files on a disk - The maximum number of files (regardless of size) that can be stored on a drive is 64.

CHAPTER 2-00 - SURVEY EQUIPMENT

SECTION 2-09 TRIBRACHS, PRISMS, AND PRISM POLES

Revised 11/01

A. TRIBRACHS

1. General - Tribrachs are one of the most versatile of all surveying instruments. When equipped with an optical plummet, they serve as a leveling and positioning base for theodolites, total station instruments, reflector prisms, sight poles, and targets.

   Although versatile, optical plummet tribrachs are the weakest link in the quest for quality measurements. Optical plummet tribrachs have optical plummets that are not self-checking, and a bulls-eye bubble that is designed for rough leveling. If the optical plummet is out of adjustment, the instrument, prism, etc. will not be positioned directly over the mark. The optical plummet must be checked on a regular basis.

2. Adjustment - The equipment needed to adjust the optical plummet on a tribrach are one tripod, two tribrachs and one tribrach adjusting cylinder. The adjusting procedures are:

   Step 1 - Set up tribrach on tripod. Place cylinder on tribrach and then position tribrach (the one to be adjusted) upside down on cylinder.

   Step 2 - Look through optical plummet of the upside down tribrach and place a mark that is in view on a ceiling. Adjust leveling screws on bottom tribrach to center optical plummet reticle on this mark.

   Step 3 - Rotate upper tribrach 180 degrees and note difference on mark. Remove half the difference with leveling screws on lower tribrach. The remaining difference is to be adjusted by the reticle adjusting screws. Loosen the adjusting screw that is opposite the direction the reticle must move to be on the mark. Then tighten the opposite screw until the reticle is on the mark or as close as it can be using this combination of screws. Repeat adjustment on second combination of screws and so on until the reticle is centered on the mark.

   Step 4 - Repeat Step 3 until reticle stays centered on the mark as the upper tribrach is rotated 360 degrees.

B. PRISMS

1. General - Prisms are used with electro-optical EDMI (light, laser, and infrared) to reflect the transmitted signals. A single reflector is a cube corner prism that has the characteristic of reflecting light rays back precisely in the same direction as they are received. This retro-direct capability means that the prism can be somewhat misaligned with respect to the EDMI and still be effective.

   Cube corner prisms are formed by cutting the corners off a solid glass cube; the quality of the prism is determined by the flatness of the surfaces and the perpendicularity of the 90☜ surfaces.

   In control surveys, tribrach-mounted prisms can be detached from their tribrachs and then interchanged with a theodolite (and EDMI) similarly mounted at the other end of the line being measured. This interchangeability of prism and theodolite (also targets) speeds up the work, as the tribrach mounted on the tripod is only centered and leveled one time. Equipment that can be interchanged and mounted on already set up tribrachs is known as forced-centering equipment.

   Prisms mounted on adjustable-length prism poles are very portable and, as such, are particularly suited for data collection and stakeout surveys.

2. Prism Offsets - Prisms can be mounted in most holders to provide either 0 or -30 mm offsets. To eliminate confusion and error, all of the Division's prisms should be mounted in their mounting bracket at "0" offset.

   It should also be noted that a "0" offset setting requires more care in the alignment of the prism to the EDMI. Misalignment in either the horizontal or vertical direction can cause an error in the distance measured. For example a combination misalignment of 30 degrees will result in an error of 5.1 mm (0.017 feet).

C. PRISM POLES

1. General - Prism poles are constructed of aluminum

tubing with a 5/8" x 11 mounting stud on top and have a

circular bubble attached. Two types of bubbles are available. One is okay for data collection work. The other is much more precise and is to be used with a bipod during metes-and-bound work.

Using a collet-type locking system, the prism pole may be adjusted in height from 1.3 m to 2.5 m (54 to 100 inches). The inside tube is graduated in both decimal feet and metric. These poles are very portable and, as such, are particularly suited for stakeout and data collection surveys.

2. Adjustment - The hard use that prism poles normally receive require the circular bubble to be periodically checked. To test the bubble -

   a. Screw a point into the top of the prism pole.

   b. Place the point of the pole beneath a low doorway or other structure and extend the upper section until the top point sticks in the wood with the pole plumbed by the circular bubble.

   c. Rotate the pole 180☜. If the bubble remains centered, the bubble is in good adjustment. If it is out, move the bubble 1/4 of the way back to center with the adjusting screws and repeat steps b and c.

CHAPTER 3-00 - SURVEY DATUMS AND THE MARYLAND COORDINATE SYSTEM

SECTION 3-01 HORIZONTAL DATUM

Revised 11/01

A. SHAPE OF THE EARTH

The earth, though normally thought of as spherical, is flattened at the poles and assumes the general shape of a mathematical figure called an oblate spheroid. Computations cannot be performed on the earth's true surface due to the difficulty in deriving equations, which would fit the surface variations. Thus, calculations relating various positions are made on a mathematical surface called an ellipsoid.

Throughout the world, various reference ellipsoids have been established which closely approximate the shape of the earth's surface where they are used. With the advent of the Global Positioning System, a need for a single ellipsoid arose. This new ellipsoid is call the GRS 80 ellipsoid and is the basis for all NAD83/91 positions. See Figure 3-01-A for GEOID - Ellipsoid - Surface Relationships.

1. The Ellipsoid

   The reference ellipsoid used in North American is the Geodetic Reference System Ellipsoid of 1980 (GRS 80) This earth-mass-centered ellipsoid has a semimajor axis (equatorial radius) of 6,378,137 meters.

   In general, survey data referenced to the ellipsoid are "geodetic" values.

2. The Geoid

   The geoid is the irregular surface of variable radius that would exist if the earth were covered with water. The irregularity is caused by local variations in the direction of gravity. Large dense masses, such as mountains, exert a gravitational force, which tends to pull the plumb line (the direction of gravity) toward the concentration of mass. Whereas, the ocean is less dense than rock and the plumb line is attracted toward the land and away from the water. The result of these variable forces is that the geoid assumes an undulating surface.

   Usually, survey data referenced to the geoid is called "astronomic".

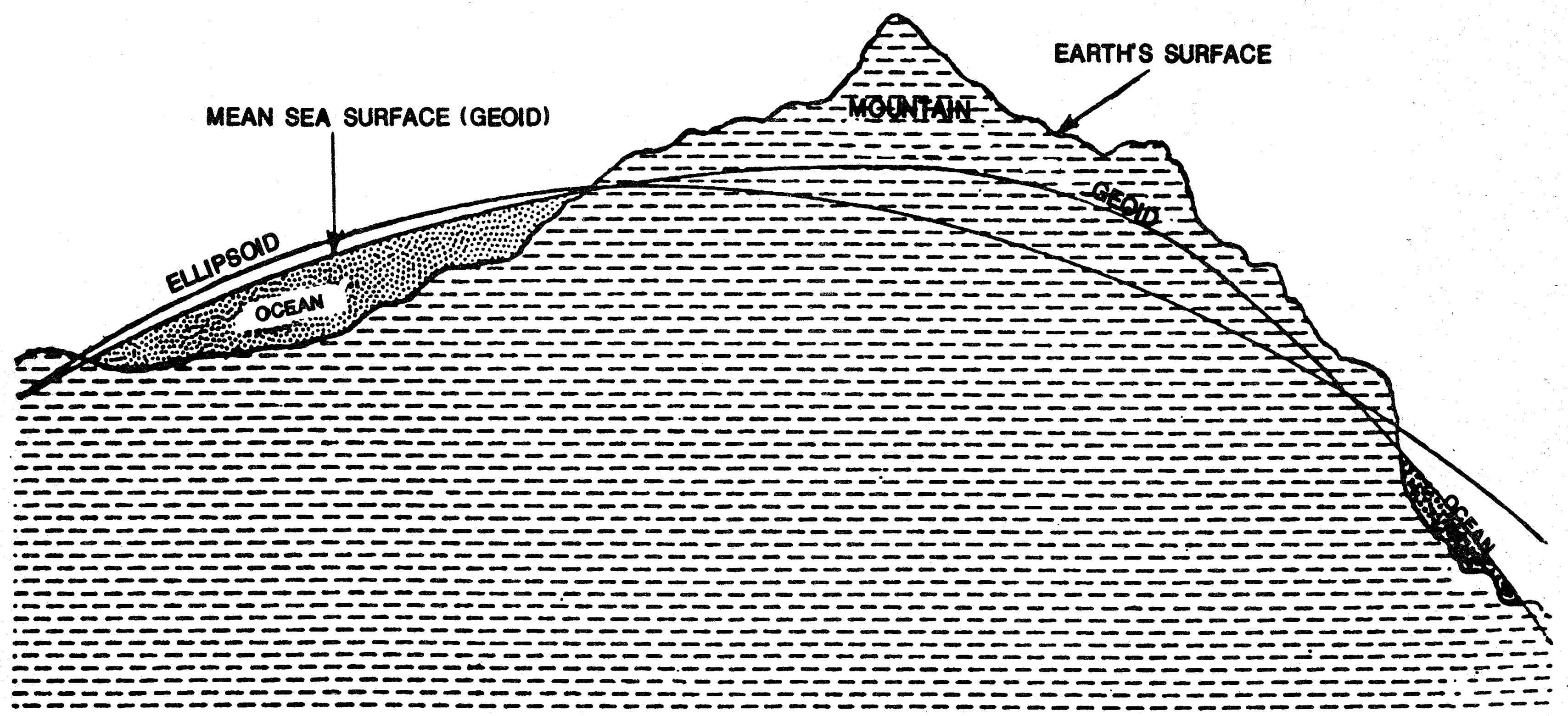


FIGURE 3-01-A GEOID-ELLIPSOID-SURFACE RELATIONSHIPS

B. POSITION ON THE EARTH

The position of a point can be defined by plane coordinates, geographic place names, or other systems. These various systems are related by spherical coordinates, which are expressed in terms of latitude and longitude. These are commonly referred to as the geographic position of a point.

1. Latitude - Latitude is measured in a north-south direction from the plane of the equator.

   a. Astronomic Latitude - The angle between the direction of gravity, at a given point, and the plane of the equator. Astronomic latitude results directly from celestial observations, which are not corrected for the deflection of the vertical.

   b. Geodetic Latitude - The angle between the normal to the spheroid, at a given point, and the plane of the equator. Latitude shown on topographic maps and on navigators' charts and that obtained from GPS is geodetic latitude.

2. Longitude - Longitude is measured in an east-west direction from the meridian through the observatory of Greenwich, England.

   a. Astronomic Longitude - The angle, measured at the polar axis, between the meridian plan parallel with the plumb line at a given point and the Greenwich meridian plane. Astronomic longitude results directly from celestial observations, which are not corrected for the deflection of the vertical.

   b. Geodetic Longitude - The angle between the meridian plane of the normal to the spheroid at a given point and the Greenwich meridian plane. Longitude shown on the topographic maps and on navigators' charts and that obtained by GPS is geodetic longitude.

C. AZIMUTHS

Azimuth is the horizontal direction of a line measured to the right (clockwise) from a reference line. Azimuths used by the National Geodetic Survey, the Army, and some other agencies prior to NAD83 were south oriented. This follows the custom in Europe. However, it is more convenient to refer azimuths to the north. This is because the algebraic signs of trigonometric functions are correct when calculating departures and latitudes. Many organizations have adopted this practice.

1. Policy - Azimuths for work shall be referred to north.

2. Astronomic - An azimuth measured from the celestial pole in a plane perpendicular to the direction of gravity at the point of observation. Astronomic azimuths are determined directly from celestial observations.

3. Geodetic - An azimuth referenced to the pole of the spheroid in a plane perpendicular to the spheroid at the beginning or ending point of a line. Geodetic azimuths can be computed from astronomic azimuths by applying the Laplace correction.

   The difference between astronomic and geodetic azimuths can be visualized by imagining the slight adjustment necessary in an instrument to keep it leveled over a point if the plumb line is deflected (deflection of the vertical). This small adjustment would cause a corresponding small change in the measured angle.

4. Grid - Grid azimuth is the angle in the plan projection between grid north and the straight line from the point of observation to the point observed. Grid azimuth is the same as geodetic azimuth only when the point of observation falls on the central meridian (77° West Longitude for Maryland).

5. Forward and Back Azimuths - The azimuth for a line is usually stated as the azimuth measured at its beginning point. This is called the forward azimuth. However, each line has a corresponding back azimuth, which is the azimuth measured at its ending point.

   Because of convergence of the meridians, the difference between forward and back geodetic and astronomic azimuths is 180° plus the angle of convergence. The convergence correction for lines up to 15 miles in length can be determined by the following expression.

   Convergence (seconds) = difference in longitude in seconds of arc of the two end points, times the sine of the mean latitude of the two end points.

   For grid azimuths the difference between the forward and back azimuths will always be exactly 180°.

D. NORTH AMERICAN DATUM OF 1983 (1991 ADJUSTMENT)

The North American Datum of 1983 became the officially adopted reference system for horizontal control surveys in the United States, Mexico, and Canada. However, when the High Accuracy Reference Network (HARN) was established in Maryland, It became necessary to re-adjust the existing network to conform to the more accurate HARN. This work was completed in 1991 - hence NAD 83/91.

1. Origin and Controls

The North American Datum of 1983/1991 (NAD 83/91) is a geodetic datum based on the Geodetic Reference System Ellipsoid of 1980 (GRS80). It is the third horizontal geodetic datum of continental extent in North American Datum. It replaces both the original North American Datum and the North American Datum of 1927 (NAD 27) for all purposes.

The idea of performing a general adjustment of the horizontal control networks in North America began as an increasing awareness of the inadequacies of the existing North America Datum of 1927 (NAD 27). These inadequacies were ascribed to several causes, rooted both in the sparsity of the data used in the 1927 adjustment and in the way the network had grown since then.

The network became inadequate because it was weak in relation to the increasing demands that were placed upon it. The weaknesses became apparent in several ways. Surveyors were buying accurate electronic distance measuring (EDM) equipment and finding unexplainable discrepancies between the existing control network and the distances measured by their new instruments. Missile ranges and satellite tracking systems demanded their own independent surveys. The geodesists of the National Geodetic Survey experienced increasing difficulty in fitting new urban surveys into the existing NAD 27 system.

The NAD 83 project began on July 1, 1974 and ended on July 31, 1986 at an approximate cost of $37 million. The State of Maryland, in cooperation with NGS, established the HARN network at a cost of $60,000.

2. Responsible Agency - In the United States the National Geodetic Survey (NGS) was responsible for maintaining and expanding the network. However in the 1980's, due to shrinking budgets, state and local agencies now perform much of this work.

   Network maintenance includes perpetuating stations, resetting destroyed station marks, and establishing new stations. The Division of Plats and Surveys is engaged in a cooperative effort with NGS in performing these activities. Division surveyors plan these network extensions, perform the field surveys, and check all field notes according to NGS standards. NGS computes and publishes the positions of the new stations.

CHAPTER 3-00 - SURVEY DATUMS AND THE MARYLAND COORDINATE SYSTEM

SECTION 3-02 VERTICAL DATUM

Revised 11/01

A. GENERAL

Elevations for engineering projects must be referenced to a single vertical datum so various phases of a project, and contiguous projects, will match. This datum can be based on some particular standard, such as sea level, an assumed elevation, or the elevation of a local permanent point or natural object. Various organizations, private and public, use datums that best serve their individual needs. This has led to many different datums, causing confusion.

B. POLICY

The vertical datum for the State Highway Administration shall be the North American Vertical Datum of 1988 (NAVD 88) as established by the National Geodetic Survey.

C. GRAVITY

Engineering leveling, except barometric leveling, depends on establishing a plane that is perpendicular to the direction of gravity.

Gravity is the resultant of gravitation and centrifugal force. Gravitation is an attraction force and is exerted generally toward the center of mass of the earth. Centrifugal force results from the earth's rotation. It is exerted away from and perpendicular to the earth's axis of rotation. Gravitation varies with the concentration of mass and the distance between the affected bodies. Centrifugal force increases as the elevation increases and decreases as the latitude increases. Thus, the resultant, gravity varies in both direction and magnitude.

In most leveling work for the Division, variations in the direction of gravity can be ignored since the effect on leveling is negligible. The corrections which might be necessary for some control level networks are discussed below.

1. Orthometric Correction - Since the direction of gravity varies with elevation, level surfaces at different elevations are not exactly parallel. Thus, elevations established by differential leveling at altitudes other than sea level will not be referenced exactly to the

theoretical sea-level surface (the geoid). The small errors thus introduced are corrected by applying the "orthometric correction". This correction is applied only in precise level adjustments, second-order or higher.

2. Correction for a Large Concentration of Mass - Occasionally a large concentration of mass, such as a nearby mountain, will cause a local deflection in the direction of gravity. This might be large enough to necessitate a special correction in precise level networks. This correction is rarely necessary for transportation surveying.

D. NATIONAL GEODETIC VERTICAL DATUM OF 1988

The basic vertical datum for the United States (except Alaska and Hawaii) is now NAVD 88.

1. Origin and Controls - Due to inconsistencies in the previous vertical datum (National Geodetic Vertical Datum of 1929 or NGVD 29), NGS decided to perform a general re-adjustment of all leveling data. This new datum is referred to as NAVD 88. Elevations for most bench marks can be determined in both datums.

2. Responsible Agency - NGS is responsible for perpetuating and extending the datum network. Due to budget problems, much of this work has been delegated to state and local agencies. SHA's Plats and Surveys Division should be contacted if any geodetic bench marks are in danger of being destroyed.

E. LOCAL DATUMS

Prior to the conception of large, interrelated engineering projects, such as our complex highway system, a large network of related bench marks was not needed. Therefore, many local datums were established. Often these datums are referred to as "assumed" datums. These datums are based on something other than NAVD 88.

CHAPTER 3-00 - SURVEY DATUMS AND STATE PLANE COORDINATE SYSTEMS

SECTION 3-03 STATE PLANE COORDINATE SYSTEMS

Revised 11/01

A. POLICY

Surveys performed by the Maryland Department of Transportation shall be on the Maryland State Plane Coordinate System (MSPCS).

B. GENERAL

All engineering personnel should have a basic understanding of the MSPCS. This section provides a brief explanation of the system. Additional study materials are available in many other publications, such as surveying textbooks and NGS publications.

1. Definition - The MSPCS is a system of plane-rectangular coordinates that has been established by Maryland statutes for defining and stating the positions of points on the surface of the earth within the State of Maryland.

2. Origin - The MSPCS, as with all other state coordinate systems, was developed by the National Geodetic Survey (NGS). Legislation establishing the system was enacted in 1957 and amended in 1987. The statutes are included in Article 91 "Surveyor and State Survey" of the Annotated Code of Maryland, under Sections 19, 20, and 21. Surveyors should be familiar with these statutes because they define the MSPCS and provide for its use.

3. Benefits - The MSPCS fulfills several needs. Among these are:

    a. Provides a means by which geodetic values of monumented points can be used for plane surveying.

    b. Permits plane surveying over large areas without introducing significant error.

    c. Establishes a single reference system for all surveys in an area. Thus, it provides a positive mathematical relationship between contiguous projects regardless of elapsed time between the projects.

    d. Establishes a uniform computational base.

e. Provides a lasting reference system. This makes retracement surveys less costly.

f. Provides a positive mathematical base for locating and describing property boundaries.

g. Facilities the establishment of Geographic Information Systems (GIS).

C. DESCRIPTION OF THE GRID

1. Geometry - The MSPCS consists of one plane rectangular coordinate system. The system is represented by two sets of parallel straight lines which intersect at right angles. (See Figure 3-03-A). The network thus formed is termed a grid.

   One set of these grid lines is parallel to the plane of the meridian (longitude) which passes approximately through the center of the state. In the MSPCS this meridian is 77☜ 00' west longitude and is termed the "central meridian". The y-axis is a grid line at the extreme west of the grid and is parallel to the central meridian. The x-axis is a grid line at the extreme south of the grid and is perpendicular to the central meridian.

   The origin of the MSPCS is at the intersection of the central meridian and the parallel 30☜ 40' north latitude. The origin is given the coordinates: easting = 400,000 meters and northing = 0 meters.

2. Positions of Points - The position of point on the grid can be defined by stating two distances, termed "coordinates". One distance, the "y-coordinate", gives the distance from the x-axis and is commonly referred to as the "northing". The other distance, the "x-coordinate", gives the distance from the y-axis and is known as the "easting".

3. Location of Axis - The y-coordinates increase from south to north; x-coordinates from west to east. All y-coordinates are made positive by setting the x-axis outside and to the south of the State. Similarly, all x-coordinates are made positive by assigning the value of 400,000 meters as the x-coordinate of the central meridian. This places the y-axis outside and to the west of the State.

D. THE LAMBERT CONFORMAL PROJECTION

A plane-rectangular coordinate system is, by definition, on

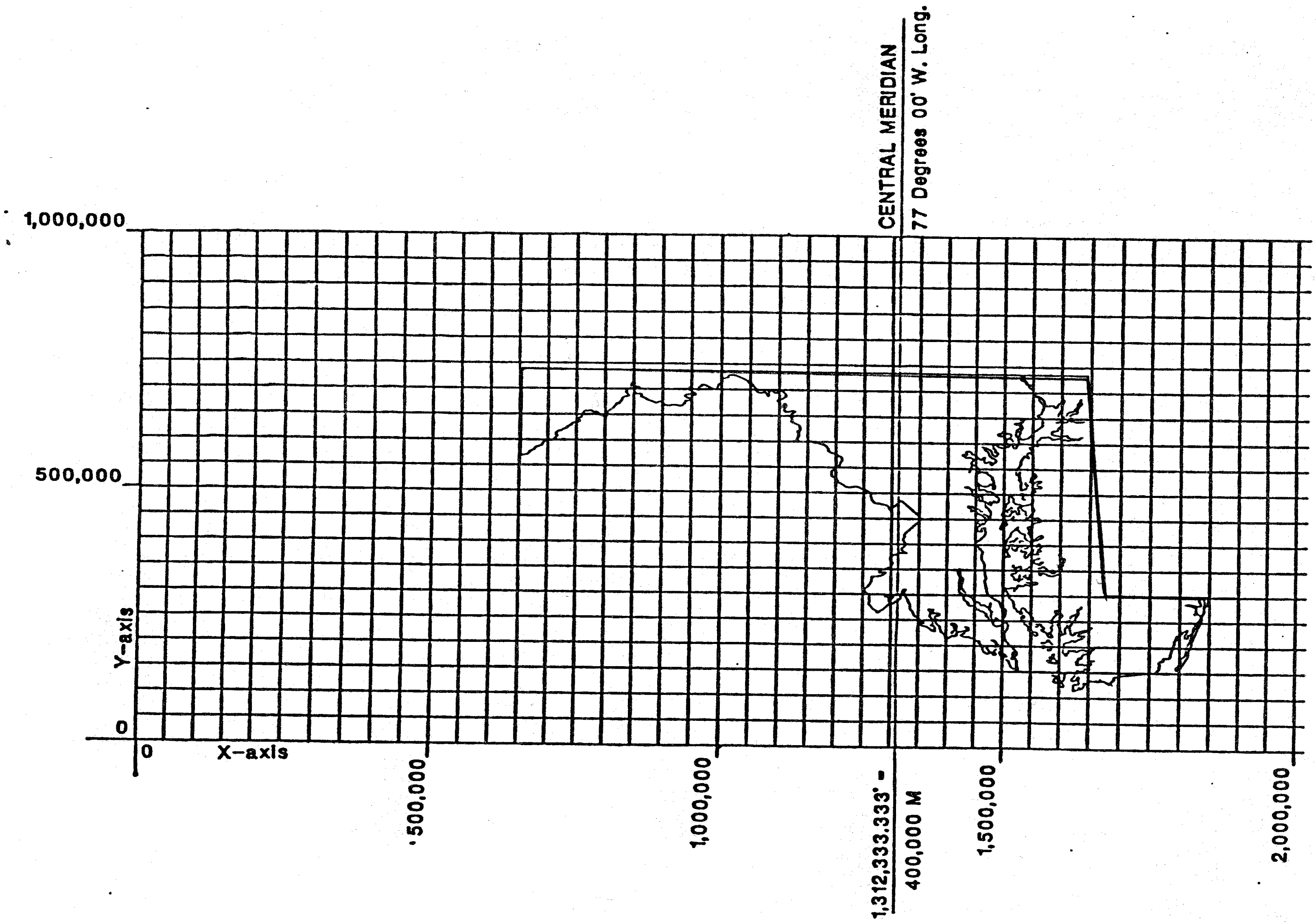


Fig. 3-03-A Maryland State Coordinate System Grid a flat surface. Thus, the geodetic positions must be "projected" from the curved surface of the spheroid to plane coordinate positions.

The NGS used two types of projections when developing state coordinate systems. The "Lambert conformal conic projection" was devised for zones of limited north-south dimension and indefinite east-west extent. The "Transverse Mercator Projection" was developed for systems whose zones have their greatest extent in a north-south direction.

The MSPCS is based on the Lambert conformal conic projection of the Geodetic Reference System Ellipsoid of 1980. This MANUAL briefly covers only the Lambert projection.

1. Description of Projection - The Lambert projection can be pictorially illustrated by a cone which intersects the spheroid along two parallels of latitude as shown in Figure 3-03-B. In the MSPCS these parallels are at north latitudes 38° 18' and 39° 27'. These latitudes are known as the "standard parallels" for the projection. Positions of points and lines on the spheroid are projected onto the surface of the cone. Then, the cone is split along an element and unrolled into a plane. (See Figure 3-03-C.)

   The meridians of spheroid are represented on the projection by straight lines that meet at a common point which is the apex of the cone. This point is the "central point" of the grid. The parallels of latitude appear as arcs of concentric circles whose common center is the central point. (See Figure 3-03-D.) The plane-rectangular grid, as described in the preceding section, is shown superimposed on the surface of the unrolled cone in Figure 3-03-D.

2. Scale

   a. Factor - Along the standard parallels, grid distances are equal to their corresponding geodetic distances. Therefore, the scale, expressed as a ratio, along the standard parallels is equal to unity. (It is also said to be "scale exact".) It is defined as the grid distance divided by its corresponding geodetic distance.

   b. Variance - It is evident from inspection of Figures 3-03-E and 3-03-F that between the standard parallels, grid distance is slightly shorter than geodetic distance. The scale factor varies from unity at the standard parallels to a minimum value approximately halfway between them.

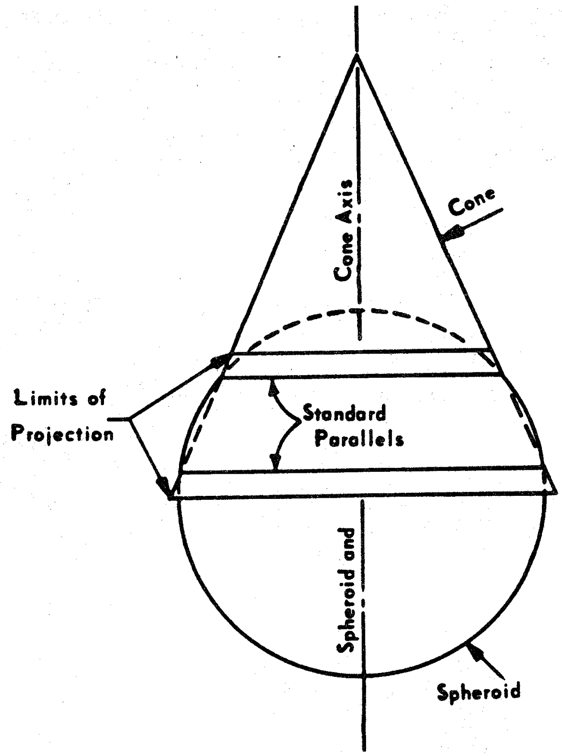


Fig. 3-03-B Intersecting Cone Illustration of the Lambert Conformal Projection

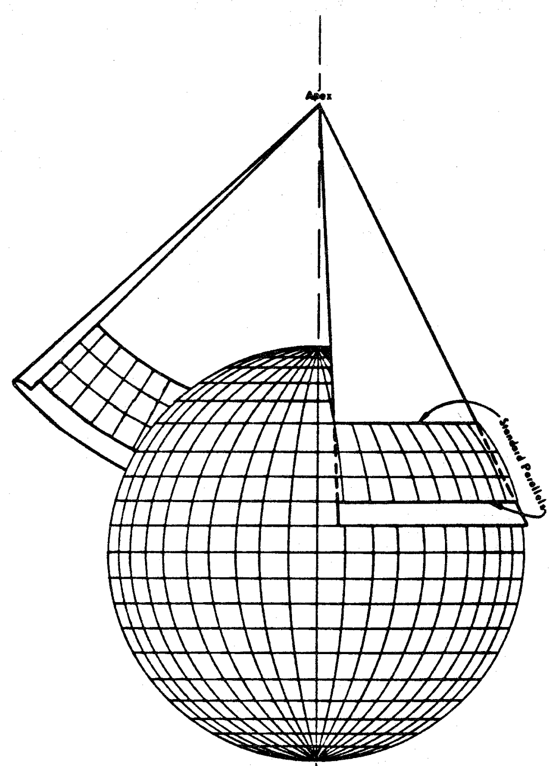


Fig. 3-03-C Unrolled Cone Illustrating the Lambert Conformal Projection

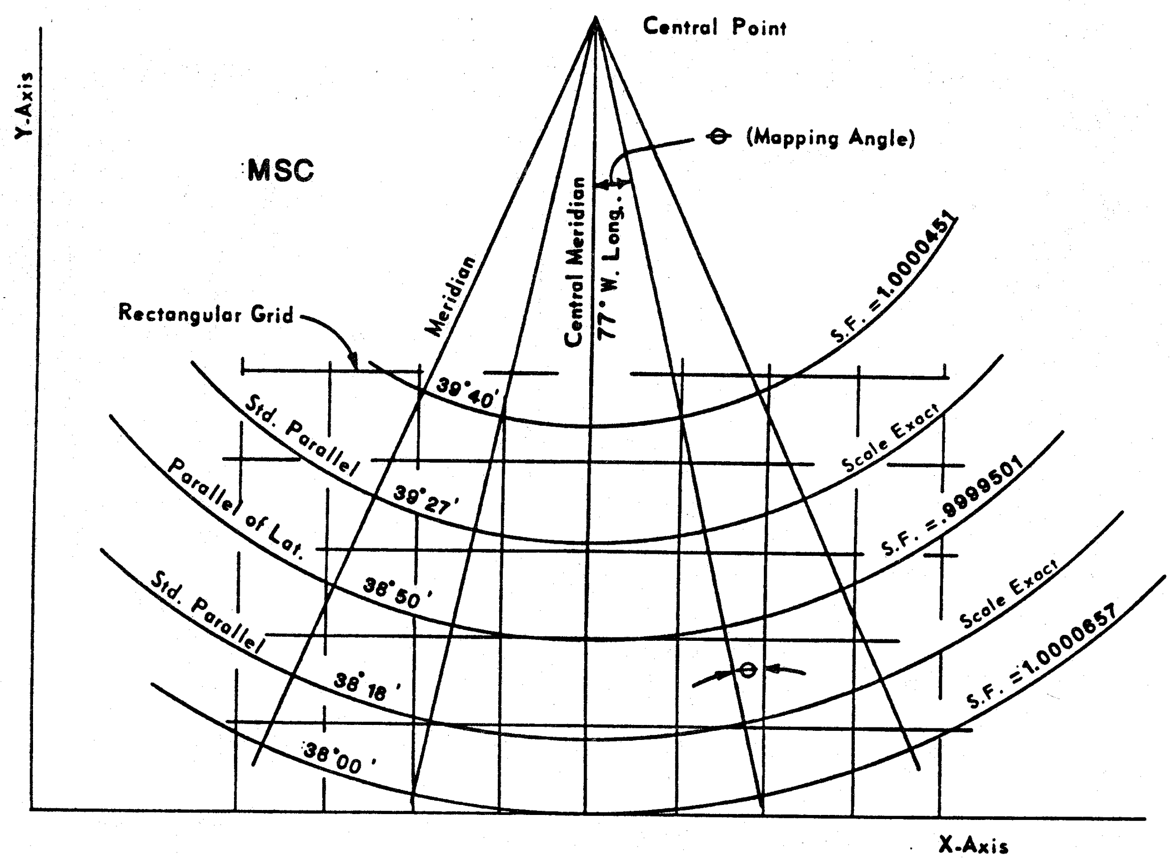


Fig. 3-03-D Cone Unrolled into a Plane with Grid Superimposed

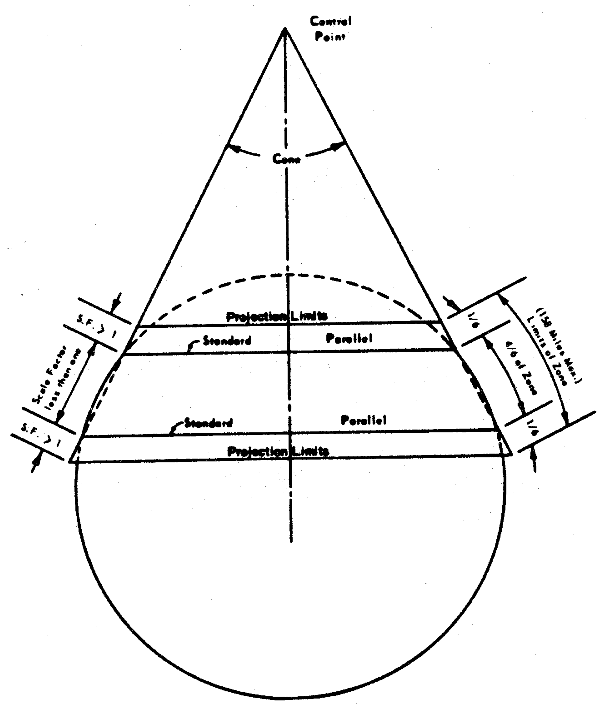


Fig. 3-03-E Scale Factors and Projection Limits

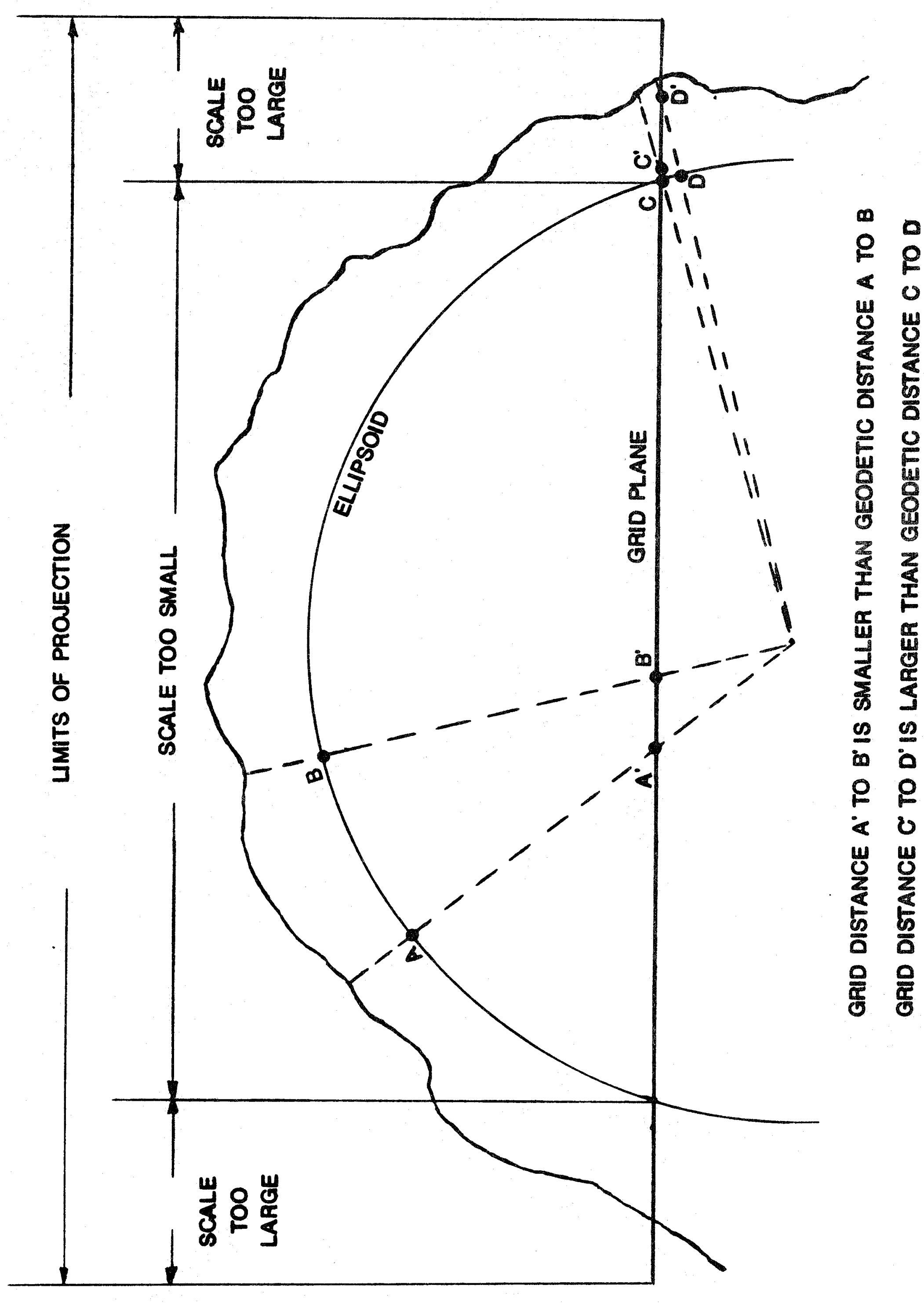


FIGURE 3-03-F GEODETIC VS. GRID DISTANCES

It also can be seen that outside the standard parallels grid distance is slightly longer than geodetic distance. The scale factors for these portions of the grid are greater than unity and increase with the distance from the standard parallel. Figure 3-03-D shows the scale factors for various parallels of latitude in the MSPCS.

c. Relative to Latitude - A noteworthy characteristic of the Lambert projection is that the scale varies with the latitude. It is constant along true east-west lines (parallels of latitude).

d. Discrepancy: Grid/Geodetic - The MSPCS has been so devised that the discrepancy between a grid distance and the corresponding geodetic distance will seldom be more than one part in 10,000.

E. CONVERSION OF GROUND DISTANCES TO GRID DISTANCES

When using the MSPCS, all measured distances must be converted to grid distances. The measured distances are first reduced to horizontal distances; then each horizontal distance must be converted to grid distances by using the equation,

Grid Distance = Ground distance x grid factor

where grid factor = scale factor x elevation factor

Alternatively, grid distance ÷ grid factor = ground distance

Both the scale factor and the elevation factor can be determined from tables or computer programs and obtained from the Division office, if the need arises.

CHAPTER 4-00 - ERRORS AND CLASSIFICATIONS OF ACCURACY

SECTION 4-01 ACCURACY AND PRECISION

Revised 11/01

A. ACCURACY

Accuracy is the degree of conformity with a standard or a measure of closeness to a true value. Accuracy relates to the quality of the result obtained when compared to a standard. It is distinguished from precision, which relates to the quality of the operation used to attain the result. The standard used to determine accuracy can be - An exact value, such as the sum of the three angles of a plane triangle is 180☜.

A value of a conventional unit as defined by a physical representation thereof, such as the international meter.

A survey or map value determined by refined methods and deemed sufficiently near the ideal or true value to be held constant for the control of dependent operations.

B. PRECISION

Precision is the degree of refinement in the performance of an operation (procedures and instrumentation) or in the statement of a result. The term precise also is applied, by custom, to methods and equipment used in attaining results of a high order of accuracy, such as precise level rods.

Precision is indicated by the number of decimal places to which a computation is carried and a result stated. However, calculations are not necessarily made more precise by the use of tables or factors of more decimal places. The actual precision is governed by the accuracy of the source of data and the number of significant figures rather than by the number of decimal places.

C. ACCURACY VERSUS PRECISION

The accuracy of a field survey depends directly upon the precision of the survey. Although through luck (for example, compensating errors) surveys with high-order accuracies might be attained without high-order precision, such accuracies are meaningless.

Therefore, all measurements and results should be quoted in terms that are commensurate with the precision used to attain the results. Similarly, all surveys must be performed with a precision, which ensures that the desired accuracy is attained. However, surveys performed to a precision, which excessively exceeds the requirements, is costly and should be avoided. In other words, "Do not over-survey".

D. SIGNIFICANT FIGURES

The significant figures of a numerical value are those digits, which are known plus one doubtful digit following the known digits. Zeros, which are used merely to locate the decimal point, are not significant figures. For example, the number 5,630 have three significant figures - digits 5, 6, and 3. Digits 5 and 6 are known and digit 3 is the one doubtful digit. Digit 3 is doubtful because the exact value of the example could be any value between 5,625 and 5,635. The zero is not a significant figure in this case because it is assumed that it merely locates the decimal point.

Other examples are --

Numerical Value	Significant Figures
49	2
1,600*	2
.1284	4
0.21	2
00.000213	3
129.85	5
11.00+	4
10,000.0001	9
5,280 ft./mi.+	infinite

* Generally, in such cases the zeros merely place the decimal point. Thus, they are not significant figures. However, if they indicate a true zero value, they are significant and should be counted as such. In this example, if 1,600 happens to be the height of a tower measured to the nearest foot, this number would have four significant figures.

+ If correct recording procedures are being followed, the zeros are significant because they indicate a true zero value. For example, 11.00 could be the distance measured between two points as measured with an engineer's tape.

+ All values, which are exact by definition, have an infinite number of significant figures.

The general rules of significant figures are as follows:

1. Recorded numerical values, measured and computed, must

contain only those digits, which are known plus one doubtful digit. Zeros, of course, may be used to indicate the location of the decimal point. (A minor exception to this rule is stated in Paragraph 2.)

For example, the length of a line must be determined by adding three measurements of different accuracies.

EDM	301.46 m*	=	989.04 ft.
Clothe Tape	4.1 ft.	=	4.1 ft.
Stadia Distance	210. ft.	=	210. ft.
Total Distance		=	1203. ft.

* The metric value of this distance, to the nearest centimeter, is accurate to the nearest 0.03 foot. Thus, the conversion to 989.04 feet indicates precision, which is inflated. However, if such conversions were reduced by one significant figure, for example 989.0 feet, this would indicate precision that is considerable further from the true precision than the inflated precision indicated by 989.04 feet. Surveyors must be aware of such limitations when recording field data and computing and establishing resolved values thereof.

2. Recorded field measured values should never indicate a precision greater than that used in the actual survey. For example, when measurements are made with a cloth tape, values should be recorded to the nearest 0.1 foot; not 0.01 foot.

3. Computations

   a. Multiplying or dividing -- The result must not have more significant figures than the term with the least number of significant figures.

      Example: 12.182 X 11.1 = 135

      Exception: If one term has a beginning numeral that is close to a double digit number, such as eight or nine, another significant number may be used. For example, 9.2x2.11=19.4 not 19.

   b. Adding or subtracting -- The number of significant figures in the result is determined by the position of the first doubtful digit to the right of the known digits. That is, the result must not contain any significant figures to the right of the first column containing a doubtful digit.

Example:

10.001
9.2
306.2954
87.8
413.3

c. When calculations involve several steps, it is advisable to use one extra significant figure throughout the intermediate steps. However the final result must always be rounded off to the appropriate number of significant figures according to "1" and "2" above.

4. Zeros should be used only to indicate a true zero value or for locating the decimal place. Extra zeros are to be avoided. (Exception: When the number is less than one, one zero should be placed to the left of the decimal point -- 0.21) Extra zeros cause confusion. For example, if a value were recorded as 29.0 when it really was 29, those that use this value will receive the misconception that the precision is three significant figures.

   Conversely, if a value were actually measured as 85.00, do not omit any significant figures. State the value as 85.00, not 85, so those using this value will realize it was determined to the nearest 100th rather than to the nearest whole number.

CHAPTER 4-00 - ERRORS AND CLASSIFICATIONS OF ACCURACY

SECTION 4-02 ERRORS - DEFINITION, TYPES AND SOURCES

Revised 11/01

A. GENERAL

1. Likelihood of Error - Statistically speaking, field observations and the resulting measurements are NEVER exact. Any observation can contain various types of errors.

   Often errors are known and can be eliminated by applying appropriate corrections. But, even after all known errors are eliminated, a measurement will still be in error by some unknown value.

   Usually the greater the precision used in making the observations, the less the magnitude of the unknown error. But, a measurement is never exact, regardless of the precision of the observations.

2. Responsibility of Field Personnel - Although this manual contains many guidelines and standards, the ultimate responsibility for providing surveys that fulfill desired accuracies remains with field personnel. To meet this responsibility the Party Chief and his assistants must understand errors, including --

   a. The various sources of errors.

   b. The effect of possible errors upon each observation, each measurement, and the entire survey.

   c. Economical procedures, which will eliminate or minimize errors and result in surveys of desired accuracies.

3. Scope - The sections covering errors in this chapter are primarily concerned with definitions and the theory of errors. Refer to the various procedural chapters, such as Chapter 5, "Surveying Procedures", for a discussion of the specific errors which occur and the methods used to minimize them.

B. BLUNDERS

1. Definition - A blunder (also called a mistake) is an unpredictable, human mistake. It is not an error,

although a small blunder may remain undetected and have the same effect as an error.

Examples of blunders are --

a. Transposition of two numbers.

b. Neglecting to level an instrument.

c. Misplacing the decimal point.

d. Misunderstanding a callout to be "7" when it is "11".

2. Cause and Prevention - Blunders are caused by carelessness, misunderstanding, confusion, or poor judgment. They are avoided, for the most part, by alertness, common sense, and good judgment.

   Blunders are detected and eliminated by using proper procedures, such as:

   a. Making independent check observations and measurements.

   b. Checking each recorded and calculated value.

   c. Checking the mathematical closure of each survey, using data recorded in Field Survey Book or in the Data Collector. DO NOT USE PEG BOOK.

   All blunders must be eliminated prior to correcting and adjusting a survey for errors.

C. ERRORS

1. Definition of Error - Error is the difference, after blunders have been eliminated, between a measured or calculated value of a quantity and the true or established value of the quantity.

2. Types of Errors - Errors are of two general types: systematic and accidental.

   a. Systematic Error

      1) Definition - A systematic error is an error, which will always have the same magnitude and same algebraic sign under the same conditions.

      2) Causes - In most cases, systematic errors are

caused by physical and natural conditions that vary in accordance with fixed mathematical or physical laws. However, some result from the observer's personal observing habits -- his tendency to react mentally and physically in the same way under similar conditions.

3) Effect - A systematic error, of a single kind, is cumulative. However, several kinds of systematic errors occurring in any one measurement could compensate for each other.

4) Examples - Some examples of systematic errors are --

   a) Thermal contraction and expansion of a steel tape.

   b) Refraction.

   c) A particular chainman's tendency to always slightly overpull a tape.

   d) Failure to apply an atmospheric correction (PPM correction) while using an EDM.

5) Detecting and Minimizing - Some systematic errors can be difficult to detect. Therefore, the surveyor must recognize the conditions (instrument imperfections, atmospheric temperature and pressure, personal habits, etc.) that cause such errors. Once the conditions are known, the effect of these errors can be minimized as follows:

   a) Use procedures that will automatically eliminate systematic errors. Examples of these procedures are:

      (1) Balancing foresights and backsights when leveling.

      (2) Turning angles directs and reverse.

      (3) Using standardized tapes.

   b) When systematic errors cannot be eliminated by procedures, corrections are applied to the measurements. These corrections are computed from the fixed relations between the systematic errors and the conditions of the observations. A simple example would be the temperature correction applied to a taped measurement.

All systematic errors must be eliminated prior to any adjustment of a survey for accidental errors.

b. Accidental Error

1) Definition - An accidental error (also called a random error) is an error which does not follow any fixed relation to the conditions or circumstances of the observation. For a single measurement, it is the error remaining in the measurement after eliminating all possible systematic errors.

2) Causes - Accidental errors are produced by irregular, complex causes that are beyond the control of the observer. Their occurrence, magnitude, and algebraic sign cannot be predicted; each is truly random.

3) Analyzing - Since accidental errors are random, they obey the laws of chance. Therefore, they are analyzed according to the mathematical laws of probability.

4) Effect - Theoretically, an accidental error has an equal chance of being negative or positive. Thus, errors of this type tend to be compensating. However, since the magnitude is also a matter of chance, accidental error to a small degree remains in every measurement.

5) Example - An example of an accidental error is an Instrument Man's inability to point a theodolite exactly. But, if his personal habits make him consistently point off to the same side of the sight line, this error becomes a systematic error.

6) Compensating - Corrections cannot be computed for accidental errors as for systematic errors. Accidental errors must be compensated by adjustments.

7) Least Squares Adjustment - Of the many different methods used by surveyors, this method provides the "most probable" values. Prior to adjustment, all possible systematic errors must be eliminated because the least squares adjustment (and other adjustment methods as well) is applicable only to truly random accidental errors.

8) Adjustment Results - The surveyor should remember that any adjustment only provides what he believes to be the best solution for the total survey. Even after proper adjustment, each individual value (such as the position of a specific point) is in error by an amount depending on the precision of the survey. Possibly, an adjustment could increase the error for a specific point. Collectively, however, the errors have been reduced and the total survey is improved.

3. Sources of Errors - There are three general sources of errors: personal, instrumental and natural.

a. Personal Errors

1) Causes - Theses errors are caused by the physical limitations of the observer and by his personal observing habits. They can be either systematic or accidental.

2) Personal Systematic Errors - These errors are caused by the observer's tendency to react the same way under the same conditions. For example, a Chainman may measure slightly long on every measurement because he always stands in a certain position when taping. Each observer, whether he believes it, makes a personal systematic error of a small degree on each individual observation.

Fortunately, such errors are minimized by proper procedures.

3) Personal Accidental Errors - Because of the human limitations of sight and touch, exactly correct observations are impossible. Some error remains in a measurement even after all systematic errors are eliminated. For example, regardless of the amount of care a Chainman uses to mark a taping point, the distance will be in error by some amount.

Sometimes it will be slightly short, other times slightly long. The magnitude of these errors will also vary. Errors caused by the physical limitations of the observer are called personal accidental errors.

b. Instrument Errors

1) Causes - Instrument errors are caused by imperfections in the design, construction, and adjustment of instruments and other equipment. Some such imperfections are:

a) Eccentricity of theodolite circles.

b) A tape which is too short or too long.

c) Misadjustment of level vials (bubbles).

2) Type - In an individual observation, instrumental errors are systematic because they will be of the same magnitude and sign under the same observing conditions. However, if several observations are made of the same value (such as observing an angle at different positions of the theodolite circle), the systematic error of each observation could have the effect of an accidental error on the resulting measurement, the arithmetic mean.

3) Eliminating/Minimizing - Most instrumental errors are eliminated by using proper procedures, such as observing angles direct and reverse, balancing foresights and backsights when leveling, and repeating measurements.

Instrumental errors that are not eliminated by procedures must be minimized by maintaining a regular program of periodically checking and adjusting (or calibrating) instruments and other equipment. Thus learn and follow the checking and adjusting guidelines provided in Chapter 2, "Survey Equipment".

c. Natural Errors

1) Causes - Natural errors (or external errors) result from natural physical conditions, such as atmospheric pressure, temperature,

humidity, gravity, wind, and atmospheric refraction.

2) Type - Natural errors are systematic. But if undetected and thus not eliminated or if incorrectly determined, they can have the same effect as accidental errors.

3) Correction - natural errors are removed from measurements by determining corresponding corrections from known relationships between an error and the natural phenomena. A familiar example is the correction for atmospheric temperature and pressure which is applied to EDM instrument measurements.

   Generally, the least certain value used in figuring a correction is the measurement of the natural phenomenon. For example, in an EDM measurement, atmospheric temperature is usually measured at each end of the line. But temperature along the line might not be constant, especially if the height of the line above the ground varies considerably. However, sufficient accuracy is usually obtained by assuming a constant natural condition, if proper procedures are used.

4) Minimizing - Natural errors can be controlled to some extent by making observations only when natural conditions are most favorable (that is, when they are the most constant). Examples of this would be:

   a) Precise taping at night or in cloudy weather (the temperature is most constant at these times).

   b) Measuring angles only at night, in the early morning or in cloudy weather (The sun has the effect of heating the earth's surface unevenly).

   Sometimes the effect of natural errors can be eliminated by using certain procedures, such as balancing foresights and backsights when leveling. This eliminates the effect of curvature and refraction.

CHAPTER 4-00 - ERRORS AND CLASSIFICATIONS OF ACCURACY

SECTION 4-03 CLASSIFICATION OF ACCURACY

Revised 11/01

A. POLICY

All surveys by the Division of Plats and Surveys shall be classified according to the standards specified in Paragraph D.

A survey of a given classification must conform to all standards for that classification.

The standards listed in Paragraph D are minimum requirements. Generally, closure errors should not exceed one half the allowed error. Any survey, which barely meets the minimum standards, in part or in whole, should be suspected and checked.

B. FIELD PROCEDURES

In addition to conforming to the applicable standards, surveys, which are to be "classified", must use field procedures that meet or exceed the requirements for the specified classification. To some extent, basic procedural requirements are included as part of the standards; for example, the minimum number of angle observations is given in several instances. However, refer to Chapter 5 for a discussion of the procedures to be used for each classification of accuracy.

C. REASONS FOR STANDARDS AND PROCEDURES SPECIFICATIONS

1. Achieve Desired Accuracy - The primary reason for detailed standards and procedural requirements is to ensure that a desired accuracy is attained throughout a survey. This means that the accuracy is not only attained at the points of closures, but at all points in the survey. Furthermore, the closures achieved are not just accidental but are true indications of the surveys precision.

2. Establish Uniformity Among Surveys - Standards and procedural specifications also will create uniformity among surveys of the same classification. It is impossible to achieve uniformity when different survey parties use different procedures and standards to perform surveys, which are purported to be of the same classification.

3. Minimize over-surveying - Standards and procedures can prevent, or minimize, over-surveying. Under most conditions, the procedures specified herein will provide closing and relative position accuracies well within the standards specified. Thus, the use of procedures involving a greater degree of precision shall be avoided, unless unusual conditions warrant.

4. Provide Requirements Beyond Linear Closure Standards - Linear closure standards (such as 1:15,000) are often used. However, linear closure standards, by themselves, are nearly meaningless. At best they are only indications of precision and might have little if any relationship to accuracy. Unless all standards have been fulfilled and the proper procedures used, the accuracy of a survey is questionable. With luck and compensating errors, required linear closures might be achieved without proper precision being used. For example, a closed loop traverse can have satisfactory closures regardless of the magnitude of the systematic error in the linear measurements.

D. CLASSES OF ACCURACIES TO BE USED

The class of accuracy to be used for a specific type of survey is stated in the chapter of this MANUAL where that survey is discussed. For example, the class of accuracy to be used for Project Control Surveys is discussed in Chapter 6.

1. Leveling

   a. Second order, class 1

      1) A valid check connection (line tie) must be made to a minimum of four published bench marks, two at each end of a leveling line.

      2) Maximum collimation error, single line of sight, should not exceed 0.05 mm/m (10 arc seconds). Collimation error determinations are required at the beginning of each day. Collimation data must be recorded with the leveling data and the daily updated value must be used during the days leveling.

      3) Level rod bubble verticality must be maintained to within 10 minutes of arc.

      4) Sections between and to new bench marks will be double run.

5) The difference between forward and backward sight lengths should never exceed 5 meters per setup and 10 meters per section.

6) The maximum sight length from level instrument to rod is 60 meters.

7) The minimum ground clearance of the line of sight is 0.5 meter.

8) An even number of setups is required per section when using leveling rods without detailed calibration.

9) The maximum section misclosure between the forward and backward running shall not exceed 6mm times the square-root of the one way distance in kilometers.

10) The maximum loop misclosure shall not exceed 6 mm times the square-root of the distance in kilometers.

b. Third order - The maximum section misclosure shall note exceed 12 mm times the square-root of the distance in kilometers (0.05 ft. x √ miles).

2. Traverse - All traverse shall conform to the following **minimum** specifications for class A surveys as defined by The American Land Title Association:

Number of replications:	2D + 2R
Spread from mean not to exceed:	5"
Azimuth closure not to exceed: Where S is the number of stations where angles were measured.	10" x √ S
Linear misclosure not to exceed:	1:15,000
Minimum distance between stations:	81 m (265 ft.)

3. Global Positioning Surveys

a. B order positional misclosure not to exceed: 1:1,000,000

b. 1st order positional misclosure not to exceed: 1:100,000

CHAPTER 5-00 SURVEYING PROCEDURES

SECTION 5-01 LINEAR MEASUREMENT

Revised 11/01

A. GENERAL

This section covers three methods of obtaining linear measurement: taping, Electronic Distant Measurement (EDM) and stadia.

Definitions:

1. An OBSERVATION is a single, unadjusted determination of a linear value. A single "pull" of a tape and a single reading of an EDM are observations. Also, if a value of a long tangent is determined by a series of pulls or EDM readings the sum of either is an observation.

2. A MEASUREMENT is either a single observation or the arithmetic mean of more than one observation of the same distance. It is the final value determined before adjustment.

B. TAPING

EDM instruments have replaced taping in much of the Division's routine work. However, the measurement accuracy of newer EDMs is ✂(2 mm + 2ppm) which translates into the minimum distance required to meet a precision of 1:15,000 is 60 m (200 ft.) Therefore, any distance 30 m (100 ft.) or less should be considered for taping if the accuracy requirements of the survey so dictate. Distances to hand references will be measured by a tape and not by holding a "0" offset reflector against the reference nail.

1. Errors

   a. Tape not standard length - this type of systematic error can be eliminated by standardizing the tape using the tape calibration monuments set at some of EDM calibration stations.

   b. Imperfect Alignment - This type of error is easily controlled and seldom causes significant error. Alignment is more critical on short pulls than on long ones. In many instances too much time is spent in setting a "chaining point" exactly on line. For example, if a chaining point is set 0.15 m (0.50 ft.) off line at 30 m (100 ft.) it will result in a linear error of only 0.3

mm (0.0013 ft.). However, a chaining point should be set "right on" line if the point is to be used as a starting point or a check-in point for subsequent alignment work.

c. Tape Not Level - This error is similar to imperfect alignment. That is, the error produced is the same for a given amount of either vertical or horizontal misalignment. Slopes are deceptive and "eyeballing" is not adequate for determining level. Such carelessness can result in taping with the tape considerably out-of-level. On uneven terrain a 0.6 m (2 ft.) imbalance, in a 30 m (100 ft.) pull, can easily result in errors if a hand level is not used. Short distances must be measured with the tape level: 0.15 m (0.50 ft.) out-of-level in 7.5 m (25 ft.) is equal to 0.6 m (2.0 ft.) out-of-level in 30 m (100 ft.) This would cause an error of 6 mm (0.02) ft. in a 30 m (100 ft.) pull. In "ordinary" taping that is, perhaps, the most frequent source of error. This type of error can be prevented by using a well-adjusted hand level.

d. Incorrect Slope Determination - A small error might be introduced when turning a vertical angle to the Head Chainman's taping HI. This error often results because the Head Chainman cannot simultaneously take line, pull tension, and keep the plumb bob tip just above the chaining point. Also, the Instrument Man can have trouble in "tracking" the tape if it is bobbing. To eliminate blunders, the slope distance should be measured twice, at two different vertical angles and the results meaned. One angle should be measured direct and the other reverse. The reduced distances should agree with the accuracy requirements for the survey. For example, in third-order taping, two measurements of a 30 m (100 ft.) pull should not differ more than 5 mm (0.015 ft.).

e. Plumbing Error - These errors stem from such sources as wind, parallax, unsteadiness of either Chainman, letting the plumb bob cord slip along the tape before reading. Plumbing errors and errors caused by the inability to read and mark points exactly are accidental errors. But, only the error due to plumbing is of real consequence. Some techniques that can reduce the magnitude of the errors inherent in taping with plumb bobs are:

1) The Chainman must look straight down the bob string to avoid parallax.

2) The Rear Chainman should initially hold behind the chaining point and allow his plumb bob to be slowly pulled over the point by the Head Chainman. When the Rear Chainman initially holds exactly over the point, he can be pulled beyond the chaining the chaining point. He then pulls back, thus increasing the tension in the tape. The pulling back and forth, to correct tension and to stay over the point, causes swing and flutter in the tape. This makes it difficult to keep the bobs over the points.

f. Temperature - A tape lengthens as the temperature rises. It shortens as the temperature falls. The coefficient of expansion for steel is 0.0000116 meter per meter per degree Celsius (0.0000065 foot, per foot, per degree Fahrenheit). The difficulty in making temperature corrections is trying to remember a formula for adding or subtracting the correction. The surest method is to picture two monuments which are exactly 30 m (100 ft.) apart. The signs of corrections are reckoned by mentally stretching a "Hot" Tape (Long) and a "Cold" Tape (Short) between these marks. Between the points a "Hot" Tape (Long) reads less than 30 m and the correction would be added. A "Cold" Tape (Short) would read more than 30 m (100.00 ft.) and the correction would be subtracted. When setting or laying out points the correction signs are the opposite. When laying out with a Hot Tape the correction is subtracted and with a Cold Tape the correction is added.

g. Tape Not Straight - Before measuring, pull the tape taut and see that is clears all obstructions.

h. Incorrect Tension - Steel Tapes are standardized at some specific tension, and being elastic, change length due to the variations in the tension applied. For 30 m (100 ft.) tapes the standard tension would be 5 kg (10 pounds) when the chain is supported throughout and 15 kg (20-25 pounds) when suspended (supported at the two ends). The tension applied usually varies either above or below these standards and can be considered an accidental error and disregarded in all but precise measurements. Inexperienced Chainmen are likely to apply tension lower than the standard.

C. ELECTRONIC DISTANCE MEASURING

1. Operating Instructions - Each EDM should have the manufacturer's operating manual in its carrying case. EDM operators should be familiar with the manufacturer's manual and follow its instructions for proper operation of the EDM. EDM operators should always:

   a. Remove the thermometer from its case, hang it in the shade, and allow it to react to the outside temperature.

   b. Observe the temperature and pressure, compute the PPM correction, and input into the EDM.

   c. Electronically point the EDM to assure that the instrument is operating in the center of its light cone.

   d. Allow the EDM to cycle several times before recording the distance. Make sure the instrument has settled into a measurement. This is especially true for the first measurement of the day and in cold weather.

   e. During hot weather, shade the EDM whenever possible. When it is not being used, place the EDM in the shade.

   Refer to Chapter 2 for EDM adjustment (calibration) and care and for technical data on the Division's EDMs.

2. Use of EDMs - EDMs must be used for all traverse measurements over 30 m (100 ft.) in length and may be used for shorter distances if conditions warrant. Steel tapes may be used for measurements less than 30 m (100 ft.)

3. Planning - EDM instruments have made revolutionary changes in surveying procedures and methods. Field surveys progress so rapidly they require intensive planning. The surveyor cannot think just in terms of the next point - he must consider the entire survey. Planning and reconnaissance are the keys to efficient EDM surveys. Regardless of the quality of the survey's planning and reconnaissance, the Party Chief can organize and plan his work to be more effective. To more efficiently use EDM instruments:

   a. Prior to beginning the actual work, develop a "plan of attack" for the survey.

b. Be sure that all planned traverse lines are intervisible.

c. Be sure all available information, such as computer printouts, maps, and reconnaissance notes are in hand.

d. Before leaving the office, check for locked gates and other entry problems with the Area Engineer who "reconned" the project.

e. Be sure that you have all the necessary equipment before proceeding to the field. (Do not leave the battery at home).

f. Do NOT plunge into the day's work without first organizing the day's activities. A few minutes spent planning at the beginning of each day will save backtracking, duplication of effort, and, in general, "wheel spinning".

g. Be sure that all party members understand the job and their individual duties. Give complete and understandable instructions.

h. Measure as many lines from a single setup, as possible: move reflectors not the instrument.

i. Use two-way radios. They also serve as safety equipment.

j. Record data directly into the traverse program.

k. Look ahead. If subsequent work will be expedited by setting additional points while on a setup, such points should be set.

l. Prior to leaving the project, verify that all points have been checked, or can be checked by the record data.

m. Close the survey, if possible.

4. Errors - With EDM instrument and support equipment properly adjusted and calibrated, errors and blunders to watch for are:

   a. Incorrect temperature-barometric pressure (ppm) are entered into the instrument.

   b. Misalignment of the retroprism to the EDM. Misalignment in either the horizontal or vertical direction, can cause an error in the distance measured.

c. Recording the distance incorrectly. It is a good practice to have the recorder call back the reading.

d. Failure to properly level the instrument and/or the piece of equipment holding the prism.

e. Reflections from Extraneous Objects

1) Natural and Man-Made Obstructions - Under most circumstances, an EDM measurement will be within the accuracy specified for that instrument. This is true even if the line of sight passes through trees, fences, or other such obstructions. However, such objects can sometimes reflect or interrupt the light rays and cause erroneous measurements. Usually this occurs only if the object is relatively close to the instrument.

Be especially careful of plastic reflectors, such as those used on guide marker posts. If one of these is in the path of or behind the prism, it can and often does cause erroneous measurements. When the line of sight can not be cleared, the recorder should note the conditions of the measurement. Then, if poor closures result, these distances can be isolated and checked.

2) Extra Prisms Set Out - When making EDM measurements, only one set of reflectors should be facing the instrument along the line of sight. If an extra set of reflectors faces the instrument, it might reflect light rays to the instrument and cause error. This can occur when various distances are being measured along a straight line of fairly uniform grade when more than one reflector is being used. When doing such work, reflector tenders should always keep their reflectors turned away from the instrument except during the actual measurement to their point.

5. Setting Up

a. Tripods - The weight of EDM equipment puts an added strain on tripods and instrument stands. Thus, the tripods used to support EDM instruments must be sturdy and in good condition.

b. Tribrach Checks - Plumbing errors cannot be eliminated by measuring procedures. Therefore, tribrachs must be checked for adjustment (bubble and optical plummet) frequently. This includes not only the tribrach used for the EDM instrument, but also those used with the reflectors. If a tribrach is accidentally bumped, dropped, or knocked over, it must be checked before any additional measurements are made.

c. Stability - The setup for an EDM instrument should be very stable. Not only are EDM instruments heavy but they also offer larger areas of wind resistance. In addition, the electrical cords place added forces on the setup.

6. Number of Measurements - Under most circumstances, the distance between two points shall be determined only along one line and only in one direction. In other words, reciprocal measurements usually are not necessary.

D. STADIA

Stadia is a tachometric form of distance measurement that relies on a fixed-angle intercept. This procedure utilizes two supplementary horizontal (stadia) hairs placed at equal distances above and below the central horizontal cross-hair. Usually they are short lines to differentiate them from the longer main horizontal cross hair. The stadia hairs are positioned in the reticle so that, if a level rod were held 30 m (100 ft.) away from the instrument (telescope level) the difference between the upper and lower stadia hair readings (rod interval) would be exactly 0.3 m (1.00 ft.)

It can be seen that distances can be determined simply by sighting a rod with the telescope level and determining the rod interval. The horizontal distance D from the instrument center to the rod equals 100 times the stadia intercept S. D = 100 S. It is not always possible to keep the telescope horizontal; more commonly, the line of sight is inclined. When this occurs the distance calculated by multiplying the stadia intercept by 100 is greater than the true horizontal distance. The horizontal distance may be found by using the formula HD = 100 x S x Cos VA, where the vertical angle (VA) is measured from the horizontal. The "topo" routine in the Sharp programmable calculator can be used to rapidly determine horizontal distances, should the need ever arise.

CHAPTER 5-00 - SURVEYING PROCEDURES

SECTION 5-02 ANGLES AND ANGULAR MEASUREMENT

Revised 11/01

A. GENERAL

Three dimensions or combinations thereof must be measured to locate an object with reference to a known position; specifically, horizontal length, difference in height (elevation) and angular direction. This chapter discusses the design and uses of surveyors' theodolites and total stations to measure horizontal and vertical angles.

1. Angular Definition - An angle is defined as the difference in direction between two convergent lines.

   A horizontal angle is formed by the directions to two objects in a horizontal plane.

   A vertical angle is formed by the directions to two objects in a vertical plane. Most theodolites and total stations measure the vertical angle between straight up (the observers' zenith) and the object sighted. This is called a "zenith angle" or "zenith distance".

2. Units of Angular Measurement - The "sexagesimal system" uses angular notation in increments of 60 by dividing the circle into 360 degrees; degrees into 60 minutes; and minutes into 60 seconds. Therefore, a complete circle contains 360☜, 21600' or 1296000". This angular system is employed almost exclusively by surveyors, engineers, and navigators in the United States, as well as in other parts of the world.

3. Horizontal Angles - Three types of horizontal angles, shown in Figure 5-02-B are defined as follows:

   a. "Interior angles" are measured clockwise or counterclockwise between two adjacent lines of a closed polygonal figure.

   b. "Deflection angles", right or left, are measured from an extension of the preceding course and the "ahead" line. It must be noted whether the deflection angle is right (R) or left (L).

   c. "Angles to the right" are turned from the back line in a clockwise or right-hand direction to the

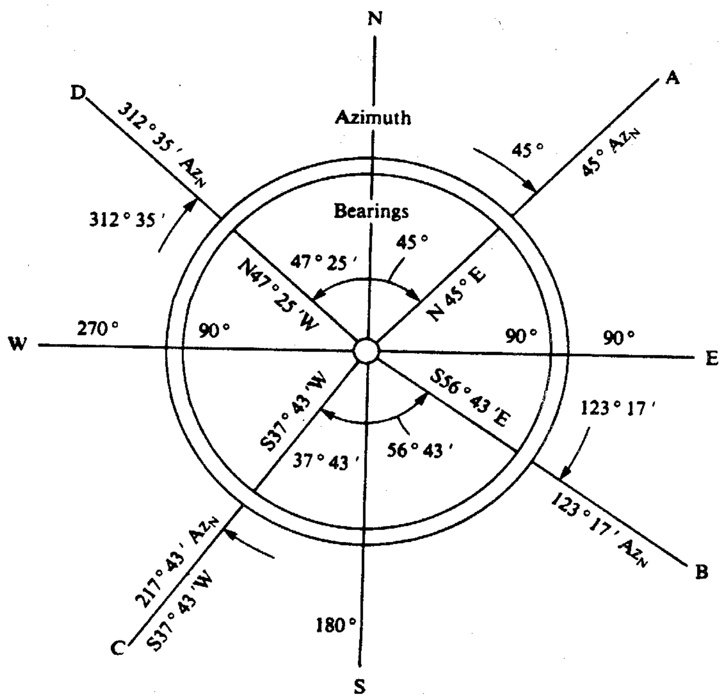


FIGURE 5-02-A RELATIONSHIP OF BEARINGS AND AZIMUTHS

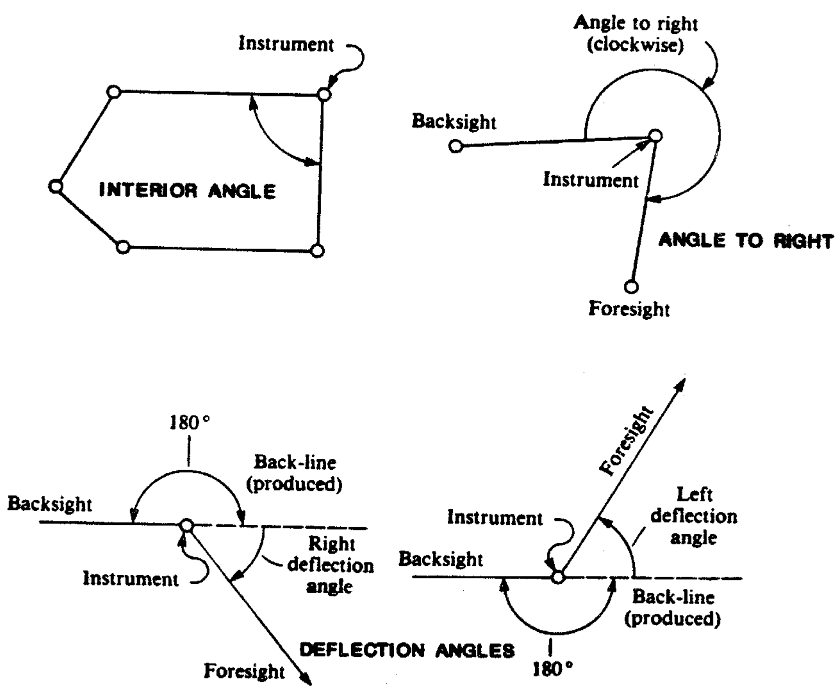


FIGURE 5-02-B DIFFERENT TYPES OF HORIZONTAL ANGLES "ahead" line.

4. Zenith angles - Zenith angles are usually measured in pairs. The first reading, taken with the scope in direct position (sometimes referred to as "circle left" as the vertical circle is to the left of the telescope) and the second reading taken with the telescope inverted (sometime referred to as "circle right").

5. Terms used - The following terms are defined specifically for angular measurement; their meanings might differ slightly in other contexts.

   a. A POINTING consists of a single sighting and circle reading on a single object.

   b. An OBSERVATION is a single, unadjusted determination of the size of an angle. For example, an observation is made by pointing both sides of a horizontal angle. Thus a single angular value, an observation, is derived by subtracting the value of a pointing on a reference object from the value of a pointing on an observed object.

   c. A MEASUREMENT is the final determination of the magnitude of an angle before adjustment. Minimum angular measurement is the mean of at least two observations, one direct and one reverse.

   d. A REFERENCE OBJECT (RO) is a survey point which is used as an initial sight for orientation when measuring horizontal angles and "directions". (This term will be used herein instead of the term "backsight".) Usually the azimuth or bearing to the RO is known and the RO is chosen before observations are started.

   e. A DIRECTION is the value of a clockwise angle between an RO and any other survey point. Circle readings of each RO observation are reduced to zero degrees and the directions to the other survey points are computed from this zero point.

   f. The direct telescope mode will be called simply DIRECT, or D, and the reverse or inverted mode will be called REVERSE, or R, in the following discussions.

   g. The term POSITION is used in two different but closely related ways when referring to direction instruments:

1) SETTING A POSITION is the act of setting a specified horizontal circle reading while the telescope is pointed toward an RO.

2) TURNING A POSITION is the act of making one direct and one reverse observation on each survey point to which a direction is required. The horizontal circle remains stationary for a given position, but is reset for each new position. Notes for angles turned with a direction theodolite are usually grouped by position. A set of observations with a direction theodolite is a SET OF POSITIONS. For example, in a project control traverse a direction is computed as the mean of a set of four positions.

h. A REPETITION is a single observation (of a series of observations) of a horizontal angle, made with transit or repeating theodolite. A repetition may be made with the instrument telescope in either direct or reverse mode. A SET OF REPETITIONS is a series of observations of the same angle, where each observation is accumulated on the horizontal circle of the instrument. Half a set is measured in the direct mode (D) and the other half in the reverse mode. (R).

i. INDIRECT MEASUREMENT - By "trilateration" the angles of a triangle are computed from measurements, usually by EDM, of the three sides.

j. DIRECT MEASUREMENT - Direct measurement of angles and line directions by theodolite, compass, or transit is familiar to all surveyors. But, many surveyors are not completely familiar with specific procedures which will achieve specified results. This section covers procedures and precautions which produce increased reliability in observations and desired accuracies.

B. PROCEDURE

1. Tripod set-up - Most surveyors are efficient with their own style of instrument set-up. Any efficient, safe method that produces a steady tripod is acceptable. Refer to the topic "Errors, Corrections, and Precautions" in this section for specific precautions to be observed when setting up an instrument.

   The "English method" is easy to use, dependable, and fast. Inexperienced Instrument Men and those who set up instruments infrequently, usually find this much faster than "conventional" methods. Some proficient Instrument Men also have improved their efficiency by adopting this method. Procedures for using the "English method" are:

a. Set one tripod leg about two feet beyond the setup point.

b. Grasp the other two legs and, while looking through the optical plummet, position these legs so the ground point is visible through the plummet eyepiece. (The plummet eyepiece should be on the same side of the instrument as the Instrument Man.)

c. Push the tripod shoes firmly into the ground.

d. While looking through the plummet eyepiece, adjust the leveling screws until the optical plummet cross hairs are centered on the setup point.

e. Approximately level the circular bubble by adjusting the legs of the tripod. Adjust one leg so the bubble is placed in a position which will make a line drawn through the bubble and the center of the circular vial parallel with any other leg. Adjust the leg which is parallel, up or down, to center the bubble (approximately).

f. Perform final leveling and centering with the plate bubble and the leveling screws. Centering is accomplished by shifting the instrument on the tripod head. When centering, do not rotate the instrument on the tripod head. If the head is not level, rotation will move the instrument out of level.

2. Horizontal Angle Measurement (Single) - Single measurements for angles should only be used for stadia and data collection. Traversing, metes and bounds or other surveys of higher precision require multiple measurements of an angle.

   a. The instrument is set up and centered over a point, carefully leveled, and the telescope checked for parallax.

   b. The telescope is pointed at the backsight and the vertical cross hair centered on the target.

   c. The instrument will read 0 degrees, 00 min 00 sec

d. The upper horizontal clamp is loosened and the instrument is then rotated about its vertical axis and pointed to the foresight. The upper clamp is tightened and the cross hair is precisely centered on the target using the upper tangent screw.

e. The horizontal angle that is displayed is noted and recorded.

3. Horizontal Angles Measurement (Multiple) - The DIRECTION METHOD is the fastest, most accurate, and most efficient method for making multiple measurements of angles. The procedure is as follows:

   a. Sight the reference object with the telescope direct and set a reading of approximately 0☜ 00' 10" in the instrument.

   b. Sight the reference object precisely and record the circle reading.

   c. Turning clockwise, make a pointing to each object to be observed.

   d. After the last foresight is observed, invert the telescope and observe each object in reverse order, ending with the reference object. This completes one position.

   e. If two positions are to be used, keep the telescope inverted and advance the circle setting to approximately 270☜ 30' 30".

   f. Repeat steps b. through d.

   g. Reduce the readings to arrive at the directions for each position. Mean the two positions to arrive at the final value for that set of directions. Check to see if any of the positions differ from the mean by more than 5". If so, repeat the measurements to the appropriate objects.

4. Measuring Zenith Angles

   a. Relation to Vertical Angle - A zenith angle is measured from directly overhead to the point observed. (A vertical angle is measured between the horizon and the point observed.) A zenith angle less than 90° or greater than 270° (reverse zenith) is called an "angle of elevation" and is equal to a plus vertical angle. A zenith angle greater than 90° or less than 270° is called an "angle of depression". It is equal to a minus vertical angle.

b. Division Instruments

All instruments regularly used by the Division read zero zenith angle when pointed directly overhead. That is, they directly measure zenith angles. All instruments read 90° from the zenith when the telescope is horizontal, in the direct mode. When the telescope is reversed, the horizontal will read 270°

c. Importance

The increased use of Total Stations to perform trigonometric vertical measurement and vertical traversing has created a greater need for accurate zenith angle observations.

d. Procedures

The key sequence used to measure zenith angles differ, depending on the model and manufacturer of the Total Station instrument. Instructions contained in the operator's manual should be followed when measuring zenith angles.

However, the following should be considered

1) When the line-of-sight is horizontal and the instrument is out of adjustment, or not carefully leveled, a reading other than 90° or 270° may occur. This is called the index error. With modern instruments, the index error shows up as collimation error (cross-hairs not in the center of the scope). Manufacturers use the expression "automatic vertical index". This means the vertical circle is vertical, even when the standing axis is not truly vertical. It does not mean the instrument is automatically adjusted for collimation error.

2) If the total station has a vertical collimation error, the vertical circle reading in a single face will be in error by the amount the horizontal cross hair is away

from the center of the telescope. Residual instrumental errors and index errors are eliminated by observing in both faces, i.e. taking both a direct (D) and a reverse (R) reading on the object.

The reverse reading is used as a check on the direct reading, and when the two readings are averaged, it provides a means of compensating for index error. This can be important when using the Total Station for trigonometric leveling - an index error of 10 seconds of arc and a measured distance of 200 m (656.17 ft.) would result in an elevation error of 10 mm (0.033 ft.).

C. ERRORS, CORRECTION AND PRECAUTIONS

Through caution and good observation procedures, the expense of isolating and correcting errors can be minimized. Factors which might influence the occurrence of errors can be roughly divided into three classes: instrumental, personal, and natural.

1. Instrument Factors

    a. Adjustment - Check all adjustments of an instrument at regular intervals, as specified in Chapter 2.

    b. Level Bubbles and Optical Plummet - Normal measuring procedures do not compensate for maladjustment of either the plate bubble(s) or the optical plummet. These components must be checked more frequently than others.

    c. Replicating the Angle - Check all angles measured (or laid off) by replicating the angle, no matter what the purpose of the survey. This means one complete position (1D and 1R) with a direction theodolite. (One exception can be vertical angles when setting out points with EDM equipment.) This procedure compensates for lack of adjustment of almost all components of the instrument; it should be standard practice.

    d. Parallax - This occurs when the focal point of the eyepiece does not coincide with the plane of the cross hairs. The condition varies for each observer because the focal length depends in part on the shape of the observer's eyeball.

1) When to Check - Parallax should be checked by each Instrument Man when he begins to operate a new instrument or one which has been operated by someone else.

2) How to Check - Focus the telescope on some well-defined object a long distance from the instrument. With the eye about one inch from the eyepiece, slowly move the head back and forth while watching the relationship of the object to the cross hairs. If the object appears to move, parallax exists.

3) To Eliminate - Rotate the knurled eyepiece ring (either clockwise or counterclockwise) until apparent object movement is no longer present. It might then be necessary to refocus the telescope to clearly see the cross hairs.

2. Personal Factors

a. Setting Up the Instrument

1) Be sure the tripod is in good condition and all hardware is snugly fitted.

2) Push the tripod shoes firmly into the ground.

3) Place the legs in a position that will require a minimum of walking around the setup.

4) If the ground is muddy, drive long, 2"x4" wedges in the ground to support the tripod. In addition, use duckboards to support the Instrument Man.

5) On warm asphalt pavement set the tripod feet on stakes which have been nailed to the pavement. This will prevent settlement of the instrument.

6) Set the instrument exactly over the point.

7) Check the optical plummet after the instrument is set up and just before moving to another point. If the instrument has moved, check the angle just measured.

8) Carefully level the instrument.

b. Setting Sights

1) When tribrach mounted targets are used, take the same precautions as when setting up an instrument. With this equipment, "leap frogging" (clipping out and exchanging the instrument and targets while leaving the tripods and tribrachs in place) can speed-up traversing operations and will greatly decrease the effects of plumbing errors in traverse closures. Leap-frogging is especially helpful with short traverse legs.

2) ALWAYS check each sight before picking it up to see that it has not moved.

3) ALWAYS use fixed sights when traversing.
   d) Be sure that the line of sight is clear of all obstructions be at least 0.3 m (1 ft.).

4) Avoid traverse angle measurements under poor conditions, such as when refraction is excessive. On very sunny days, ground level sights are not advisable.

c. Pointing

1) Tangent Screw Use - When sighting an object, always make the last turn of the tangent screw, clockwise. This clockwise movement increases the tension on a small spring which is loaded against the tangent screw. A final turn counterclockwise releases tension and the spring can temporarily hang up in the heads. A "backlash" error results if the spring moves after final pointing is made.

2) Cross Hair Use

   Consistency - Sight each object with the same part of the cross hair, preferably near the center of the field of view. This practice will minimize small residual adjustment errors. This procedure is a "must" for traverse work.

   Technique - Experiments have proved that the human eye can estimate the center of a wide object more accurately than it can line up two objects. For this reason, different pointing techniques should be used. The technique depends on the type of sight and the apparent size of the sight in the telescope.

Narrow Sights - When pointing on narrow sights, such as the center of a red and white target or a distant range pole, straddle the sight with the double cross hairs.

Wide Sights - When pointing on wide sights, such as a lath or a range pole at close range, split the sight with the single cross hair.

d. Measuring Angles - Measure angles as rapidly as comfortably possible. Take the first pointing on each object, rather than fidgeting with the tangent screw trying to improve the pointing. Too much pointing time increases the probability of error through instrument settlement or atmospheric changes. Such error could cancel any gains made by taking excessive care. But, speed should not be cultivated at the expense of good results. Accuracy is more important than speed.

e. Reading the Instrument and Call-Outs - Carefully read and call out each reading to the recorder. Call out the entire reading each time so any large blunders will be caught. If recording problems arise, have the recorder repeat each reading to the Instrument Man after it is recorded.

3. Natural Factors

a. Differential Temperatures - Bright sunlight striking certain parts of an instrument might cause differential expansion of the metal components of the instrument, resulting in small errors. Efforts should be made to shade the instrument when performing precise surveys.

b. Refraction - Refraction is the bending of light rays and is usually caused by one of two conditions.

The first is caused by observing a line of sight too close to an intermediate object such as a tree, utility pole, building, road surface, or embankment. In this case the line of sight is "bent" toward the object. This can be eliminated by insuring a 0.3 m (1 ft.) minimum clearance between the line of sight and all obstructions and at least a 0.6 m (2 ft.) minimum clearance above the ground.

The second type of refraction is also known as "heat waves" and is caused by observing a line of sight on a sunny day. The sun heats the surface of the earth and the surface heats the air close to the surface. This uneven heating of the air causes the light waves to bend and can make a range pole look like a snake! To eliminate this problem, make angular measurements before 9:00 am or under cloudy conditions.

c. Phase - If a sight is not evenly lighted on both sides, the Instrument Man will tend to point toward the lighted side. This phenomenon is called phase. It can be reduced by using a target with a flat surface pointed directly toward the instrument.

CHAPTER 5-00 - SURVEYING PROCEDURES

SECTION 5-03 VERTICAL MEASUREMENTS

Revised 11/01

A. GENERAL

Refer to Chapter 2 for vertical measuring equipment and its care.

1. Purposes

   Vertical measurements are made for two purposes. The first is to determine the elevations of points with respect to a particular datum. The second is to determine a linear, vertical distance. This second purpose is seen most often in the measurement of vertical dimensions.

2. Methods

   Vertical measurements are made directly or indirectly. Direct means "The Direct Reading of Elevations or Vertical Distances." Values are not mathematically manipulated. An example of direct elevation determination is the reading of a altimeter. Indirect vertical measurement requires calculations be made from measurements to determine elevations and vertical distances. This MANUAL will discuss this method only.

B. INDIRECT VERTICAL MEASUREMENT

1. Description

   With this method, calculations are made from measurements to determine elevations and vertical distances. Direct elevations and vertical distances are not read out on dials, gauges, or tapes.

   Leveling is the procedure most used for indirect vertical measurement. Herein, the term "leveling" is reserved for vertical measurement which requires readings through a leveled telescope.

   Trigonometric procedures are also used for indirect vertical measurement. In trigonometric procedures, slope measurements and zenith angles are resolved into vertical distances.

2. Differential Leveling

a. Description - Several techniques are used. Basically, elevations are derived from readings made on a vertical, graduated rod. First, the rod is read on a point of known elevations. This "plus" reading is added to the known elevation to give the elevation of the instrument (the HI). Then, on points where elevations are required, "minus" rods are read. these are subtracted from the HI to give the required elevations. Thus, the computed differences, "differentials," between plus and minus readings are used to determine elevations.

Rod readings are made through the horizontal telescope of an automatic level. The line of sight of an automatic level telescope is leveled by activating a prism/pendulum compensator. The pendulum is automatically activated and controlled by gravity after the instrument is approximately leveled. Approximate level is attained by using the foot screws and a circular spirit level.

b. Equipment - An engineer's level, usually pendulum type, leveling rod(s), and accessories as required are used in differential leveling.

c. Single-Wire Leveling - This is the fastest and most widely used technique for routine leveling (third-order accuracy or less). It forms the basis for all differential techniques. Procedural guidelines are:

1) Instrument Setups

a) In uneven terrain use a hand level to pick a setup site from which the plus rod can be read. Also, use it to guide in setting turning points.

b) Do not waste time by deeply imbedding tripod feet. Settlement is usually insignificant. Also, do not waste time in precisely centering the bulls-eye bubble. However, sloppy initial leveling can cause errors. Avoid setups on hot bituminous pavement or in spongy or muddy soil.

c) Set up 75 m (250 ft.) or less from the bench mark (BM) or turning point when reading to the nearest millimeter (0.01 ft.).

d) Set up away from sources of vibration. Also, minimize movement around the level.

e) When setting up to turn into a BM, balance the backsight and foresight distances. (Also see Paragraph 2)a) below.)

f) Before reading any rod shots, make certain the instrument is actually leveled.

g) Periodically test the level to be certain the pendulum compensator is working. Point on a "natural" sight with the telescope over a foot screw, and turn that screw back and forth. If the cross hair dips and returns to its original position, the compensator is operating properly.

h) Make certain the tripod is free of excessive play.

i) Periodically test the level for adjustment. (See Chapter 2)

j) Before "breaking" a setup, check the bubble to make sure the setup has not been disturbed.

2) Turning Points and Bench Marks

a) Set turning points (TPs) so backsight and foresight distances will be equal (balanced). This compensates for instrument maladjustment and for curvature and refraction.

b) Establish bench marks (BMs) as good in physical quality as the technical quality of the leveling procedure. Set them in a protected, stable location. Do not use spikes in utility poles or wooden stakes except as temporary BMs (TBMs). In general, do not mark the elevations on "permanent" control BMs.

c) In uneven terrain the Instrument Man should monitor TP placement with either his hand level or the instrument, so the

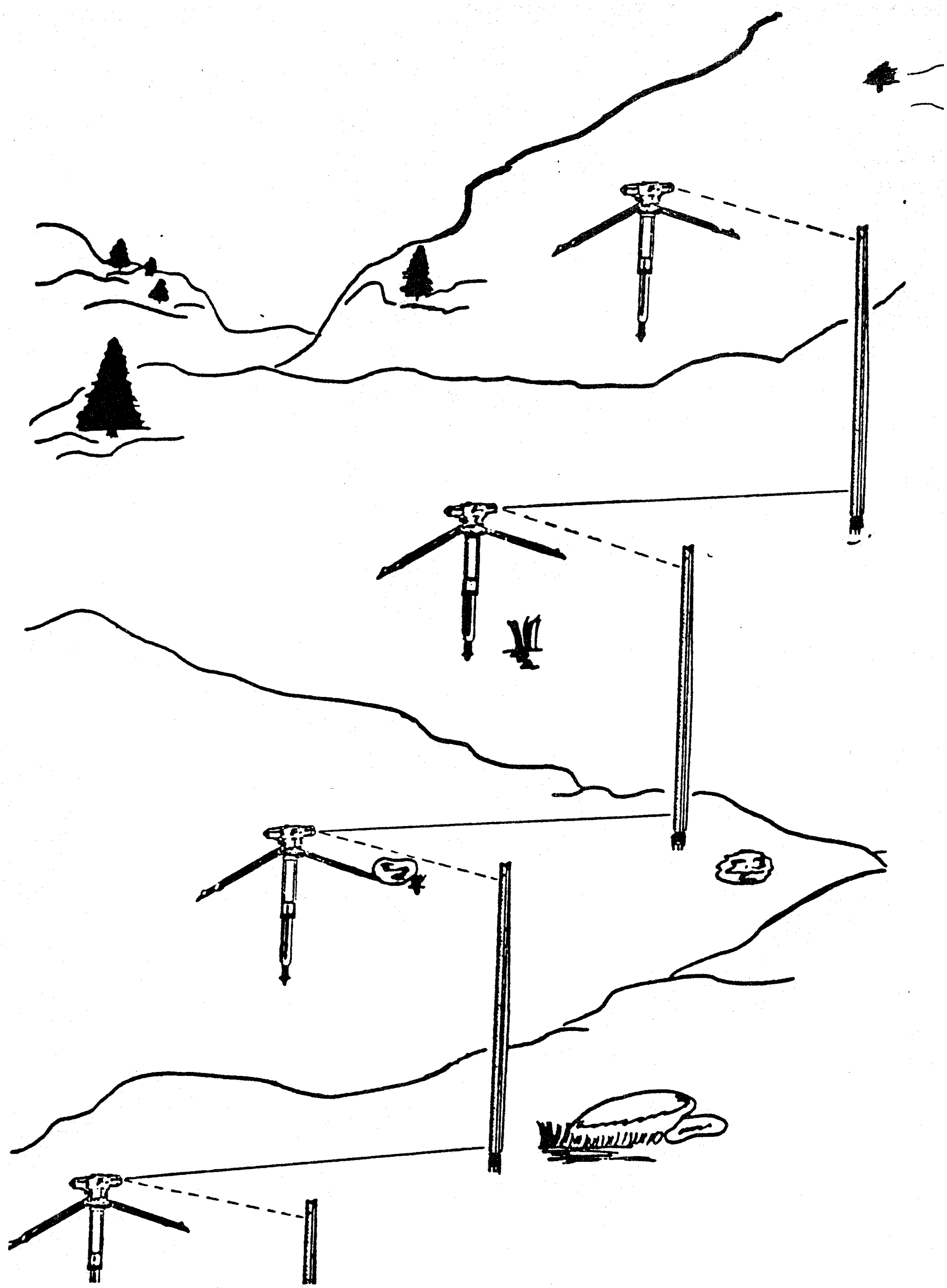


FIGURE 5-03-A LEVELING IN STEEP TERRAIN

rod will be readable.

d) When leveling in steep terrain, place "turns" and instrument setups so they follow parallel paths - not along the same path. This gives equal backsight and foresight distances. See Figure 5-03-A.

e) Make each turn stable and with a definite high point. If a TP does not have a prominent point, mark with keel (or paint) the exact place where the rod is set.

f) Unless necessary, do not set removable TPs, such as axe heads. Leave TPs for checks and for TBMs.

g) When possible, find and mark existing solid features as TPs.

h) Mark and identify such "permanent" TPs with keel, flagging, or paint. But, do not deface pavement, natural features, structures, etc. with excessive painting.

i) Turn into a different BM than the starting BM.

3) Rod Readings

a) Focus the eyepiece to eliminate parallax before any readings are made. Parallax should be tested before operating a new instrument or one that has been used by someone else. (See "Errors, Corrections, and Precautions" in Section 5-02.)

b) When possible, point out the readings on all TPs to the Instrument Man.

c) Do not deliberate over readings. Read and call them out in a moderate rhythm.

d) Turn through important points rather than take "side-shots." (Bench marks should never be side-shots.)

e) Plumb rods by using a rod bubble or, in calm weather or for routine work, by balancing by "fingertip feel."

(f) Avoid low, ground-skimming shots where refraction might become pronounced. Also, avoid sighting close to obstructions which might affect the line of sight.

4) Equipment - Single-wire levels are run with an engineer's level and a level rod. Normally, an automatic level shall be used.

Many types and lengths of rods are available for routine single-wire levels. Because of the variety, a rod is often available which seems to be tailor-made for a job. Suggested rods are:

a) Moderate Relief - 3.6 m (12-ft.) Frisco.

b) Marked Relief - 7.5 m (25-ft.) fiberglass.

c) Restricted Vertical Clearances - Collapsed Frisco, fiberglass, folding rule or pocket tape.

d) Control (geodetic) levels - Invar-type single section calibrated metric rods.

Any rod used should be clean, "tight," and have properly indexed scales. Periodically check slip-joint rods for index.

5) Field Notes - Sample notes for a short single-wire run are shown in Figure 5-03-B. See Chapter 7 for a general discussion of notekeeping.

a) Turns - Record the first plus rod on the same line as the elevation of the beginning bench mark and record the resulting H.I. at the center of page. This should be the second line of the four line grid squares. Record the minus rod on the second line of the next grid square, approximately 1/2 the distance from the centerline of the page to the right edge of the grid. Enter the resulting elevation to the right of the minus rod and near the right edge of

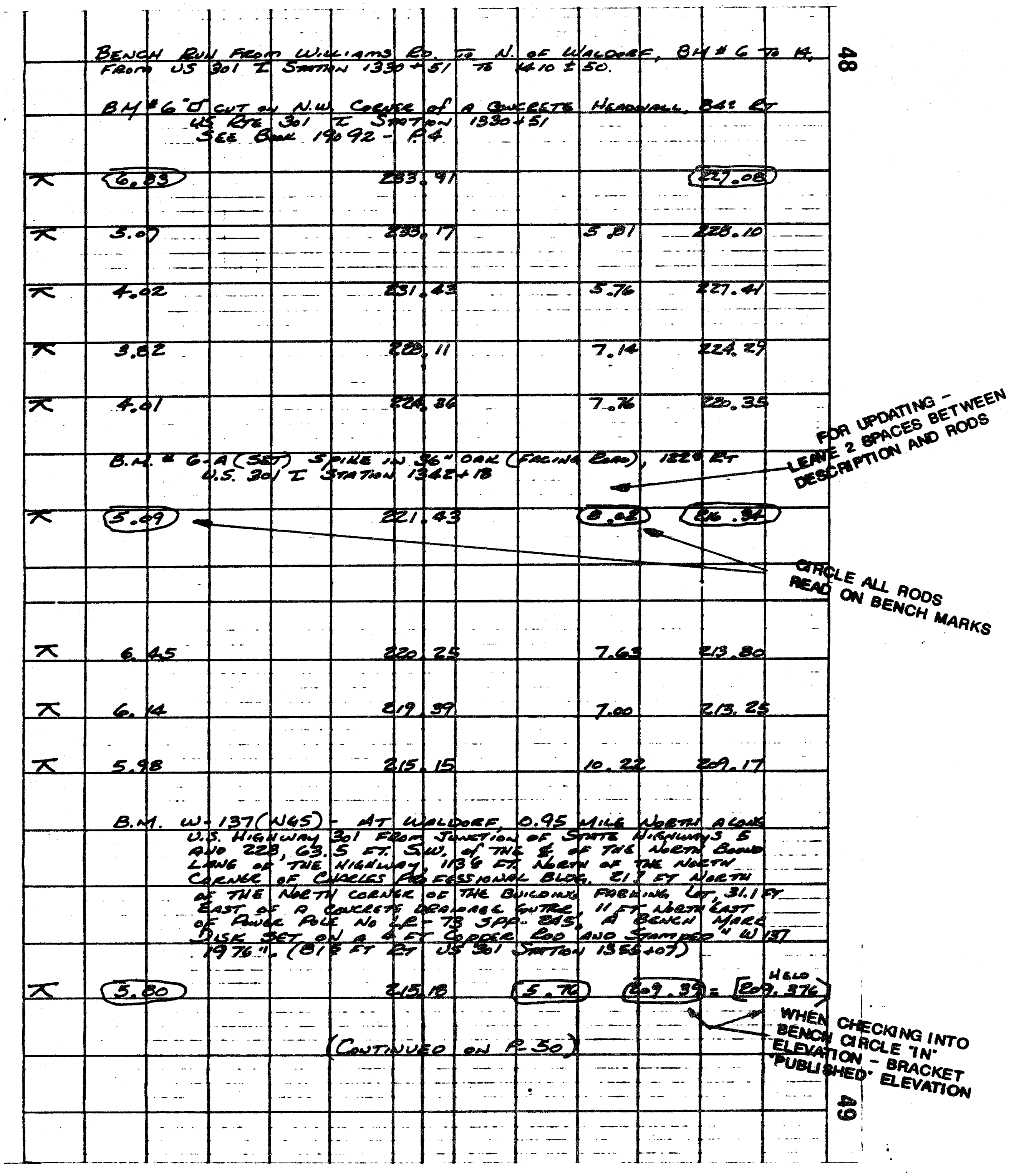


FIGURE 5-03-B SINGLE WIRE LEVEL RUN

the grid. Enter the next plus rod on the same line and so on.

b) Side Shots - Record each side shot on a separate line.

c) Shot Descriptions - Record bench marks that are not recovered. Fully describe and reference BMs used. When using NGS BMs DO NOT describe as "See File." Use full description. Enter descriptive notes of solid, left-in-place TPs so they can be used for TBMs or for checking the run. Identify or describe side shots for note users benefit.

d. Reciprocal Leveling - This technique is used when it becomes necessary to determine the relative elevations of two widely separated intervisible points between which levels cannot be run in an ordinary manner. For example, it may be desired to transfer levels from one side to the other of a wide river. The technique was devised to compensate for unbalanced backsights and foresights between consecutive turns. The procedure for making a reciprocal level crossing is (see Figures 5-03-C and 5-03-D):

1) Eliminate Accumulated Imbalance - Accumulated backsight and foresight distance imbalance must be eliminated before reaching a reciprocal leveling site.

2) Set BMs - Set a firm BM, or turning point, on each side of the obstacle. Each BM must be visible from the opposite side. Set the BMs, if possible, at approximately the same elevation so low rod readings are not required. This will enable reading the distant rods high enough to minimize refraction.

3) Test Adjustment - Test the level and, if required, adjust to minimum collimation error. (See Chapter 2.)

4) First Setup - Set up the instrument about 6 m (20 ft.) from one of the BMs.

5) Rod Readings - Without deliberation, read a plumbed rod on each BM and record the readings. A rod target might be required for

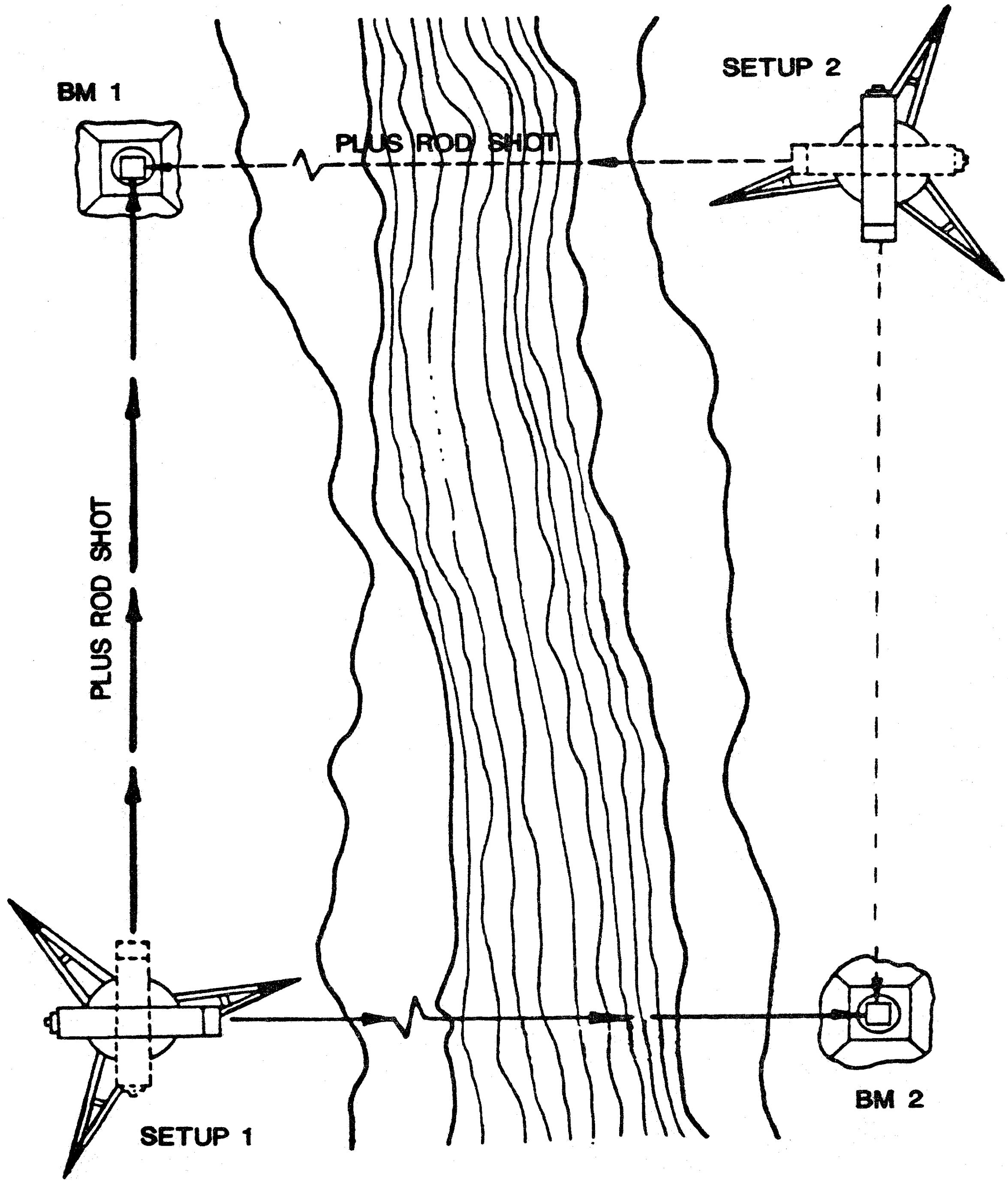


FIGURE 5-03-C RECIPROCAL LEVELING SCHEMATIC
(see Fig. 5-03-D)

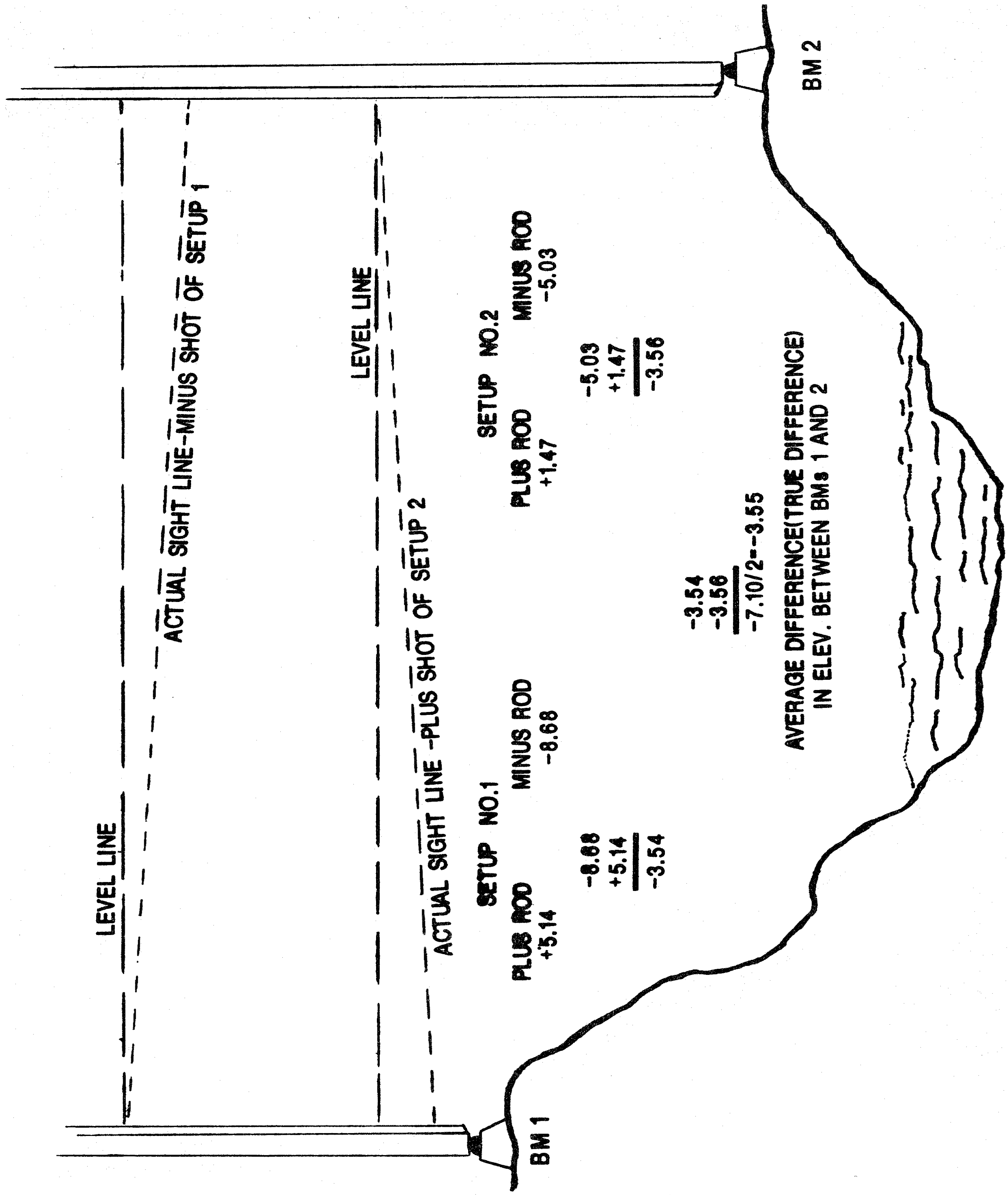


FIGURE 5-03-D RECIPROCAL LEVELING CALCULATIONS the reading on the far rod. If targets annot be used for long shots, make repeated readings. Use the arithmetic mean of the repeated readings.

6) Second Setup - Move the instrument to the other side of the obstruction and repeat paragraphs 3), 4) and 5). Keep the short sights of each setup approximately equal.

7) Calculations - Independently calculate the differences in elevation of the two BMs for each setup, then average.

Use the longer sight as the backsight for one of the computations and as the foresight for the other. This causes the plus-rod reading to be on the same bench mark for both setups. Systematic errors in the measurements will have opposite signs for the two sets. Thus, the errors will tend to cancel when the differences in elevation are averaged. This procedure minimizes the effects of refraction, curvature, and residual errors in instrument adjustment.

8) Elapsed Time - Minor variations in atmospheric conditions will cause very small errors. They will be negligible if the shots are taken with little elapsed time between the two setups. If crossing the obstacle requires considerable time, use two instruments and make simultaneous observations. Then exchange the instrument positions and again make simultaneous readings. The average of these measurements should be almost error free.

e. Double - TP Leveling (Double-Rodded) - This technique uses two, parallel, independent foresight and backsight TPs for each HI. It is usually used for third-order leveling. Each pair of TPs is set, if possible, at an appreciable difference in elevation (preferably one-half foot or more). They are also set a few feet apart so the level will have to be rotated slightly between the two rod readings. This provides a check on the instrument setup. From each setup, single-wire plus shots are read on both backsight TPs; minus shots are read on both foresight TPs. Readings are estimated to the nearest half-hundredth of a foot. Notes are kept separately for each line of levels.

The adjusted elevations from the two lines of TPs are averaged.

1) Advantages

   a) Two lines of levels are run while traversing the line only once.

   b) The HI of each setup is determined from each of the two lines of TPs. This gives a check at each HI. Blunders can be isolated at each setup; not just at existing bench marks.

   c) If the Instrument Man forgets to level the instrument, the HIs will not check.

   d) Because of the self-checking process, double-TP leveling can be advantageous for blunder detection. In brushy areas, parts of the rod are often hidden. In steep terrain, very close shots might be required. Even-foot blunders often occur in such areas, and isolation of blunders can be difficult. Double-TP leveling is also useful in any terrain when very long distances separate controlling bench marks.

2) Disadvantages

   a) Both lines of levels are run in the same direction and at the same time of day. This does not follow precise leveling techniques which tend to cancel natural, systematic errors.

   b) Setting two TPs can be time consuming. In loose soil, setting the second stable TP might waste much time. This often disrupts the "rhythm" of leveling.

   c) To keep backsights and foresights balanced, TP distances must be cloth taped or read by stadia. (Stadia distances are routinely produced in three-wire leveling techniques.) Consistent pacing on even terrain is adequate.

d) Because the two HIs at a setup site contain accumulated error, a tolerance check cannot be applied as in double-HI leveling or in three-wire leveling.

f. Double-HI Leveling - This technique is similar to double-TP leveling and is used for the same reasons. A double line of levels is run through a single line of TPs. At each setup site two HIs are established, at approximately one-half foot difference. From each HI the rod is read, to the nearest half-hundredth of a foot, on a single backsight TP and on the single foresight TP.

1) Advantages - The benefits of double-HI leveling are essentially the same as those of double-TPs. Differences are:

a) Two, separate, checking elevations are established on each TP. Unlike the check of "parallel" HIs, this check remains after each setup is broken.

b) With automatic levels, two HIs can usually be established quicker than two, stable TPs.

c) For both setups the difference in elevation of the two TPs is figures by the notekeeper. If the difference is more than 1 mm (0.002 ft.) a third setup is made to give a pair of readings that meets tolerance. By this the accuracy of rod readings is known at each setup.

2) Disadvantages - See disadvantages listed in e.2)a) and e.2)c) above.

g. Single-Wire Computations and Adjustments

1) Computations - Normally single wire notes are reduced to HIs and TP elevations as the survey progresses. To check the elevations of BMs that are turned through, differences in elevation, DEs, may also be calculated. To find the unadjusted DE between any two BMs:

a) Add the plus rod readings between the bench marks for a positive sum.

b) Add the minus rod readings between the bench marks for a minus sum.

c) Algebraically add the two sums. The result is the uncorrected DE, plus or minus, between the two points.

d) Apply the DE, according to its sign, to the beginning BM elevation. The resulting elevation should agree, exactly, with the elevation which was reduced as the survey progressed.

2) Adjustments - Normally, level runs are not adjusted in the field. The closing error is obtained by observing the difference in elevation (DE) between the field run and the published elevation of the bench mark. If the closing error is within acceptable tolerance for the type survey (see Chapter 4), no further operations are necessary. If the closing error is not within the prescribed tolerance, the level run or part(s) of the level run must be repeated to find the error.

3. Non-Reciprocal Trigonometric Leveling

a. Description - This procedure determines elevations by trigonometric means. Vertical differences in elevations are computed from slope distances and zenith (or vertical) angle measurements.

With modern total stations, difference in elevation is calculated automatically; all the operator has to do is push the correct button on the instrument to display this value.

b. When Used - Trigonometric Leveling is often the most practical (and economical) method for establishing elevations in rolling to steep terrain. It is useful for many types of surveys. Some of these are:

1) Control for aerial photography.

2) Establishing low order bench marks on either project control traverses or on Supplemental Traverses (see Chapter 6).

3) As an alternative to reciprocal leveling, when the points are widely separated vertically.

c. Accuracy Attainable - The accuracy which can be realized from trigonometric leveling is sufficient for much of our work. Factors which determine accuracy are:

1) Zenith Angle - The effect of the zenith angle error will depend on the size of the angle and the slope distance.

2) HIs - The major cause of error in trigonometric vertical measurement is that of inaccurate HI determination, at both the Total Station and the target. The net error that results from the two HI measurements produces a direct error in the difference in elevation.

   Measure HIs with a precision that is compatible with zenith angle precision.

3) Earth Curvature and Refraction - The main source of error, over long distances, is earth curvature and refraction. To maintain an accuracy of 3 mm (0.01 ft.) difference in elevation, distance should be limited to 200 m (700 ft.).

d. Procedures - The trigonometric leveling procedures are written for the Topcon GTS-3B Total Station instrument. Procedures may differ for other instruments.

1) How Computed:

   a) When coming off a known elevation (bench mark) the elevation of the setup point is determined by the following equation:

      Grd Elev.@ Inst.= BM Elev.+ PH + ED - IH

      Where PH is the height of the prism (measured) above the BM, IH is the height of the instrument (measured above the ground point), and ED (Elevation Difference) is the vertical distance displayed on the total station. When the BM is above the horizon (vertical angle less than 90☜) the ED is negative, when below the horizon the ED is positive.

NOTE: Ignore the "+" or "-" signs that are displayed on the instrument when coming off a bench mark.

b) When the ground point elevation at the instrument is known, the ground point elevation at the prism is determined by the equation:

Grd Elev. @ Prism = Grd Elev. @ Inst. + ED + IH - PH

Here the "+" or "-" signs as displayed on the instrument are valid and used in the computation.

2) Field Procedures - The procedures detailed here are for precise trigonometric levels. When less accuracy will suffice, these procedures may be relaxed.

a) Turning Points - Usually each setup point will be a bench mark. Therefore, on most projects select all TP sites before traversing begins.

b) Control Check - If feasible, make the first course between two controlling bench marks. This serves as an early check on the survey techniques.

c) Equipment - The Total Station and tribrachs should be in adjustment.

d) Setups - Carefully set up each instrument or sight. Determine the HIs of setups to 1 mm (0.01 ft.) accuracy and record HIs when measured. Excessive closure errors often result from inaccurate measurements of HIs. Each measurement must be to the horizontal axis of the total station and prism.

e) Elevation Differences - Measure each ED in both the Direct (D) and reverse (R) positions. If a difference is found, mean the readings. Normally, EDs will be measured in one direction only.

f) will not be adjusted in the field. If Adjustments - Normally trigonometric levels an adjustment is required, the closing error is distributed proportionally according to the slope distance of each course.

4. Reciprocal Trigonometric Leveling

a. Description - This type of leveling involves taking zenith observations from both ends of a traverse line.

b. Use - This type of leveling can be performed when taking traverse measurements and, if done carefully, can provide reasonably accurate elevation differences over long distances. Observing zeniths from both ends of the line has the effect of canceling the affects of curvature and refraction. It is important that observations from each end of a line be taken within 1 hour of each other so that the amount of refraction will be the same.

c. The following data required when taking reciprocal trigonometric leveling observations:

1) Instrument station name

2) Observer's name

3) Instrument serial number

4) Target station name

5) Time of observation

6) Height of instrument above mark

7) Height of target above mark

8) Circle readings

9) Slope distance between stations

d. Computations - Refer to section 6-01(C) for instructions for recording and computing elevation differences using the TRAVERSE program.

e. Problems encountered

1) Lines "grazing" roadways or objects causing refraction problems.

2) Observations taken under different conditions.

3) Mistakes reading zenith angles.

4) Mistakes reading instrument and target heights.

CHAPTER 5-00 SURVEYING PROCEDURES

SECTION 5-04 CONTROL MONUMENT SETTING

Revised 11/01

A. GENERAL

The purpose of setting control monuments and marks is to establish permanent points on which to base current and future surveys. Marks are set by The National Geodetic Survey (NGS or USC&GS), The National Ocean Service (NOS), The US Geological Survey (USGS), The State Highway Administration (SHA), The Department of General Services (DGS), The Department of Natural Resources (DNR or MSFC), and other Federal, State, County, and City governments.

Control marks are used for a variety of purposes such as horizontal control, vertical control, tidal control, etc. A single mark can provide several different types of control and should be set with this in mind.

B. RECONNAISSANCE

1. Site location

   A mark is useless if it is destroyed or lost. With this in mind, it is important to locate new marks in areas where they will be protected from damage caused by road construction, farming operation, ditching, building construction, utility construction, erosion, etc.

   Marks should be located on property accessible to the public where possible. Road Right-of-Way, parks, pumping stations, court houses, churches, schools, hospitals, cemeteries, government buildings and government installations are good locations.

   When necessary, marks can be located on private property with the permission of the property owner. It is best to locate the mark about 2 to 3 meters (5 to 10 feet) from the corner of the property. This location is usually out of the way of the property owner as well as out of the area of road and utility construction.

   Marks must have a relatively open view of the sky in order to be used for Global Positioning Surveys (GPS). Typically, this would be about 20☜ to 90☜ above the horizon. Some obstructions such as utility poles, etc. are permissible. The monument must be at least 2 meters from any utility poles and 5 meters from a chain link fence.

2. Mark Spacing

   a) Vertical Control - Bench marks should be set between 1 km and 1.5 km (3/4 to 1 mile) apart, depending upon the intended use, the cost of material, and the likelihood of destruction.

   b) Horizontal Control - As required but no closer than 1 km (0.6 mi) apart for main stations. Azimuth marks must be at least 400 m (1/4 mi.) distant from the main station.

   c) Tidal Control - 5 marks, 60 to 200 meters (200 - 660 ft.) apart for a particular tidal station.

3. Utility lines - Miss Utility must be called at least 48 hours prior to setting a monument or rod mark to mark the location of any underground utilities.

C. MARK SETTING

1. Stability

   The mark MUST be stable in all three dimensions. The most stable marks are:

   a) Sleeved stainless steel rods driven to refusal.

   b) Disks set in massive structures with deep foundations such as bridges and overpasses.

   c) Disks set in rock outcrops.

   Moderately stable settings:

   a) Poured in place concrete monuments, at least 0.2 m (8 in.) in diameter at the top, 0.3 m (1 ft) in diameter at the bottom and 0.9 m (3 ft) deep.

   b) Marks set in drill holes of buildings.

   Least stable settings:

   a) Pre-cast concrete posts.

   b) Drainage inlets.

   c) Small headwalls.

d) Concrete slabs or pads, pavements, etc.

e) Rebars, stakes, etc.

2. Procedure for Sleeved Stainless Steel Marks

a) Dig a hole 0.3 m (12 ft.) in diameter and (0.9 m (3 ft.) deep at the desired location.

b) Assemble two sections of rod and a driving head together and position the rod vertically in the center of the hole.

c) Using a rock drill, drive the rod down until almost flush with the surface.

d) Remove the driving head and add another section of rod and the driving head on top.

e) Repeat steps c) and d) until very little movement is attained while driving. The mark can then be considered at "refusal".

f) Attempt to twist the mark in a clockwise direction. If the mark turns easily and does not spring back, it is not properly anchored in the soil. This is typical if the mark reaches refusal after a short distance (less than 8 meters). If this is the case, fill in the hole and pick another location or set a concrete mark here.

g) Cut the rod off about 50 mm (2 inches) below the surface of the ground. Using a portable grinder, grind the top until it is rounded or bullet-shaped.

h) Center-punch the rod on the top.

i) Push the grease-filled sleeve over the mark until the top of the rod sticks out above the sleeve about 25 mm (1 inch).

j) Fill the hole 2/3 full with coarse sand.

k) Set the logo cap and pvc casing over the mark and level with the ground. Be sure there is about 25 mm clearance between the cap and the top of the rod. Place additional sand inside the casing if necessary until the sand is about 25 mm below the top of the grease-filled sleeve.

l) Place concrete around the outside of the PVC casing until flush with the ground and finish the top.

3. Procedure for concrete marks

   a) Dig a hole about 0.25 m (10 inches) in diameter and (0.9 m (3 ft.) deep. Make the bottom of the hole larger in diameter than the top. Remove all loose material from the bottom of the hole.

   b) Fill the hole with concrete until flush or slightly below grade, rodding the concrete to remove entrapped air.

   c) Finish the top with a small trowel and set the stamped disk in the top. Be sure that concrete covers the edge slightly to prevent vandalism.

4. Procedure for drilled marks

   a) Using a rock drill or hand drill, drill a small hole in the top of the concrete or rock, slightly larger than the stem of the disk. Wear safety goggles while drilling and chipping.

   b) Chip a circle around the hole the diameter of the disk to allow the disk to be counter-sunk. Remove any debris from the hole and recess.

   c) Fill the hole with clean water. Mix a ratio of 50% cement and 50% sand mix in the hole. Fill the underside of the disk with mortar.

   d) Place the shank into the drilled hole and press the mark firmly into place. Tap the disk gently to remove any entrapped air. Work the excess mortar around the disk to cover the outer edge. This prevents vandalism.

D. MARK DESCRIPTIONS

General - Marks must be well described to aid in future recovery. This should be done using the description program on a laptop PC, but can be hand recorded for later input.

1. General location - Measure the distance from the nearest intersection with the truck odometer to the nearest 0.01 mile and carefully plot the mark on a map. Scale the distances and directions to the nearest towns. Scale the approximate latitude and longitude.

2. To Reach - Write a brief narrative of how one may reach the mark from a major intersection or post office. Always give the distance and direction of travel along each street or road taken.

3. Property ownership.

4 Nearby references - Make at least four measurements (direction and distance) to nearby PERMANENT objects. The center of the object is assumed unless otherwise stated. DO NOT use mailboxes, small signs, small trees or bushes, mobile homes, and the like. Some examples of permanent objects are:

utility poles	building corners	large trees
pipe culverts	roadways	fences
headwalls	large signs	railroads
edges of woods	ditches	retaining walls
bridges	electric Trans.	inlets
curbs	headstones	

5. Relative height above or below the road surface.

6. Physical description of the monument including the height above or below the ground.

7. Mark type and stamping.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-01 TRAVERSES

Revised 11/01

A. GENERAL

This section covers traverse for all type of surveys.

1. Applications

   a. Project control
   b. Data Collection control
   c. Topography control
   d. Cross-section control
   e. Construction staking
   f. Metes and bounds surveys

2. Definition - A traverse is a series of survey points whose relative positions are determined by measured distances and directions between each set of consecutive points. The measured distances are usually referred to as "courses" or "legs". The survey points are called "traverse stations", P.I.s (points of intersection), or angle points. Normally, some type of mark is left in the ground or roadway to indicate each survey point.

3. Types - There are two basic types of traverses:

   a. Closed
      1) Closed-Figure - A traverse which begins and closes on the same point.

      2) Closed-Line - A traverse which closes on a known station of accuracy equal to of higher than that of the beginning station.

   b. Open-end - A traverse that ends on a station of unknown position.

4. Purposes - Traverses are primarily run for three reasons:

   a. Establish intermediate control points.

   b. Extend the scope of control points.

   c. Include ground points of interest (property corners, topography points, etc.) in a closed survey to preclude blunders in the positioning of such points.

5. Advantages - Four principle advantages result from traverse surveys:

   a. Flexibility - Since a rigid, geometrical form is not required, obstacles and problem areas can be avoided.

   b. Blunder detection - Blunders in positioning subordinate survey points can be detected if the points are included as stations in a closed traverse.

   c. Economy - Traversing requires a minimum of reconnaissance in the planning phase (compared with triangulation or trilateration).

   d. Linearity - The linear nature of traverse conforms to that of transportation corridors.

6. Disadvantages

   a. Sways easily. Frequent checks for azimuth required.

   b. Less checks to locate mistakes in data.

   c. Subject to compensating errors in angle and length measurements.

   d. Clear lines of sight required.

   e. Subject to refraction problems during certain times of the day under sunny conditions.

B. TRAVERSE SPECIFICATIONS

1. Application - As GPS now provides primary horizontal control for all projects, the necessity for long traverses to bring in control from distant NGS monumentation has been eliminated. Traverse is now primarily used to densify project control between GPS points.

2. Specifications - All traverse observations will conform to the specifications for Class A Surveys. These are as follows:

a. Traverse point spacing - The minimum distance between traverse points is 81 meters (266 Ft.)

b. Angle observations - A minimum of 2 direct and 2 reversed. Each set must be within 5 seconds from the mean of all sets.

c. Azimuth closure - The maximum closure is 10 seconds times the square-root of the number of angles.

d. Linear closure - After azimuth adjustment the minimum closure is 1:15,000.

3. Equipment - All equipment must be in good adjustment prior to beginning any traverse work. Tribrachs should be checked every 3 months or less. Total stations must be taken to a calibration range every 6 months for calibration. Check tripods daily for loose legs or shoes.

4. Existing control - Check all existing control points to make sure that they have not been disturbed. Always measure distances between existing controls if possible to see if they match published data.

5. Traverse layout

a) Choose angle points carefully to maximize the distance between them and to avoid "grazing shots" (lines of sight that pass within 0.3 m (1 Ft.) of the surface or other objects). Try to select points where traffic will not interfere with observations.

b) Set points-on-line (P.O.L's) at sufficient intervals for the type of work to be performed. Spacing should normally range from 81 m. to 300 m. (266 Ft. to 1000 Ft.).

c) Spurs - The layout of spurs should be limited to points that can be measured directly from the main traverse line. If this is not possible, try to make a connection to another spur to form a closed loop. Be sure to observe all angles and distances.

6. Point numbering - If existing control points have already been numbered, **do not re-number them.** Instead, start with the next unused point number and number the traverse points in a northerly or easterly direction. The range for traverse point numbers is 1-300.

7. Reference points - Reference traverse points to nearby objects using nails and caps in trees or telephone poles, cross-cuts in concrete curbs, inlets, or foundations, corners of buildings, etc. **Do not set points in roadways for use as reference points.** Reference points should form an approximate 90 degree angle to the control point if possible.

8. Notes - Sketch the traverse in a standard plats and survey field book as shown in figure 6-01-A. Show all angles clockwise from the main backsight. If there are POL's, show the distances between points and the overall distances between break points.

C. TRAVERSE PROGRAM

1. General - The traverse (TRAV) program was developed to facilitate the checking and saving of traverse data in the field with the PARAVANT data collector. TRAV may be used on any dos computer with a display screen of 16 lines by 40 characters or larger. This program uses a "one touch" system whereby data can be entered with a single key press. The data collected electronically via cable if desired.

2. Configuration - The program utilizes a BBK.PAR file for necessary parameters for computations and an INST.PAR file for instruments. Both parameter files must reside on the default drive. The parameter files may be edited to work with any lambert conformal conic projection zone and group of instruments. The same parameter files must be used with the TRATOBBK program to create a standard NGS BLUEBOOK data file from any traverse file. In addition, the .TRA file created can be used as input to the PCCOGO program for traverse adjustment.

3. Loading the program on the PARAVANT

    a. Place the floppy disk in the portable disk drive.

    b. From the B:> prompt, type COPY D:TRAV.EXE A: and press the ENTER key. This will copy the program to the ramcard.

    c. Type COPY D:BBK.PAR and press the ENTER key. This will copy the parameter file to the B: drive.

4. General Operation - When using the PARAVANT data collector, TRAV should be run on the B: drive, but the program itself should reside only on the A: drive to save space.

The data will be stored in a ".TRA" file on the B: drive and backed up on the A: drive in a ".TBK" file if the operator chooses (STRONGLY RECOMMENDED).

Whenever the letters "RECORD? --> **Y**" appear, press ENTER to store the record in the file or **N** to discard it. Only one traverse file should be made for each job. When the job is complete, print the job out and make pencil corrections as necessary to the printout before turning in. Make two disks of the file, the same as in data collection work.

5. Aborting and re-starting - To abort most routines, simply press ENTER when prompted for a point number without entering the number. If entering data in the ANGLE routine, enter A to abort the routine. If the paravant is shut down while in the program, the CAPS LOCK key may need to be pressed after re-starting.

6. Start-up

   a. Turn the paravant on by pressing the FUNCTION and POWER keys simultaneously. If the ETSC program comes up, use QUIT to exit to the B:> prompt. Check to see if sufficient space exists on the A: and B: drives to store data. If necessary, copy old .FLD files to a floppy disk and delete them from the PARAVANT.

   b. Type in the word TRAV at the B:> prompt. If the BBK.PAR file is not found, a message indicating this will be displayed.

   c. The first screen will ask the user if he wants to back-up the data on the A: drive (**Y** is the default). Press ENTER.

   d. Next, a list of TRA files on the default drive will be displayed.

   e. Enter the filename without the extension. The file should be named by the book and page number of the start of the new work. Ex: 24331p8

   f. If the file does not exist, the user will be asked if he wants to create it. Press ENTER for yes.

   g. If this is a new file, the user will be asked to enter the job information.

   h. Key in the route number and location of the work. Example: US RT 50 ANNAPOLIS TO WASHINGTON .

i. RECORD? --> **Y** will be displayed. Press ENTER to record or **N** to repeat the procedure.

j. The user will be prompted for the party chief's name. Enter the data and record it if correct.

k. The user will be prompted for the measurement units he intends to use. Choose the appropriate response. **Note: THE CORRECT RESPONSE MUST BE ENTERED AS IT CANNOT BE CHANGED!**

l. The MAIN MENU will appear. The left column of the menu is for data input selections. The user will be able to create data records utilizing the routines from this column of the menu. Simply press the appropriate letter to start the routine. The right column is for performing various functions.

   Note: Should the machine lose power or be shut down while in the program, the CAPS LOCK key must be pressed to enter capital letters. The user may exit the program any time from the MAIN MENU by pressing the **E** key or the ESC key.

7. Entering Data

a. Weather - Press **W** to begin the routine and answer the prompts to create and store the weather record. If the user fails to create a weather record for the current day before attempting to store observed data, he will be prompted to create one.

b. Text - Text records may be placed anywhere in the file, but should be entered when the point is set and before observations to that point are taken.

   1) Press **T** to create a text record for a point. The highest point number will be displayed along with its description.

   2) Key in a point number. Note - point numbers can range from 1 to 300 for traverse points that are not property corners. Use point range 301 to 999 for property corners. Point numbers need not be consecutive. Press ENTER.

   3) Key in the description for the point in the box provided. If the description is long, press ENTER before reaching the end of the box and a prompt for additional text will be displayed. Enter additional text if needed.

c. Coordinates - Coordinate records should only be made for the fixed control points on the job.

1) Press **C** to begin the routine.

2) Enter point number, northing, easting, and/or elevation when prompted. If the elevation of the point is not known, enter an approximate elevation for the point, rounded off to the nearest ten feet. The elevation will be used later in the program to reduce distances to grid values.

3) After the elevation is entered, "ENTER TYPE --> " will be displayed. Press **B** if it is a monumented bench mark. Press **L** if you determined the elevation of the point by differential leveling. Press **R** if it is a trig elevation. Press **P** if the elevation is estimated.

d. Instrument data - Instrument records must be created for each instrument used on the project. An instrument can be a total station, theodolite, EDMI, steel tape, etc. Data is copied from the INST.PAR file. DO NOT create multiple instrument records for the same instrument. The correct instrument must be entered to enable electronic collection from the total station.

1) Press **I** to create the Instrument record.

2) Enter the three-digit job-specific instrument number (JSIN). If the JSIN is not known press ENTER and enter the serial number.

3) If the instrument is in the INST.PAR file, all of the data available for the instrument will be displayed. If the correct instrument was selected, Press ENTER to record the data. **Instrument records must be created prior to using the instrument for an observation.**

e. Angles - Angles are recorded using the method of directions. This method is one of the simplest and easiest to use, once the operator is familiar with the procedure.

1) Press **A** to begin the horizontal angle routine. If this is a new day and a weather record has not been created, the user will be asked to create a weather record.

2) Enter the observers initials.

3) Enter the instrument number used.

4) Enter the occupied point number.

5) Enter the number of objects to be sighted, including the backsight (a maximum of 5 may be sighted).

6) Enter the backsight point number, and foresight point number(s) when prompted. If text for the points have been stored, it will be displayed next to the point number.

7) CONTINUE? --> Y" will be displayed. Press ENTER to continue or **N** to abort the routine.

8) A listing of points to sight will appear to help guide you in entering the data. Sight on the backsight with the telescope direct and enter the clockwise angle reading, separating the degrees, minutes, and seconds with a space or dash. If the collector is connected to the total station, press ENTER to collect the data electronically.
Enter A to abort the routine. Enter B to back up to the previous entry. Enter the values to the foresights in like manner.

9) After entering the value to the last foresight, "--- REVERSE TELESCOPE ---" will appear. Flop the scope and sight each of the sights in REVERSE order. After sighting the backsight, the reduced values for the set will be computed and displayed. The spread between direct and reversed measurements will also be displayed. Higher spreads are allowed to objects less than 30 meters (100) feet from the instrument.

10) RECORD? --> Y will appear. If all is well, press ENTER to record the values shown, or **N** to discard them.

11) TAKE ANOTHER SET? --> Y will appear. Press ENTER to measure another set of directions to the same objects.

12) After the second set and with all subsequent sets, the mean of all sets will be displayed.

If two sets are taken and one is rejected, take a third set. Usually the third set will agree with one of the first two. If the spread between sets is large and difficulty is encountered, refraction problems may exist which CANNOT BE CORRECTED FOR. If this occurs, come back and measure the angles in the morning under better conditions.

If the message "ERROR - REOBSERVE THIS DIRECTION" is displayed, a large spread between the direct and reversed angles for a sight was entered. Note - the data for the direction in error will not be stored.

13) After the last set of angles is measured and TAKE ANOTHER SET? --> Y appears, press **N** to end the procedure.

f. Zeniths - Zenith angles must be measured to reduce the slope distances to horizontal, and may be used to compute trig elevations for traverse points.

1) Press **Z** to start the routine.

2) Enter the observer's initials.

3) Enter the instrument number.

4) Enter the occupied point number or accept the default.

5) Enter the measured height of the instrument above the occupied point if elevations will be computed from the observations.

6) Enter the sighted point number or accept the default.

7) Enter the height of the target or prism above the control point for elevation computations.

8) ZEN 1? will be displayed. Enter the reading in degrees, minutes, and seconds separated by spaces or dashes. You may enter either the direct or reverse reading at this time. If the collector in connected to the total station, press ENTER to collect the data electronically.

9) --- INVERT TELESCOPE --- and ZEN 2? will be displayed.

Flop the scope and enter the reading. Press

ENTER for data collection.

10) The mean reading and RECORD --> Y will be displayed. Press ENTER to record the data.

11) TAKE ANOTHER SET TO THE SAME TARGET? --> Y will be displayed. Press ENTER to repeat the measurement or **N** to stop.

g. Distances - EDM and taped distances can be recorded using this routine.

1) From the main menu, Press **D** to begin the routine.

2) EDM DISTANCE? --> Y will be displayed. Press ENTER for EDM distance or **N** for a taped distance.

3) Enter the observers initials.

4) Enter the instrument used.

5) Enter the occupied point number.

6) Enter the Foresight point number.

7) Entering distances

a) EDM DISTANCE - If a zenith angle has been entered between the points, that data will be displayed. CHANGE INSTRUMENT, HEIGHTS? --> N will be displayed. Press ENTER if the data shown is correct. Otherwise, Enter "Y" and key in the correct values.

Enter the slope distance in meters. (If you are using a PENTAX Press ENTER and enter the slope distance in feet.) If the instrument is connected to the collector, press ENTER again to collect the data electronically. If the distance is over 150 meters (500 ft.) the instrument will repeat the measurement 2 more times and display the mean.

b) TAPED DISTANCE - The maximum taped distance allowed is 30 meters (100 ft.) Enter the horizontal distance in meters if available otherwise press ENTER and

enter the horizontal distance in feet.

The horizontal distance in meters will be displayed.

8) Enter the horizontal distance in feet. The computed horizontal distance will be displayed. If the spread between these distances is too great, the machine will beep, alerting the operator. Press ENTER to collect the data electronically. If the distance is over 150 meters (500 ft.) the instrument will measure the distance 2 more times and display the mean.

9) RECORD --> Y" will be displayed. Press ENTER to record the data or **N** to discard it.

h. NOTES - Notes may be placed anywhere in the file.

1) Press **N** to begin the procedure.

2) Enter the notes you wish to make.

8. Functions - A number of functions are available to check the recorded data. No computed data using the functions will be recorded, except for trig elevations if the operator desires.

a. Data from a .DAT file - If the user has coordinates from a .DAT file, he can store them in the .TRA file.

1) Press **G** to begin the routine.

2) Key in the name of the .DAT file.

3) Coordinates and descriptions will be written to the .TRA file with C and T records.

b. View file

1) Press **V** to view the contents of the file at any time. 14 lines of data will be displayed as well as a top of file and bottom of file marker as appropriate.

2) Use the arrow keys to page up, down, left, or right. Any other key will exit the routine.

c. List data

1) Press **L** to list specific data recorded in the file. A listing menu will appear.
2) Press the letter of the type of data you wish to see.

d. Compute data - Press **M** to bring up the computation menu.

1) Angles - Press **A** to compute the mean angles between the traverse points. Enter the backsight point number. Enter the occupied point number. Enter the foresight point number. The mean angle, number of rejections, and standard error for the angle will be displayed. THERE MUST BE AT LEAST TWO GOOD OBSERVATIONS FOR ALL ANGLES IN THE TRAVERSE. If two observations were made and both are rejected, take a third and recompute the angle. The third will probably agree with one of the first two and cause only one of them to be rejected. This is okay. Nobody measures perfect angles all the time.

2. Elevations - Press **L** to compute elevation differences between points. Enter the occupied point number. Enter the foresight point number. If zenith observations have been made from both ends of the line and distance observations from at least one end, the elevation difference and coefficient of refraction will be computed and displayed. If the occupied point elevation is known and the coefficient of refraction is within tolerance, the elevation for the foresight will be displayed and can be stored if desired.

3. Traverse computation - Press **T** to compute the PRELIMINARY coordinates of traverse points and the closing azimuths and coordinates of the end control points. Enter the appropriate point numbers for the fixed control. Data will be taken from the coordinate records to compute the scale and combined factors (includes sea level and geoid reduction) for the traverse. The operator is given a chance to enter a different factor if desired. Enter the point numbers for intermediate point numbers along the traverse when prompted. DO NOT enter any POL's as these will not be used to compute the traverse closure.

e. End program - Press **E** or **ESC** to end the program and return to the DOS prompt character.

9. Error messages

ANGLE DATA NOT FOUND - The program was looking for angle data to perform a computation, and that data was not stored in the .TRA file.

ANGLE DOES NOT CHECK - The index error of the instrument exceeds one minute - readjust instrument if necessary before continuing.

ANGLE OUT OF RANGE - The zenith angle entered is too steep. Check entry.

BBK.PAR FILE NOT FOUND - The BBK.PAR file must be copied to the default drive.

COMMUNICATION ERROR - A problem exists between the collector and the total station. Try changing cables or installing a fresh battery on the total station.

DISTANCE DOES NOT CHECK - The difference between the measured horizontal distance in feet does not check the distance computed from the slope meter distance and zenith angle by 0.02 feet or more.

DISTANCE OUT OF RANGE - The maximum distance that may be entered is 20,000 ft or 6100 meters.

DISTANCE RECORD NOT FOUND - A distance observation for the line in question must be performed prior to computing elevations or traverse closure.

ELEV DOES NOT CHECK - CHECK TARGET HEIGHTS - The computed coefficient of refraction for a forward and back zenith exceeded the allowable limit. Check the target heights or repeat the zenith observations as necessary.

ERROR - DRIVE(S) FULL - Check both the default drive and the A: drive to see if there is any space left on the drive for data. The data that caused the error will not be saved!

ERROR IN BBK.PAR - The format of the BBK.PAR file is in error. Recopy the original BBK.PAR file from diskette.

ERROR IN .DAT FILE - The format of the .DAT file must be POINT NORTHING EASTING ELEVATION DESCRIPTION. Point numbers must not exceed 999.

ERROR IN ENTERING FILE NAME - Filenames must conform to DOS specifications.

ERROR - REOBSERVE THIS DIRECTION - The direct measurement of the angle did not check the reversed measurement within 15 seconds.

FILE DOES NOT EXIST - The file name entered does not exist on the default drive.

FORWARD AND BACK ZENITHS NOT FOUND - A zenith observation must be made from both ends of the line for an elevation computation to be made.

INST.PAR FILE NOT FOUND - The INST.PAR file must be copied to the default drive.

INVALID DATE - Check to see if the system time and date are set correctly in the PARAVANT. See Section 2-08 for configuration.

CHECK SYSTEM TIME - Check to see if the system time and date are set correctly in the PARAVANT. See Section 2-08 for configuration.

NO ZENITH ANGLE FOUND - A zenith observation must be made before performing a distance observation with EDMI.

PLEASE CREATE AN INSTRUMENT RECORD FIRST - An instrument record must be created before using that instrument.

PLEASE CREATE A WEATHER RECORD FIRST - A weather record must be created each day before performing any observations.

POINT ... UNDEFINED, ABORT? - The point number entered has not been used in the observation required.

PROGRAM ABORTED - An error has caused the program to end.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-02 TOPOGRAPHY SURVEYS

Revised 11/01

A. GENERAL

Topographic surveys are performed in order to determine the position of natural and man-made features (e.g., buildings, utilities, trees, roads and streams). After location, these features can then be drawn to scale on a plan or map. It is very important that all topography likely to have an effect on the proposed highway construction or improvement be accurately located. It is not the intent of this manual to limit the type of topography to be taken; however, the following section outlines some of the more important items.

It should be noted, that data collection surveys, utilizing a total station instrument and a electronic field book, have almost completely replaced the methods of feature location described in this section.

B. PRECISION

Considering plotting requirements only, survey detail need only to be located to the nearest foot if the plan scale is one inch = 50 feet. However, in addition to providing plotting data, topographic surveys also provide the designer with field dimensions that must be considered for related construction design.

In this regard, the following points should be considered:

1. Some detail can be precisely defined and located (e.g., edges of concrete roads, buildings, bridge piers, railroad tracks, etc). If using the right angle-offset method, these features would be located to the nearest half-foot-plus and the nearest tenth-distance.

2. Some detail cannot be precisely located or defined. These features include stream banks, wooded areas, edges of gravel roads, centerline of ditches, etc. Using the plus and offset method, these features would be located to the nearest foot-plus and the nearest half foot-distance.

C. METHODS

The methods used by the Division to locate topographic features include:

1. Right Angle-Offset - Using this method, plan detail is located by measuring the distance perpendicularly from a established baseline to the object (the offset) and, in addition, measuring along the baseline to the point of perpendicularity (the plus).

   A sketch is entered in the field book as the location of topographic features proceeds. If the terrain is smooth, a steel tape is laid on the ground between station marks. This will permit the note taker to move along the tape noting and booking the plus and distance to the located object. The right angle plus for each location tie is established by using a right-angle prism and the offset measured with a cloth tape. The sketch should show the plus on the dimension line of the baseline and the offset distance as close as possible to the sketched tie point. See Figure 6-02-A for sample notes.

   Often, because of traffic or other reasons, it is not practical to use the method describe in the preceding paragraph. In such cases, the total station instrument can be used to establish both the plus and offset to the object to be located. This may be accomplished by using the coordinate measuring function of the instrument and:

   a. Setting the instrument over a known point on the baseline and noting the station.

   b. Set zero on another convenient baseline point using lower motion.

   c. Sight the target prism using upper motion and key the coordinate button. The first measurement obtained is the northing coordinate, which when added to or subtracted from the station at which the instrument is set will give the plus. Key the button again and the easting coordinate is display, which will be the offset distance.

2. Stadia

   Topography located by the stadia method relies on the recording of a horizontal angle measured from a baseline and a distance measurement using the stadia cross hairs of the instrument. When used, stadia topo is shown with a sketch showing the objects located and the measured angles and distances applied to a line.

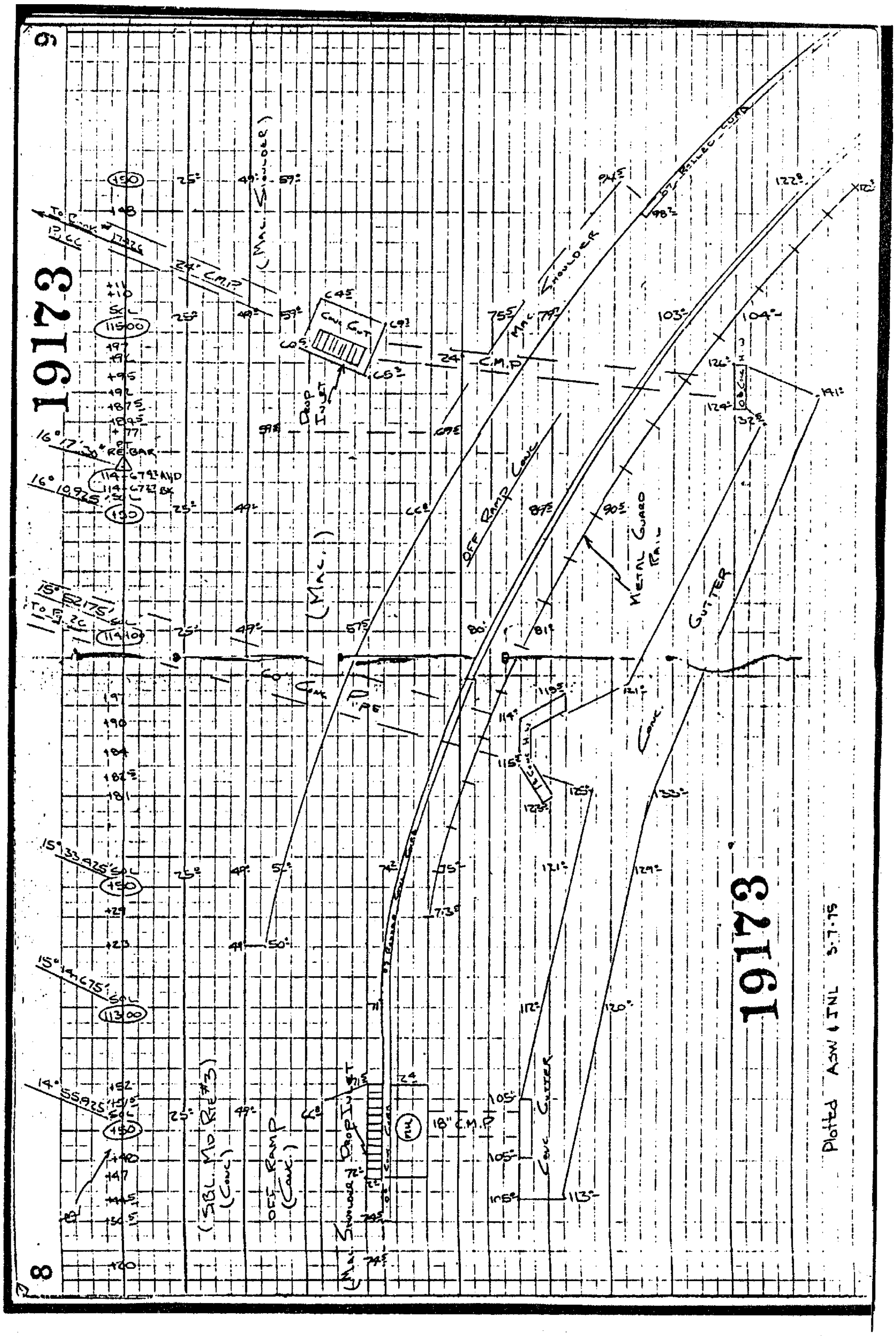


FIGURE 6-02-A SAMPLE TOPOGRAPHY NOTES

D. SCOPE AND TOPOGRAPHIC FEATURES

1. Scope

   All topography shall be located for at least twice the proposed right-of-way width. However, design and terrain requirements may dictate broader topography coverage. In general, all topography which may in any way affect the design and construction of the highway and the acquisition of the necessary right-of-way shall be located.

2. Features that shall be located include, but are not limited to the following.

   a. All buildings and structures, including description, type, use and whether with or without basements.

   b. Poles and utility structures, including underground pipe, water and gas lines, manholes, water meters and conduits, giving ownership and identification numbers; wells, springs, ditches (showing direction of flow), hedges, walls, fences, curbs, trees (showing species and trunk diameters), pipes and culverts (including size, type and direction of flow), edges of existing pavement, and any and all other objects of any nature that may affect final design.

3. Nature of land use, whether pasture, cultivated, woods, etc. (if woods, specify whether hard, soft, or mixed).

4. Location of State, county, city and town boundaries, by angles and distances (to hundredths).

5. Property corners located by angles and distances (to hundredths) to the baseline with the names of the owners indicated.

   Apparent property lines and other boundaries shall also be located.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-03 CROSS SECTION SURVEYS

Revised 11/01

A. GENERAL

Cross-sections are employed for computing volumes on construction projects. Ground profiles are secured at right angles to the centerline at specified intervals. A design template (outlines of planned embankment or excavation) can be superimposed on the plot of each cross section to get area of excavation or embankment. These are called end areas and are used in the computation of volumes.

B. CONTROLS AND ACCURACY

1. The survey is to be referenced to a minimum of two geodetic bench marks unless otherwise directed.

2. Project bench marks shall be established at 300 m (1000 ft.) intervals. If permanent structures, such as stone or concrete foundations, are available, squares approximating the size of the base of the standard leveling rod shall be cut. Otherwise, bench marks consisting of 13 mm x 165 mm (½" x 6-½") galvanized boat spikes shall be driven approximately 75 mm (3") into trees 0.3 m to 0.5 m (12" to 18") above ground level or in poles at ground level. Bench marks shall be set outside the proposed construction limits whenever possible.

3. Bench marks shall always be incorporated into the level line, and bench mark elevations shall never be established from "side shots". All elevations shall be established by differential leveling. Give clear and concise description and location of all bench marks (plus and distance location from traverse or centerline).

4. Check levels shall be run throughout the length of the project before taking cross sections.

5. The minimum vertical accuracy of these surveys shall be 3rd Order; i.e., 12 mm x √ km (0.05' x √ M.)

C. REQUIREMENTS

1. Cross sections shall be taken at all stations where a centerline stake has been set. The maximum distance

between consecutive rods is not to exceed 10 meters (33 ft.). Elevations shall be taken at all breaks in terrain.

2. Normally, the width of centerline cross sections shall be twice the proposed right of way width.

3. Cross sections under 60 m (200 ft.) width shall be taken at right angles to traverse lines and centerline tangents and radial to centerline curves. These can be established by use of a standard right angle mirror. Cross sections with widths greater than 60 m (200 ft.) must have more accurate horizontal control. This is to be achieved by setting offset lines or by turning right angle and/or radials with a survey transit. Vertical accuracy on wide cross sections shall be verified by hand level checks on elevation differential at the end of cross section between the previous station. These checks should not vary more than 0.1 m (0.3 ft.) from a true cross section between succeeding stations. Cross sections are to be obtained with a standard level (or its equivalent), cloth tapes, level rod and hand levels unless otherwise directed.

4. Rod readings of elevations on cross sections shall be taken to 1 mm (0.01 ft.) on hubs, rebars, stake points, nails, and top of rail on railroads. Readings to should be to 1 cm (0.1 ft.) for all other elevations. Both top of stake and ground elevations shall be shown for centerline stations.

5. Cross sections on spur lines shall be taken as indicated by field conditions and design requirements.

6. Entrances along the route of survey shall be profiled for a distance of twice the limits of sections. For all buildings within or immediately adjacent to the proposed right of way line, first floor elevations shall be shown.

7. The crown of existing roads shall be defined by taking rods at the centerline, road and shoulder edge, and bottom of ditch. It is important that the distance shown to the edge of road in the cross section notes coincide with the distance as shown in the topography notes.

8. Elevations on all utilities shall be obtained where possible, including overhead wires and other clearance, and inverts of inlets, storm, and sewer lines.

9. Where the centerline/baseline survey crosses roads,

railroads, rivers and streams, a profile shall be taken. On proposed dual lane roads, a profile shall also be taken along the profile grade line of each lane parallel to the centerline survey.

10. Where drainage may be a problem, elevations as well as bridge and box culvert inverts shall be shown. Culvert size and type and waterway openings of structures shall be obtained.

11. Soundings and water elevations as well as bridge and box culvert inverts shall be shown. Culvert size and type and waterway openings of structures shall be obtained.

12. Judgement is to be exercised in clearing for obtaining cross sections. Care is to be used to preserve shrubs, plants and trees in or adjacent to lawn areas. Trees 0.3 m (12") in diameter or greater, are not to be felled.

D. NOTES (CONVENTIONAL)

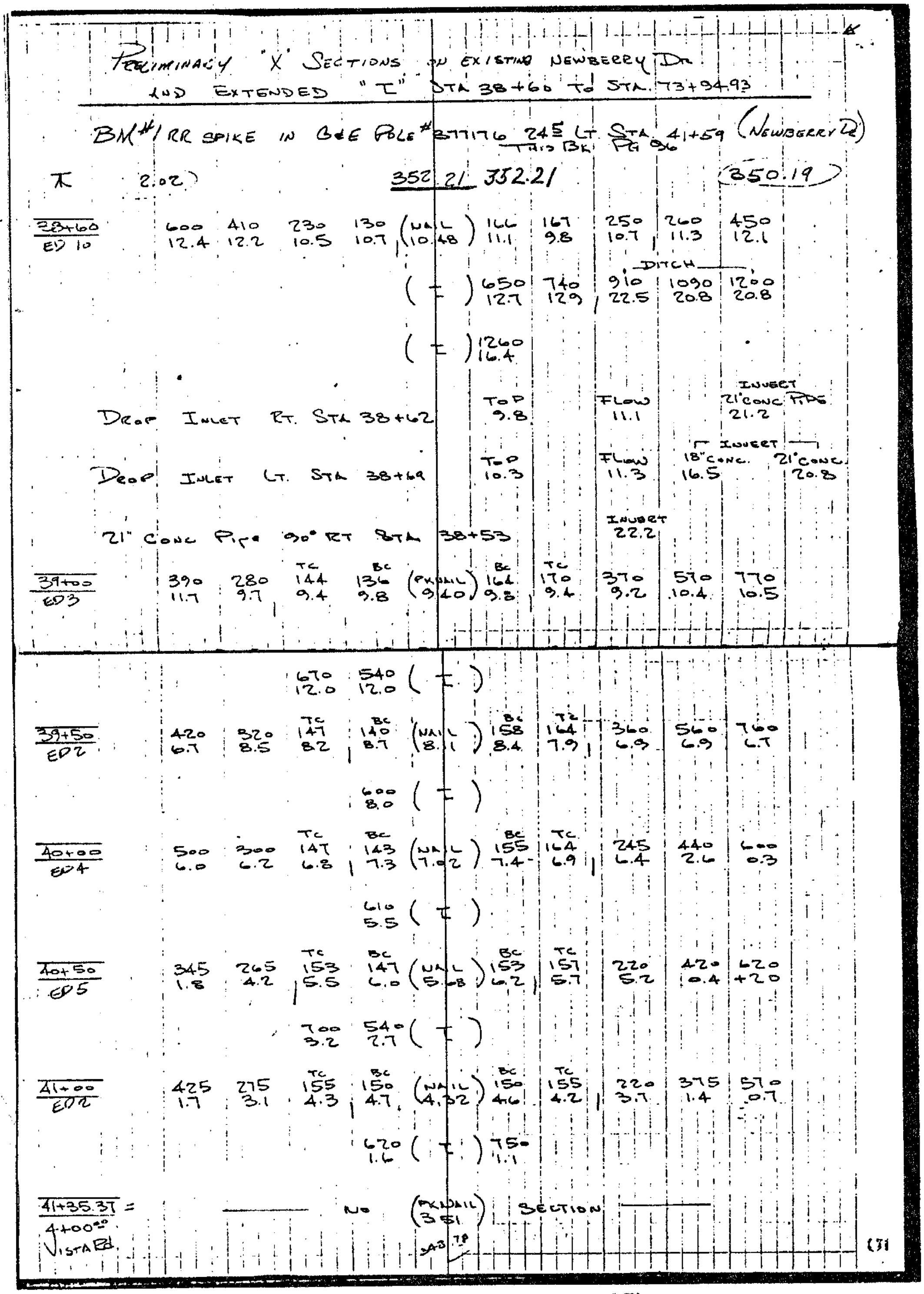
The cross section survey book shall show all cross sections, elevations, and profile data obtained. In order to provide a terrain edit check in connection with the reduction of survey notes by electronic data processing, an Elevation Difference, designated ED, shall be noted under stations listing. This Elevation Difference, expressed in even meters (feet), represents the maximum elevation difference between consecutive rod readings and is the rod differential which, if exceeded, would definitely represent an erroneous reading. A quick glance at the completed notes for each station listing should be sufficient to estimate this difference.

See Figure 6-03-A series for examples of note taking.

E. NOTES (SECTION PROGRAM)

1. General - The section program was developed to allow the recording of conventional cross-section data on the Paravant data collector. The data is recorded in a standard ASCII format which may be edited on any text editor.

2. Loading the section program on the paravant - Place the floppy disk in the portable disk drive. From the dos prompt, type COPY D:SECT.EXE A: and press the ENTER key. This will copy the program to the ramcard. The path command has already been set to find the program from any drive, so the program can be run from the A:,



(BASELINE CENTER OF PAGE)

FIGURE 6-03-A(1) SAMPLE CROSS-SECTION NOTES

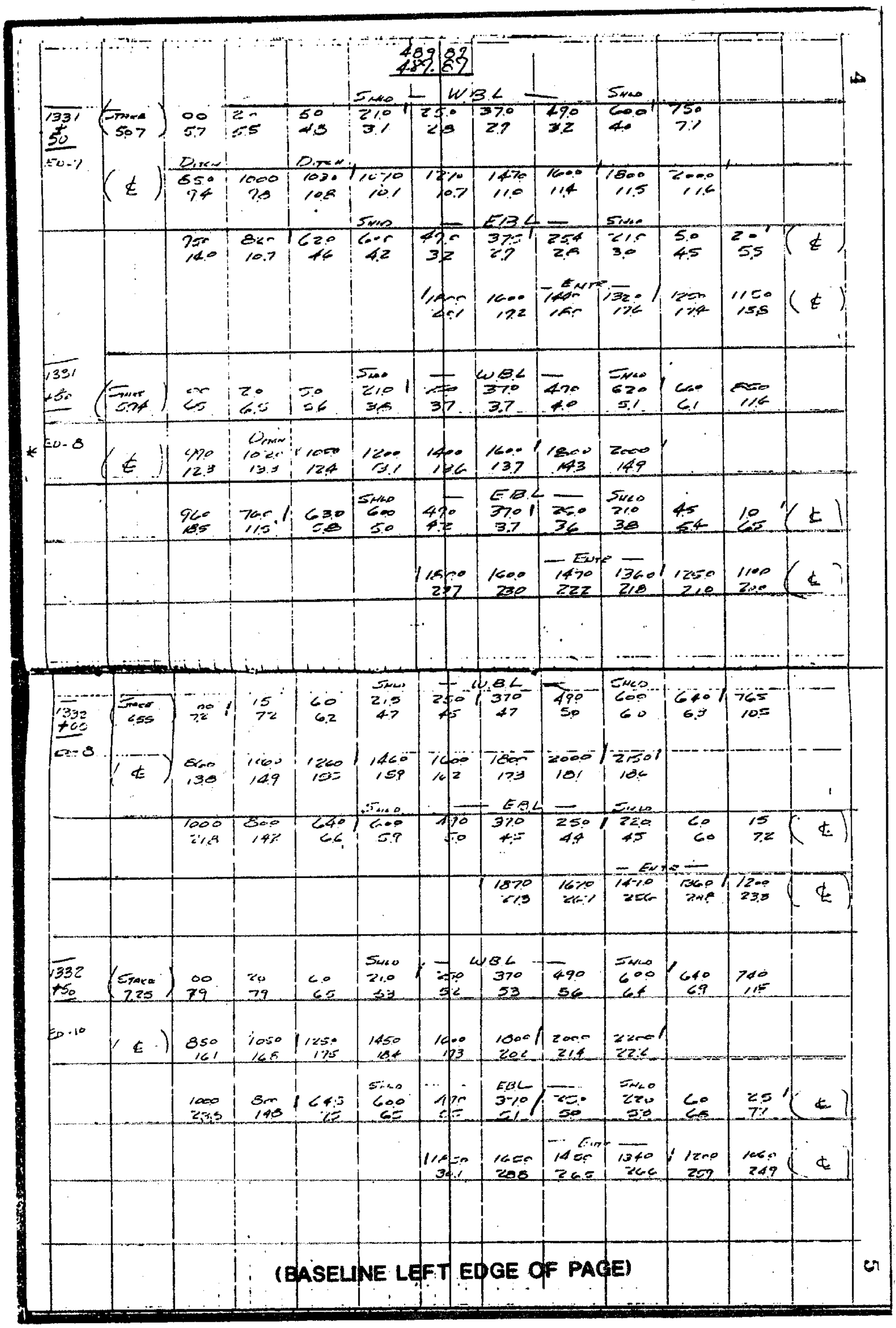


FIGURE 6-03-A(2) SAMPLE CROSS-SECTION NOTES

B:, or D: drives if desired (the B: drive is recommended).

3. Start up - Start the section program by typing the word SECT and pressing ENTER. The following screen will be displayed:

```
6444444444444444444444444444444444444447
5                                      5
5     STATE HIGHWAY ADMINISTRATION     5
5      PLATS AND SURVEYS DIVISION      5
5                                      5
5         CROSS-SECTION PROGRAM        5
5              Version 1.15            5
5                                      5
5               Written By:            5
5         Malcolm R. Archer-Shee       5
K)))))))))))))))))))))))))))))))))))))))M
5     BACK UP DATA TO DRIVE A?  Y      5
9444444444444444444444444444444444444448
```

Press ENTER to create a back-up file on the A: drive.
A directory listing of .XCT files on the B: drive will be displayed along with a prompt for the filename to be used:

```
6444444444444444444444444444444444444447
5      FILENAME -->         .XCT       5
5                                      5
9444444444444444444444444444444444444448
```

Key-in the filename using the following naming convention:

(X) (Rte.) (Date)

Ex.- If you are working on Md. Rte. 410 on March 4th you would use X4100304 as your filename. If this is a new day's work, the program will display:

```
6444444444444444444444444444444444444447
5      FILENAME --> X4100304.XCT       5
5  FILE DOES NOT EXIST - CREATE?  Y    5
9444444444444444444444444444444444444448
```

Press ENTER to create the new file.

For new files, the program will prompt for the following header information:

CONTRACT NUMBER -->

LEVEL RUN BOOK NUMBER -->

MD/US RT NUMBER -->

TERMINI -->

PARTY CHIEF -->

Fill in with the appropriate data and press Enter.

4. THE MAIN MENU

This is the main menu screen:

```
64444444444444444444444444444447
5  ADD TO CROSS-SECTION FILE   5
5  LIST STATIONS COMPLETED     5
5  NOTE                        5
5  VIEW CROSS-SECTION FILE     5
5  END PROGRAM                 5
94444444444444444444444444444448
```

Choose one of the above and press Enter.

ADD TO CROSS-SECTION FILE

The first prompt will be:

```
6444444444444444444444444444444444444447
5            NEW BASELINE?  N          5
9444444444444444444444444444444444444448
```

Enter Y at the beginning and whenever you change to a different baseline. If you are continuing on the same baseline, just press Enter. If you entered Y for Yes, you will have to fill in the following information:

DESCRIPTION OF AREA OR SPUR TO SECTION -->

Ex. - MAINLINE STA 1+00 TO 12+50

STATION -->

Ex. - Enter 100 or 1+00 for station one.

ELEVATION OF INSTRUMENT? -->

Note: Enter the TRUE elevation of the level.

NOTE -->

Add any note if desired that relates to the entire section.

Ex. BI-SECTED ANGLE FOR DRIVEWAY (SKEW).

The next prompt will be for the direction of the cross-section. The four choices are:

B or C - Baseline/Centerline - Automatically inserts 0.00 for offset distance.

L - Left - Shots to the left of the baseline.

R - Right - Shots to the right of the baseline.

Q or E - Quit - Ends the section and returns you to the Main Menu.

Use the default direction or key in the desired direction. If the direction is B the distance will default to 0.00. Otherwise key in the distance. Next key in the feature code if desired.

5. HELPFUL HINTS

a. Always go from the baseline out to the limit of the section in order. DO NOT REPEAT THE BASELINE SHOT.

b. To continue to the next section, select ADD TO CROSS-SECTION FILE

c. If you need to get an oddball plus like a drop inlet, enter it like a new station. Enter R or L, Rod Reading, and Feature Code and then Q. If you miss entering a distance or rod, you will be prompted VOID? Key-in Y and then press ENTER. You may now correct the mistake.

d. If you wish to void the shot, enter VOID for the feature name and the shot will not be written to the file.

<u>IMPORTANT NOTE</u>: If you read a PLUS rod, you must enter either a minus (-) or a plus (+) sign when recording the rod reading! The shot will then be added to the elevation of the instrument to get the elevation of the point in question.

The other prompts in the Main Menu are self-explanatory.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-04 DATA COLLECTION SURVEYS

Revised 11/01

A. GENERAL

Data collection surveys are performed using an electronic total station in conjunction with an electronic field data collector. The data collector is a DOS based ruggedized hand held computer capable of storing data received directly from the total station.

Although data collection systems can be used in any type of survey, they are particularly well suited for topographic surveys. A survey party can capture the X,Y,Z (northing, easting, elevation) positions of a far greater number of points (300 to 600 per day) than could be taken by using conventional techniques. The great majority of the division's topographic surveys are now performed with the data collector.

The system's software permits the surveyor to identify each topographic feature by a feature code, figure number (for linear or curved features) and point number that will be plotted by CADD in the resultant 3D design file. Valid feature codes have been established by SHA. These codes are available to each survey party on weather resistant "flip" cards and are not detailed in this manual.

For configuration, DOS commands and operation of the Paravant Data Collector itself, see Chapter 2-08 PARAVANT DATA COLLECTOR.

B. SETUP PROCEDURES

1. Setup all traverse lines, baselines or centerlines. These must be tied to the Maryland State Grid System, unless instructed otherwise. (See Chapter 6, Section 6-01 for instruction on traversing and using the TRAVERSE program)

2. Determine elevations for all control points to be utilized for data collection surveys using the procedures for differential leveling. (See Chapter 5, Section 5-03)

3. Each traverse point is to be numbered with a number in the range of 1-300. Do <u>NOT</u> re-number existing CADD points. When entering these points in the ETSC program, only enter the number.

C. ETSC PROGRAM

1. Start-up

   To start the ETSC program, key-in ETSC at the B:> prompt.

   Ex. B:> ETSC

   This will bring up the Main ETSC menu shown below:

```
+))))))))))))))))))))))))))))))))))))))))))))),
*  64444444444444444444444444444444444444447  *
*  5                                       5  *
*  5          ETSC Version   _.__          5  *
*  5                                       5  *
*  5   Copyright (C) MapVision Systems     5  *
*  5   64444444444444444444444444444447    5  *
*  5   5  File Management              5    5  *
*  5   5  Select Instrument            5    5  *
*  5   5  Link Radio Modems            5    5  *
*  5   5  Create New Job File          5    5  *
*  5   5  Use Existing Job File        5    5  *
*  9444<  Quit                         :44448  *
*      5                               5      *
*      94444444444444444444444444444448       *
*                                             *
.)))))))))))))))))))))))))))))))))))))))))))))-
```

2. Selecting the instrument - In order for the program to operate correctly with the total station, the correct instrument must be selected.

   a. To select the instrument that will be used in conjunction with the Data Collector, use the Down arrow to highlight "Select Instrument" on the Main menu and press ENTER.

   b. Another screen will then appear showing the various instruments that the Paravant Collector supports. Select the appropriate make of instrument and press ENTER. Depending upon the instrument selected, you may have to make another selection to specify a certain model of instrument. When the selection has been made, the Collector will return to the Main menu.

Note: You should use the "Select Instrument" command each morning when you start a new file, when you change instruments or reboot the Collector.

3. To Start a New Job

a. From the main menu, use the down arrow to highlight "Create New Job File" and press ENTER. You will be prompted for a raw data file name.

b. Naming Work Files
Work files should be named in accordance with the following naming convention.

```
Topography      T _ _ _ 1 1 1 8
                1 2 3 4 5 6 7 8
```

First character should be a "T" to designate that file for topography. Second, third and fourth characters should be used to describe the route number, maintenance shop or type of project that you are working on. Fifth, sixth, seventh and eight characters should be used to describe the date of your work.

```
Bridge Survey  B _ _ _ 1 1 1 8
          1 2 3 4 5 6 7 8
```

When locating a bridge deck or any elevated surface a "B" should be used to designate that file as a Bridge file. The following characters should use the same criteria described above.

Key-in the appropriate filename and press enter.

Ex. T7950822

You will then be prompted for a Back-Up Raw Data filename. The default (what is showing) should be correct, so just press Enter. This will automatically back-up your work on drive A: (the RamCard). Every shot and command will be automatically backed-up as they are entered, in the event that a problem occurs on the B: drive. However, you still need to make 2 back-up copies on the 3-½" floppy disks.

When you are working on the same Data Collection job as another Survey Party, contact the other Party Chief to make sure that you are not duplicating filenames.

Ex. You are sent to help Bob Price collect data on I-795 (the Northwest Expressway) on November 18th. You may change the second, third and fourth spaces in the filename but the current date must remain correct.

T7951118 - Bob Price is using this filename.

TNWX1118 - This would be an alternate filename that could be used.

After entering the filename, the command collection menu will be displayed.

```
6444444444444444444444444444444447
5                                5
5    Command                     5
5    Measurement                 5
5    Note                        5
5    Review File                 5
5    List commands               5
5    Quit                        5
5                                5
9444444444444444444444444444444448
```

c. Enter the Job Location

1) At the Command Menu, select "Command" and press Enter.

2) Enter "1" for command number.

3) Enter "1" for job number.

4) Enter "2" for job/crew number.

5) Enter route number for highway.

Ex. MD355

d. Enter the user-id and date.

1) Select "Command" and enter "20".

2) Press ENTER when prompted for the time.

3) Enter your initials for user name.

4) Enter the current weather.

5) Enter the current date.

Ex. 08/22/91

You will then return to the Command Menu. Now proceed to Set-Up Information section of this manual.

4. To append to an existing job

   From the Main Menu, use the Down arrow to highlight "Use Existing Job File" and press ENTER. Enter a Raw Data File name or press ENTER to use the default. This will bring you to the Command Menu. Now proceed to the Set-Up Information section of this manual.

5. Set-up Information (C7) - Several codes must be used to store information for each instrument set-up. The first is for the occupied point.

   a. Select "Command", enter "7".

   b. Enter the occupied point number, the height of the instrument, ant the measurement mode (01)

   c. Press ENTER for instrument I.D.

6. Rod height information (C5)

   a. General - Be sure to measure the prism heights with a chain or folding rule as graduations on prism poles may be in error.

   b. Select "Command", enter "5".

   c. Enter the foresight and backsight target prism heights.

7. Backsight information (C12)

   a. Select "command", enter"12".

   b. Enter the backsight point number.

8. Taking a backsight

   a. Turn on the total station, sight the backsight prism, and set zero.

   b. Select "Measurement".

   c. Select "Collect Angles and Distance". "Waiting For Data..." will appear on the screen.

   d. After the shot has been recorded, you may enter a description if desired. A description can contain up to 29 characters.

9. The Feature Code List - While collecting topo with the Data Collector, you are required to enter Feature Codes. These are abbreviations used to define a specific feature or type of shot. The original program has been enhanced so that it is possible to review all the Feature Codes that are used. This works as follows:

   Assume you are using a Code 14 (Linear Feature Code). Key-in 14 and press Enter. The next prompt is for the Feature Code. If you know the correct Feature Code, just key it in. Remember to use CAPITAL LETTERS.

   If you do not know the proper code to use, Enter an "X". This will bring up on the right side of the screen the Feature Code list. Down arrow to select the appropriate code and press Enter. The program will automatically store your choice and go to the next prompt. You may use the combination of the Shift and 3 keys to Page Down the list or the combination of the Shift and 9 keys to Page Up in the list.

   The office processing requires that only CAPITAL letters be used for Feature Codes. The ETSC program will automatically set the CAPS LOCK "on" when it initiated. However, if you "time out" or use the FUNC and POWER keys to temporarily shutdown the collector (for lunch), YOU MUST TURN THE CAPS LOCK ON AFTER RESTARTING.

10. Collecting Single Point Topography (C13) - Fire hydrants, utility poles, mailboxes, spot grades, phone booths, light poles, water valves, water meters, manholes, etc. are single point features.

    a. Select "Command", enter "13"

    b. Enter the feature code and the starting point number.

    c. Select "Measurement".

    f. Select "Collect Angles and Distance". "Waiting For Data..." will appear on the screen.

    g. After the shot has been recorded, you may enter a description if desired. A description can contain up to 29 characters.

       You may collect as many point shots as needed by pressing ENTER at the Measurement Command. To change to a different topographical code, you must select "Command" and enter a new command code.

11. Collecting Linear Topography (C14) - This code is used to locate straight line strings. Examples of these would be edge of paved road, top of ditch, bottom of ditch, headwalls, etc.

    a. Select "Command", enter "14".

    b. Enter the feature code, figure number, and starting point number.

    c. Select "Measurement" and shoot the points that make up the line string.

12. Shooting an Arc in Linear Topography (C15) - One may insert an arc in a line string at any time. This should be limited to curves with radii of less than 60 meters (200 ft.). This cannot be done while collecting single point features (C13) or curvilinear features (C16).

    a. Shoot the P.C. of the arc.

    b. Select "Command", enter "15".

    d. Shoot the mid point of the arc.

    e. Shoot the P.T.

    f. Continue collecting the line string.

    It is possible to collect a perfectly round object such as a swimming pool using the C14 and C15 codes. Proceed as follows:

    a. Enter C14, feature code, figure number and starting point number.

    b. Shoot the first point.

    c. Enter C15.

    d. Take a shot 1/4 of the way around the object.

    e. Take a shot 1/2 of the way around the object.

    f. Enter C15.

    g. Take a shot 3/4 of the way around the object.

h. Enter C17 and recover the starting point.

13. Collecting Curvilinear Topography (C16) - This code is used to locate curved line strings with radii of 60 meters (200 ft.) or more. Examples of these would be edge of paved road, edge of paved shoulder, etc.

    a. Select "Command", enter "16".

    b. Enter the feature code, figure number and starting point number.

    c. Select "Measurement" and shoot the points that make up the curve string.

14. Recovery Shot (C17) - Once a point has been shot, the point can be used again in either a linear or curvilinear feature. This is useful for connecting different line strings together, such as connecting the bottom of a ditch to a pipe invert shot that was already collected, or "closing" a closed figure such as a building or headwall.

    a. Select "command", enter "17"

    b. Enter the number of the point to recover.

    c. Example 1:

```
50                           600          603
⊛                             x            x
 \                           *            *
  \                FIGURE 10 *            * FIGURE 11
   \                         *            *
    \                        * 601        * 602
     \                       x            x
      \                       \            \
       \                       \  ROADWAY   \
        \                       \            \
         \                       \            \ 654
          \                 651   x            x
           \                      *            *
            \                     *            *
             \             FIG.12 *            *FIG.13
              ⊛                    *            *
             51             652   *      653   *
                                   x            x
```

Assume you have previously occupied Pt. 50 and located Pts. 600 through 603. You are now occupying Pt. 51 and you want to locate the road and connect the figures together.

1) Select "Command", enter "14".

2) Enter "EPR" feature, "12" for the figure number, "651" for the starting point number.

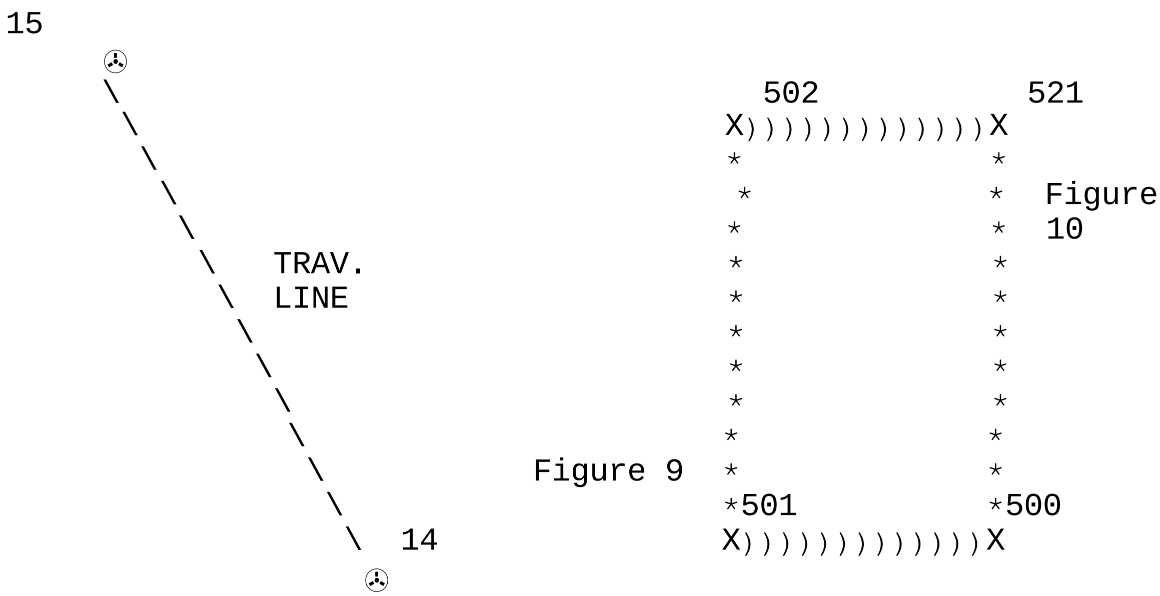
3) Select "Command", enter "17".

4) Enter "601" for point to recover.

5) Select "Measurement" and record shots 651 and 652.

6) Repeat the procedure for figure 13.

e. Example 2:



Assume you have previously occupied Pt. 14 and located Points 500, 501 and 502 using the linear feature command (Code 14).

Now, you are occupying Point 15, and want to locate the last building corner and connect the back line between 521 and 500.

1) Select "Command", enter "14"

2) Enter "BLDG" feature, Figure "10", Starting Point "521"

3) Select "Command, enter "17".
Enter "502" for point to recover.

4) Select "Measurement" and Record shot 521.

5) Select "Command, enter "17". Enter "500" for point to recover.

15. Offset measurements (C6) - Use the offset command to add to distance, perpendicular offset left or right, or to add or subtract to the prism height for the desired shot. This command must **NOT** be issued until you are ready to take the Measurement.

a. Select "Command", enter "6".

b. Enter the additive distance or press ENTER for 0.

c. Enter the left/right offset distance or press ENTER for 0. Note - a negative value is used when the object to be located is to the left of the line of sight from the instrument to the pole.

d. Enter the target height offset or press ENTER for 0. Note - a negative value reduces the height of target, adding to the elevation of the shot.

This code affects the next shot only. Therefore, if you have to offset several shots in a row, you must leave the Collect Angles and Distance prompt and re-enter the Code 6 command each time.

16. Start dual feature (C32) - Use this collection code to collect two features at the same time. The two features do not have to start and end at the same points. This code may be used any time while collecting linear (C14) and curvilinear (C16) features. (see example below)

a. Select "Command", enter 32.

b. Enter the second feature name.

c. Enter the figure number.

d. Take the shots that make up the dual features.

17. End dual feature (C33) - Use this code to stop collecting the second feature started under the C32 code. This code is not needed if both features end in the same place.

a. Select "Command", enter 33. Collection of the second feature stops. Continue collecting the first feature. In the following example, the rodman was collecting a ditch in an open area and came upon a small wooded section. After collecting both the top of ditch and woods for three shots, the woods ended and he continued collecting the top of ditch.

Example:

```
C14 TD 5 551
M 23.2334 89.5530 236.995
M 25.2110 89.5600 285.000
C32 WOOD 6
M 26.4432 89.5930 334.395
M 28.1023 89.5244 385.330
M 30.5643 90.0003 434.955
C33
M 31.0434 90.0122 486.675
C13 SG 557
```

18. Parallel figure (C34) - This command can be used to parallel a feature already collected. No point numbers are made for the offset figure, and the end of the paralleled figure cannot be recovered in the field.

    a. Select "Command", enter 34.

    b. Key in the new feature name.

    c. Key in the old figure number to be paralleled.

    d. Key in the horizontal offset.

    e. Key in the vertical offset.

    Example:

```
C14 BC 22 423
M 10.5233 90.0231 305.440
M 11.2345 90.0157 354.123
M 12.3144 90.0155 403.564
C15
M 14.3121 90.0148 410.655
C34 TC 22 -0.67 0.67
C34 SDWK 22 -5.00 0.77
```

19. Collecting directional linestrings - Currently two features are directional: WOOD and TRB. For the WOOD feature, locate the edge of the woods with the woods to the right of the direction of collection. For the TRB feature, locate the face of the traffic barrier with the posts to the right of the direction of collection. If these features are collected in the opposite direction, use a C35 code at the end of the feature to reverse them during processing.

20. Spin text (C36) - The text that will be placed into the design file can be spun from north to be parallel to the

roadway using this code. It should be entered to the nearest degree clockwise from north.

21. Locate point (C37) - This code can be used to locate a point from 2 previously shot points in the same figure or feature. It is well suited for collecting building corners. To use:

    a. Shoot the first and second building corners in the usual manner. This shots should be taken carefully as the rest of the building will be based on these shots. DO NOT use a short section of wall.

    b. Enter C37.

    c. Enter the clockwise angle backsighting the first shot and turning at the second shot.

    d. Enter the horizontal distance to the third corner on the building.

    e. Enter the elevation difference between the second shot and the third shot.

    f. Continue around the building in like manner and recover to the first shot to close the figure.

    The data should look something like this:

```
C14 BLDG 1 1001
M 23.4430 89.5850 123.450
M 25.3644 89.5945 132.360
C37 90 28.0 -0.2
C37 90 26.0 0.0
C17 1001
```

20. Adding notes to the field file - The program provides two methods for entering notes into the file.

    a. Shot description - Each measurement provides the user an opportunity to add a description or note for the point shot. A maximum of 29 characters is allowed. The user should not precede the note with asterisks as the program will add them automatically. Note the following examples:

        G+E 123456 / C+P 69

        24 INCH TWIN MAPLE

        2.7 CONC. CURB + GUTTER

b. General note - The user can enter a note (up to 80 characters) by using the note feature from the main menu. This method is best suited for describing a series of shots. Examples:

ALL TREES ARE 6 INCH CEDARS

VOID PREVIOUS FIGURE

VOID PREVIOUS SHOT

8-INCH CONCRETE CURB AND GUTTER

21. Reviewing the File - Select "Review File". "Positioning to End of File" will briefly appear and the last 14 lines of the work file will appear on the screen. Use the Up arrow to scroll through the file to view previously entered data. Press ENTER or ESC when finished and you will return to the Collection Menu.

    Note: You will not be able to change any data in your work file. However, you may insert a note at any time to bring an error in the file to the attention of the office processors.

22. Listing Commands - One can review the command codes and the associated data fields with this command.

23. Quitting the collection menu - Select Quit. This will return one to the main menu.

24. File Management - From the main menu, select "File Management" to bring up the File Management Menu.

```
6444444444444444444444444444447
5                             5
5  List Files                 5
5  Delete File                5
5  Copy File                  5
5  Serial Print ASCII File    5
5  Parallel Print ASCII File  5
5  View ASCII File            5
5  Transfer Files             5
5  Quit                       5
5                             5
9444444444444444444444444444448
```

a. Listing Files - From the File Management menu select "List Files". Select the drive you wish to list.

Enter the file name search string:

A:*.* - To see a listing of the A: drive.
B:*.* - To see a listing of the B: drive.
C:*.* - To see a listing of the C: drive.
D:*.* - To see a listing of the D: drive. Note - the disk drive must be hooked up and a floppy inserted beforehand.

b. Deleting files

1) Select "Delete File"

2) Enter the search string as shown above.

3) Select the file to be deleted.

NOTE: IF YOU DELETE A FILE IT IS GONE FOREVER! Avoid deleting files before the job has been processed in the office.

c. Copying Files

1) Select "Copy File"

2) Enter the search string.

3) Select the file to be copied.

4) Enter the drive to send it to.

d. Printing

1) Select "Serial Print ASCII File"

2) Enter the search string.

3) Select the file to be printed.

d. Quitting the ETSC program - Select Quit from the main menu. This will return one to the B:> prompt.

D. SHUTTING DOWN THE COLLECTOR

While the Paravant RHC44 can be stopped while in a program, it is advisable to exit the program to the B:> prompt before shutting the collector down for periods longer than 20 Minutes.

Press the FUNCT and POWER keys at the same time. To start up again, press the FUNCT and POWER keys again. It may be necessary to press the CAPS key to get capitol letters.

E. TIPS FOR COLLECTING VARIOUS FEATURES

1. When locating manholes, shoot the top of the manhole while in the manhole feature. Shoot the pipe inverts separately as line strings. For circular concrete (RCP) and circular metal pipes (CMP), use the appropriate feature. Ex: 24INCMP is a 24 inch Circular Metal Pipe.

2. Locate all headwalls by shooting around the perimeter of the headwall at grade. Then obtain one (1) shot on the top of the headwall using the THDWL feature code. If the headwall has wingwalls that slope, get a shot on the top of the headwall in the center and get shots on the top of the wingwalls where they end, again using the THDWL feature code.

3. Locating directional linestring features

   The WOOD and TRB features are directional and should be collected with the object to the right of the direction of collection. If you want to collect it in reverse order, collect the linestring and enter a C35 code at the end to reverse the order of shots when processed.

4. When you are locating a figure and change from a "Code 14" (linear figure) to a "Code 16" (curvilinear figure) or vice-versa, you must increment the figure number! If you want the line work to connect between the two figures use the recover shot command "Code 17".

5. "Target" prism holders should be used for all shots taken with the telescopic range poles allowing for more precise centering of the prism. Make sure that the prism is tilted, if need be, to keep it perpendicular to the line of sight of the theodolite. Failure to tilt the prism will result in elevation errors!

6. Use Code 13 and feature code CKSHOT to "reshoot" the backsight. When each checkshot is taken and before each set-up is broken, the slope distance, vertical angle and horizontal angle must be recorded on the recovery sheets. This information will be reduced using the TOPO program in the Sharp calculator, allowing the Party Chief to determine if the prism may have slipped, if the lower tangent screw on the theodolite has been moved, or if there have been any other sighting errors. If this information is not recorded from the instrument display, it may be obtained from the Data Collector.

7. All tribrachs must be checked periodically and all instruments must be checked at NGS ranges at least every 6 months. Elevation checks should be included with the normal distance calibration. Forms for recording these observations may be obtained from the office.

8. When working on projects that require surveying a bridge, all elevated surface bridge shots must be gathered and stored in a separate file. Elevated surface shots mean shots on the inside of the bridge/roadway joints.

9. At the end of each day's collecting, your work file must be printed. See procedures on how to do this. Scan the file for errors and make hand-written notes of any errors that need correcting before processing.

10. Work files must be backed up daily. Make 2 copies of the file on the 3 1/2" floppy disks. One copy will be returned to the office when the job is completed. The other copy is to be kept by the Party Chief. See procedures on how to do this.

11. Do not use a feature code unless it appears on the list. If you cannot find a code to describe a particular feature, use the MISC feature code accompanied with a Note.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-05 SURVEYING FOR RIGHTS-OF-WAY

Revised 11/01

A. GENERAL

The Division performs land surveys that are an integral part of land acquisition for operating Rights-of-Way for transportation facilities. These surveys allow:

1. Retracement of property lines (Metes and Bounds Surveys)
2. Appraisal of property to be acquired
3. Deed preparation
4. Negotiation or Condemnation actions
5. Right-of-Way staking and monumentation

B. METES AND BOUNDS SURVEYS

Metes and bounds surveys are required by law to be performed on properties that will, in whole or in part, be acquired for public transportation facilities.

1. Scope

   Survey of all properties in their entirety, unless otherwise directed, shall be made for the correct preparation of metes and bounds plats for all such properties. These surveys shall be tied to centerline, baseline of right of way, or control traverse lines.

2. Specifications

   All Metes and Bounds surveys shall conform to American Land Title (ALTA) specification for class "A" surveys.

3. Monument Recovery

   a. Using the mosaic and deed information as guides, THOROUGHLY search for all property corners on the affected properties. If one deed calls for a stone and the adjacent deed calls for a pipe at the same corner, search for both points. EVERY EFFORT MUST BE MADE TO RECOVER ALL EXISTING MONUMENTATION.

b. Examine monuments carefully to determine if they have been disturbed or damaged.

c. If no monument is found for a corner, locate existing evidence such as fence lines, hedge rows, walls, etc. using the ETSC program.

d. Evidence presented by property owner should be located even though deed may state otherwise and name of identifier recorded. The property owner usually is your best source of information.

4. Point numbering

Point numbers from 1-300 shall be used for all traverse points that are not property markers. Point numbers from 301-999 are to be used for property monumentation only. Point numbers from 1001 + shall be used for data collection only. DO NOT DUPLICATE POINT NUMBERS used by other traverses or monuments on the same job! Point numbering need not be sequential.

5. Traversing

a. Unless otherwise directed, use the TRAVERSE program for all traversing, side shots and general notes. Do not set rebars or reference traverse points of metes and bounds traverses. Draw any traverse lines run and points set on the mosaic which is to be sent to the office for processing.

b. When possible, locate corners from existing control traverse points. POL's may be set to accomplish this task. Avoid getting a "fly from a fly" point to locate monumentation.

c. If necessary, traverse around the property or properties and locate all recovered monumentation or evidence of possession. When feasible, utilize the existing monumentation as traverse points.

d. Measure angles to monumentation at the same time that angles to traverse points are observed. This is easily accomplished using the "direction method".

e. Distance measurements to monuments are to be conducted the same way as measurements to main traverse points.

f. Prism poles with bipods should be utilized to assure accurate results.

6. Topography

Any topography required shall be collected using standard data collection procedures with the ETSC program. Start with point number 1001 unless otherwise directed.

7. Notekeeping

a. Sketch traverse and property lines on the mosaic. All other information such as angles, distances, coordinates, monument descriptions, etc. shall be noted in the .TRA file using the TRAVERSE program (Use the Text routine and the Note routine if necessary.)

b. Note the size, shape, material, position and condition of each found monument (1/2" Iron pipe, rebar, concrete monument, leaning, chipped, bent, projecting, flush, buried, etc.). If the monument is leaning, note the direction and amount.

Enter text in the following order: WHAT, WHERE, DETAILS. Example: Conc. Mon., NW Cor. P. 235, Flush. or PIPE, SE Cor. P. 331, 1-1/2 DIA. PROJ. 1.5 FT. LEANING SLIGHTLY SW LSC #447.

c. Utility companies often disturb property monuments during utility construction. Indicate if any utility lines or poles are near the monument. Do not locate utilities unless directed.

d. Note the company name and license number stamped on the monument if any.

e. If the monument was not found, write "N/F" on the mosaic.

C. RIGHT-OF-WAY, BPR AND CONDEMNATION STAKEOUTS

1. General

After metes and bounds surveys have been performed and right-of-way plats generated, the Division's next step in the land acquisition process is the R/W Stakeout. R/W Stakeouts are required on all "Takes" and are used by the Office of Real Estate for appraisal. Use the TSC stakeout program when feasible.

2. Staking

Unless specified otherwise in the survey request, use the following guidelines:

a. All PC's PT's and breaks in right of way lines, lines of division, and easement lines shall be staked with hubs and tacks or PK nails as appropriate.

b. Guard stakes or wire flags shall denote the station and offset of each point. For PK nails in pavement, the station and offset shall be painted.

c. All lines shall be delineated by staking with flat stakes at 50 ft. intervals in urban areas and approximately 100 ft. intervals in rural areas.

d. All stakes shall be flagged or wire flags set with the following color coding:

   1) Red shall be used for right-of-way and existing right-of-way points.

   2) Blue shall be used on lines of division.

   3) Yellow shall be used for easement lines.

   Stakes can be flagged with more than one color if appropriate.

3. Notekeeping

   a. Show the base line of right-of-way, all existing and proposed right-of-way lines, lines of division and easement lines as shown on the plat.

   b. For each right-of-way point set, note the station, offset and type of point set.

   c. Note the plat number(s) used.

   d. Note the contract number, route number, plats used, staking limits, party chief name and date in the index.

   See Figure 6-05-B series for sample notes.

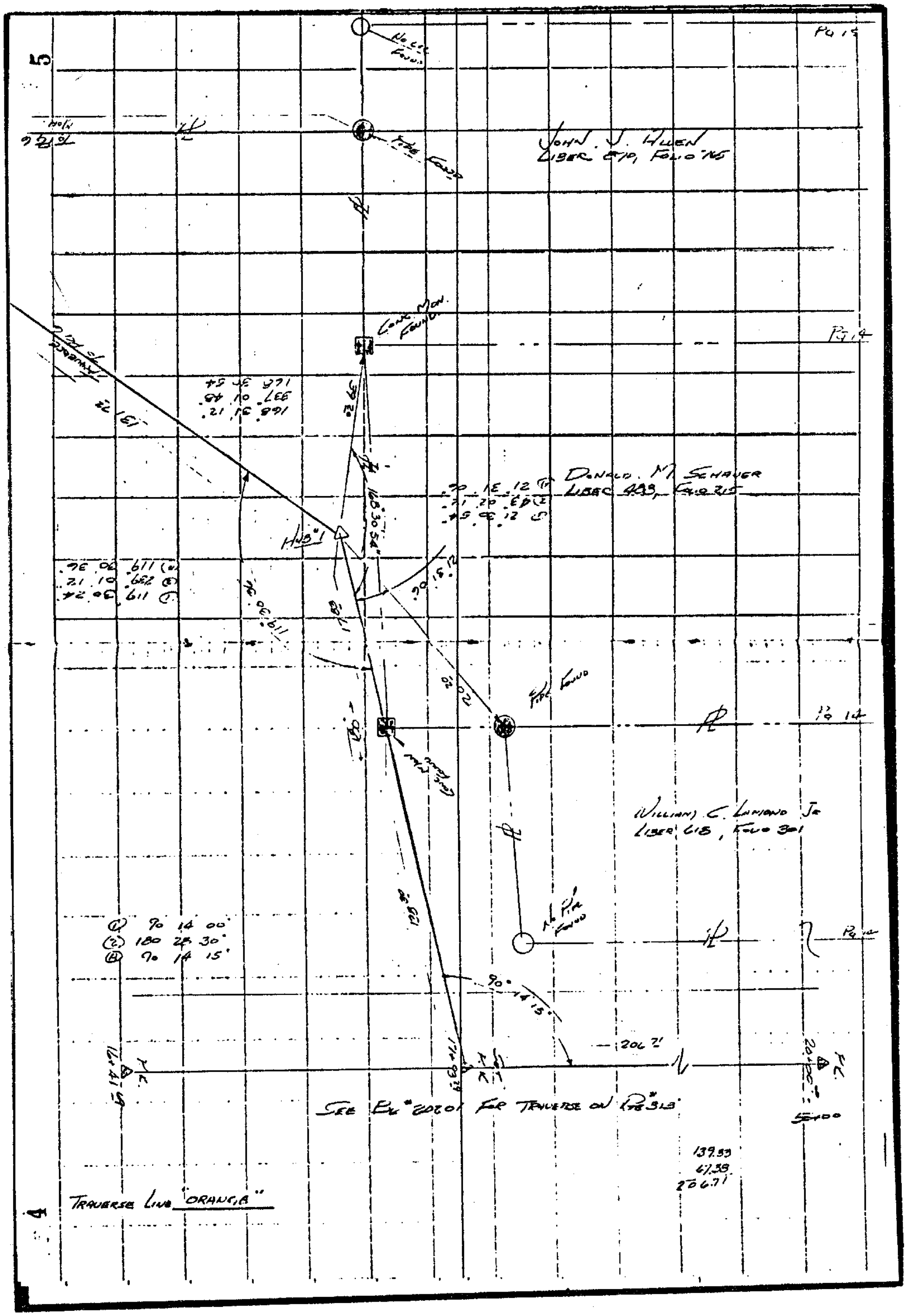


FIGURE 6-05-A(1) SAMPLE METES AND BOUNDS NOTES

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-06 GLOBAL POSITIONING SYSTEM (GPS) SURVEYS

Revised 11/01

A. GENERAL

The Global Positioning System is based on a constellation of satellites called NAVSTAR. NAVSTAR was developed by the Department of Defense for military navigational purposes. Now fully operational, there are 18 satellites (plus 3 spares) in orbit at an altitude of 10,900 miles. This number ensures that four or five of them are within range of any ground station. This coverage ensures that precise (0.01 m) Y, X and Z coordinates can be determined for the ground station after a short observation period.

B. BASIC PRINCIPLES OF GPS

The basic principles behind GPS can be broken down into five conceptual pieces.

1. General - Position is calculated from distance measurements to satellites. Mathematically, five measurements are needed to determine exact position.

2. Measuring the Distance from a Satellite - The distance to a satellite is determined by measuring how long a radio signal takes to reach a receiver from that satellite. Assume that both the satellite and the receiver are generating the same pseudo-random code at exactly the same time. We know how long it took for the satellite's signal to get to us by comparing how late its pseudo-random code is, compared to the receiver code.

3. Getting Perfect Timing - Accurate timing is the key to measuring distances to satellites. Satellites are accurate because they have atomic clocks on board. Receiver clock errors can be canceled by making measurements to a fourth satellite.

4. Knowing Where a Satellite is in Space - To calculate position one not only needs distance, but one also needs to know where the satellites are in space. GPS Satellites are so high up their orbits are very predictable. Minor variations in orbits are measured constantly by the Department of Defense and that data is transmitted from the satellites themselves.

5. Ionospheric and Atmospheric Delays - The earth's ionosphere and atmosphere cause delays in the GPS signal that can translate into errors in position. Some of these errors can be eliminated with mathematics and modeling. Other sources of error are satellite clocks, receivers, and multipath reception. Some configurations of satellites in the sky can magnify the other errors in the system.

C. FIELD PROCEDURES

1. Reconnaissance for a GPS Survey - Reconnaissance is one of the most important parts of a GPS survey. For the actual collection of GPS data, the observing station must have a clear view of the sky when satellites are passing over the job site.

   Steps involved in a typical GPS reconnaissance include:

   a. Mark the general area where GPS control points are to be located on maps or aerial photographs.

   b. Visit the job site and select the best location for the control point.

   c. Using a "Station Visibility Diagram," locate and record all obstructions exceeding 20 degrees above the horizon, as well as any radio frequency (RF) sources. Ideal tools for this are a compass and an Abney level.

   d. Using the station visibility diagrams and a skyplot of visible satellites at the time the GPS survey is to take place, the proper observing session can be planned for each station.

2. Operation of GPS Equipment - The Division has 2 Trimble Model 4000 SST - Dual Frequency receivers, 1 Trimble Model 4000 ST receiver and 1 Trimble Model 4000 SSE - Single Frequency receiver. The basic operating procedures for this equipment is as follows:

   a. Equipment Checklist - Use of the following checklist will assure that you will not lose a session due to forgetting equipment.

      Safety Equipment (signs, cones, etc.)
      Receiver
      Antenna
      Antenna cable
      Battery
      Battery to receiver cables
      Backup battery or a cigarette lighter adapter

Tripod
Tribrach
Clutch (tribrach adapter)
Measuring tape
Station info (tie sheets, maps)
Pencil and paper (station log sheets)
2-way radios
Survey schedule
Flagging/paint/pk nails/hammer
RS-232 cable
Laptop computer
Office support module
A/C transformer plug for office support module
Extra floppy disks
Dongle (software key)
Compass

b. Tribrach - Tribrachs are the weakest link in the quest for quality measurements. If either The Bull's Eye Level or optical plummet is out of adjustment the receiver will not be positioned over the station. The bubble and the optical plummet must be checked on a regular basis. See Section 2-05 for adjustment procedures for the optical plummet.

c. Tripod Setup - GPS signals can be affected by the objects around an antenna. People walking around the tripod can affect or block these signals. Therefore, a tall set up is recommended. Also, make sure your setup is stable.

d. Tribrach Leveling - Set up the tripod over the station and mount the tribrach. Use the leveling screws to position the optical plummet crosshairs on the station point. Level the tribrach bubble by adjusting the tripod legs. Fine tune the level bubble with the leveling screws. Check the plummet, the crosshairs should be very close to the mark. If an adjustment still needs to be made, loosen the tribrach and carefully slide it into the correct position. Then recheck the level bubble.

e. Measuring the Antenna Height - ALWAYS measure the antenna height and record it on a station log. Without the antenna height a GPS survey cannot produce an accurate vector. Measure the antenna height twice, before and after each session. You need to keep track of the uncorrected (raw) antenna height. When the height is written in the station log, the field crew should specify the uncorrected value and label it clearly. Always record the type of antenna is being used for each receiver.

f. Measuring the Antenna Height of a Thimble 4000 SST - On the Bottom of the receiver, built into the plastic base, is a tape measure. Pull the tape down to the mark. Read the centimeter (cm) scale of the tape measure at the very bottom edge of the receiver base. Convert the centimeter reading to meters. To convert centimeters to meters move the decimal point two places to the left. Write this number down in your field notes and label it "RAW ANTENNA HEIGHT IN METERS, SLOPE ST."

   The display will indicate which type of units to input for the antenna height. On the right side of the display will be a menu item that says "UNITS". Push this button until the units displayed change to "METERS". Input the value you just measured as meters. You should be entering a value between 1.000 meters and 2.000 meters.

   After you input the value, press the "UNITS" button until the units displayed are inches. Remeasure the height using the pull out tape on the bottom of the receiver. Read the tape again at the bottom edge of the receiver in inches. Write the inches reading down in your field notes and label it "RAW ANTENNA HEIGHT CHECK IN INCHES, SLOPE ST.". Compare the inches value that the receiver calculated, which should be displayed on the screen, to the value you measured. If the difference between the two is more than a tenth of an inch, re-start the measuring process. If the numbers are close, accept the value and continue.

g. Measuring the Antenna Height of a Trimble 4000 SST - Get out the measuring rod and screw together the links. In your field notes draw a picture of the top of the antenna. Include the north arrow in the drawing. Go to the North side of the antenna. Put the pointed end of the rod onto the center of the mark. Choose the notch closest to North that you can measure without the tripod legs getting in the way. Look and see what the notch number is that you are about to measure. Write this number down on your drawing in the same place it is on the antenna. Measure to the top edge and outside corner of the notch you picked. Write this number down in your field notes. Next to the antenna height write "RAW SLOPE ANTENNA HEIGHT NOTCH

#___". In the blanks you would insert the notch number you used.

Clockwise from your first measurement go exactly a third of the way around the antenna ground plane. Again look to see what notch you will be using and record it on your drawing. Measure the antenna height and record it just like before. Go clockwise a third again around the ground plane and measure the antenna height. You should end up with three raw measurements, these measurements should agree within 1cm. If they don't agree, restart the measurement process. If they still don't agree try re-leveling the tribrach.

Once the measurements agree, add them up and divide by three. This will give you an average measurement. In your field notes next to the average value write "AVERAGED RAW ANTENNA HEIGHT, SLOPE GEODETIC". Then input this value into the receiver and hit the ACCEPT menu selection. Remember, the rod scaled is in centimeters and the receiver expects meters. To convert to meters move the decimal two places to the left. The values you should be entering will between 1.500 meters and 2.500 meters.

h. Vehicles Near the Antenna - Park the truck at least 50 feet from the antenna or downhill from it. Signals can be affected by flat surfaces close to the antenna.

i. Receiver Start Up - You should turn the receiver on about 5 minutes before your planned start time. The receiver needs time to warm up its oscillator and collecting a few minutes of data early is not detrimental. However, avoid turning the receiver on too early, unless you are sure that there is enough receiver memory and battery power to handle that extra time. Record your start time in the station log.

j. Starting a Receiver After the Scheduled Startup Time - Getting to a point late may make a session worthless. The loss of too much simultaneous data could be so degrading that a solution may not be found. If the session is shortened by more than ten percent, lengthen the observation time. A receiver operator should tell their supervisor when they first start collecting data. The supervisor can then extend the stop time as necessary. However, if several sessions are back to back, any time changes will affect the sessions thereafter.

k. Field Notes and Station Log Sheets - You should keep a log of each session at each station. The receiver should be checked every 15 minutes with comments written in the station log. Things to record in the log include, start and stop times, visible satellites, obstructions, transmitters, elevation angles, etc. Anything that could affect a radio signal should be written down. The field crew should copy letter for letter the disk stamping onto the log. This helps prevent mix ups later, like which one did you really occupy, the station or the azimuth mark.

l. Power Failures During a Session - A power failure becomes catastrophic if the battery goes dead and the field crew doesn't check the receiver for an hour. The only way to correct a problem is to realize you have one. Check the receiver on a regular basis (every 15 minutes). Keep the batteries out of the sun and carry a spare one. If you do have a power failure don't panic. Get the power back on to the receiver as soon as possible. Try another battery or connect to an A/C power source (if available) using the office support module. If the receiver was stopped for more than ten percent of the session, extend the observation time. Record the times of a power outage in the station log. When a power failure has occurred, a second file is opened once power is restored. Thus, you will end up with two data files for one session. When you download these files from the receiver to your computer, the data collected before the power failure has the usual file name extension of .DAT. However, the data collected after the failure will have the file extension .DO1. You will need to join these two files using DOS commands. See the Trimvec-Plus manual chapter 2, pages 5 and 6.

m. Adverse Weather Conditions Affecting a Session - Use common sense. Normal weather activity does not adversely affect the GPS signals or equipment. However, snow or ice piling up on top of the antenna might start to block the signals. Cold weather will reduce the capacity of the battery, so make sure you have a back up ready. Take precautions if you are observing in a flash flood zone and it is raining heavily. Lightning can be dangerous if the antenna is the highest conductor around. Take down the setup if you feel there is a chance the weather will damage you or your equipment.

The tripod may settle during the survey due to local conditions. Be aware of this possibility and measure the antenna height at the beginning and end of each session, (you should be measuring the antenna height before and after each session anyway).

n. Tripod Settlement During a Session - Measure the antenna height before and after the session. record both of these heights. The station coordinates depend upon an accurate antenna height. If the tripod has settled, it will throw the vector off. If you determine that the tripod has settled you have several choices. First, you could average the before and after antenna height measures. Second, if you think the station settled early on in the observation, use only the end antenna height. If you believe the station settled late in the session use the beginning antenna height. Or, if the difference is too great, throw that data out, and make another observation of that vector.

o. Human Disturbances to the Tripod - There are two types of accidental tripod bumps. The first, you hit the tripod just enough to throw out the level bubble. For this, re-level the tribrach and make sure the cross hairs are still on the point. Remeasure the antenna height, note the time of bump and new antenna height on a station log sheet. Always immediately notify the person in charge of the session so that they can make a decision to accept the bump or start the session over. The second type of bump is when the neighborhood kids come out to play and knock the tripod over. Stop the survey completely. Call the other field operators and restart the session from scratch.

p. Receiver Shutdown - Stop the survey early if you positive enough simultaneous data was collected at all stations. This is where two-way communications come in handy. You can adjust the session times in the field. The field crew should be advised to stick with the schedule unless a supervisor radios them otherwise. Record the stop time on the station log.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-07 PHOTOGRAMMETRY SURVEYS

Revised 11/01

A. GENERAL

When a corridor study necessitates the gathering of a large amount of information, photogrammetric surveys offer many advantages. This is due to the fact that once photography has been secured and controlled, additional information covering a wide band can be obtained at very little additional expense and very rapidly. Photo flights are made in winter or early Spring to avoid foliage cover.

B. FIELD PROCEDURES

Field control surveys can either precede or follow acquisition of aerial photography. Generally, the procedures are as follows:

1. Pre-Flight Control

   a. Horizontal - See Section 6-01 for traverse specifications.

   b. Vertical - Vertical control can consist of differential or trigonometric leveling or a combination of both and should meet 3rd-order standards.

2. Pre-Flight Targeting

   On a corridor study survey where photogrammetry is to be used, targets or flags are placed along the traverse at approximately 150 m (500-ft.) intervals, depending on the scale of photography. A hole should be cut in the center of the target and the target placed symmetrically about the point to be marked, and level with the ground.

   On the traverse it is not necessary to place the targets on exactly 150 m (500-ft.) intervals. However, it is important that many of the targets to be placed in open areas so they will have a better chance of being visible on the photography. This means that it is permissible to move a target 50-100 m (200 or 300 ft.) along centerline to a station that is in an open area.

Where the centerline runs for long intervals in the woods, flags with legs should be placed in the least densely wooded areas to increase the possibility that they will appear on the photography. It should be kept in mind that the standard endlap used in photogrammetric mapping is 60%; sidelap 40%.

The best targets are made in the shape of a cross with the point to be marked placed in the center of the cross. The legs of the cross should be straight and placed on either level ground or ground having a regular slope. The target should have good contrast with its background.

The standard printed cloth target 1 m x 1 m (40 in. x 40 in.) is good against any background, and may be used in open areas for 1:5000 (1"=350') and large scale photography. When these targets are used in the woods, four cloth legs 150 mm (6 in.) wide and 1.5 m (5 ft.) or longer are added.

Targets painted on the pavement or sidewalk should be a cross with an overall length of 1.2 m (4 ft.) and a width of 100 mm (4 in.) for aerial photography scales 1:5000 (1"=350') or larger. White paint on new asphalt or black paint on new concrete make excellent targets.

3. Post-Flight Control

a. General - Often on photogrammetric surveys, timing and other consideration do not allow for the placing of targets before the photography is secured. This necessitates the using of natural images instead of targets for all picture points.

Natural images are never as good as targets from the standpoint of precision and identification; however, they do usually have more permanence than a targeted point. Good natural image points for both horizontal and vertical control are the corner of a concrete drop inlets, intersection of sidewalks, and traffic marking, provided the traffic marking has not been changed between the time of the photography and the time of the control survey.

Corners of buildings without overhang, fence corners, and utility poles usually make fair picture points. It is often necessary to use trees, the intersection of paths and roads, and even rock outcrops as picture points. The exact position of a vertical picture point in a level area is not critical; and for this reason, vertical picture points should be located in relatively flat areas and never on a steep slope, such as an embankment.

b. Picture Points - The survey party will be given a set of photos on which picture points have been selected by the Photogrammetry Section. If the preselected picture point cannot be used, then the Party Chief selects another point in the same area.

1) Horizontal Control - When natural images are used for horizontal control, the point is tied into the traverse by a distance and angle to the point from a station. A sketch showing how the angle was turned is made on the back of the even numbered photos on which the picture point appears.

These points are assigned a number and letter preceded by the letter "H", based on the traverse station from which they are turned. The number of the point, station, the distance to the picture point, the angle and the point sighted on should be recorded on both the photo and in the survey book containing the baseline.

2) Vertical Control - Vertical control picture points are circled on the front of the odd numbered photos. The elevation and point numbers are written in the field book and on the front of the photo, along with a brief description of the point such as base of pole, n. corner of walk, flag, etc.

Vertical photo picture point numbers are preceded by the letter "V" and the photos. An L for the left side of the photo, and R for the right and a C for the center. A number of V75L-3 would mean that the picture point was on photo 75 and was the third vertical control point obtained on the left side of the photo.

4. Editing

When photogrammetry is to be used for road design purposes, maps are usually produced with a scale of 1:500 (metric) or 1 inch = 50 feet (english). These maps show planimetric features, but not the necessary narrative descriptions of these features.

To edit these maps, Area Engineers shall take copies of the photogrammetry into the field and identify the plotted features by making notes directly onto the maps. At the same time, he will also note any features that were not plotted. If the number of missing features is great, subsequent conventional field surveys may be required. Some of the features that will need descriptions noted are:

Pipes (construction, size, direction)
Utility Poles (ownership, number); Light Poles
Manholes (use, pipe sizes, direction)
Buildings (construction, use, overhangs)
Road and Entrance Surface (type)
Culverts (type, size, pipe size, direction)
Drop Inlets (type, pipe size, direction)
Signs (type, ownership - with license number)
Curbs (type, size); Fences (type, height)
Land Use (cultivated, lawn, etc.)
Specimen Trees (type, size)
Wells
Splicing Pedestals (ownership, number)

CHAPTER 6.00 - TYPES OF SURVEYS

SECTION 6-08 CENTERLINE STAKEOUTS

Revised 11/01

A. GENERAL

Centerline stakeouts are normally performed after a control traverse has been established in the field. Usually, the proposed enterline of the improvement serves as a guide to the design engineer for use during the preliminary investigation (P.I.)

B. PROCEDURES

1. Control

   Generally, the requester of the survey furnishes a set of plans and a list of coordinate values for the proposed centerline control points. The coordinate values for the traverse line are usually shown in the traverse book. Write the centerline values for the centerline in the new centerline book.

2. Computing ties

   Ties may be computed by the area engineer in the office, or by the party chief, depending upon the size and complexity of the job. In general these guidelines should be followed:

   a. General - Ties to the centerline should be computed from all MAIN traverse points. Tie lines can be extended later to reference both the centerline and traverse lines during the construction stake-out phase.

   b. Tangents - Compute tie lines that are tangent to the new centerline to be established.

   c. Curves greater than 150 m (500 ft.) - All tie lines should be radial to the new centerline to be established. This is easily done by intersecting a line from the traverse point to the radius point and the curve itself for POCs. For the PC and PT, compute a tie that intersects the traverse line tangent to the centerline.

   d. On curves which are less than 150 m (500 ft.) in length, direct, non-radial ties may be computed to the PC, PI, and PT from the nearest traverse point.

e. Spurs - Direct ties may be computed for short spur lines.

3. Grid factor

All values shown on the plans are grid values and all computed distances computed from grid coordinates are grid distances. For stake-out purposes, a grid factor must be computed for the project. Use the GRID program on the Paravant to compute this factor or use the factor noted in the control traverse book.

4. Staking

During staking, divide the computed distance by the grid factor to obtain the horizontal distance. Use the horizontal distance to establish the new centerline points. Establish the points with the telescope in direct position first. Reverse the scope and check each new point set.

Although centerline controls are set precisely, using the total station instrument, it is not necessary to use precise chaining to set stakes/nails between controls. Distances to intermediate stakes/nails can be rough chained and then checked, with the EDM, every 150 meters (500 ft.) and adjustments made.

5. Control Points

Re-bars, P.K. nails, or cross-cuts shall be used to establish all centerline control points such as P.O.T., P.O.S.T., P.C., P.T., P.C.C., P.R.C., T.S., S.C., C.S., and S.T. Sufficient controls shall be established to ensure that consecutive control points are intervisable.

6. References

If available, swing (hand) references are usually sufficient for centerline stakeouts. If the survey is tied to the NGS, control points can always be reset by coordinates. Excessive time should not be taken to reference the centerline.

7. Centerline Survey Notes

The centerline survey book notes shall show the complete centerline and how it was set up. Coordinate values of all centerline controls and the referenced traverse are to be noted. All curve data, curve deflections, bearings, grid distances, and references shall be shown. Orientation notes, both narrative and by sketch, should be entered in the book to facilitate future recovering of the survey.

See Figure 6-08-A series for sample notes.

SECTION 6-09 CONSTRUCTION STAKE-OUTS

Revised 11/01

A. GENERAL

Construction stake-outs establish basic line and grade for project construction and are performed just prior to actual construction. It is the State's policy to provide the minimum essential control to accomplish establishment of construction lines and grades. The baseline of construction may or may not be the same as a previously established centerline.

B. PROCEDURES

Generally, the procedures listed in Section 6-08 "Centerline Stake-outs," are valid for construction stake-outs. Exceptions are:

1. Bench Marks

   Bench marks are to be established at approximately 300 m (1,000 ft.) intervals and outside the limits of construction.

2. Referencing

   a. All baseline of construction controls are to be referenced with rebars, spikes, cross-cuts in concrete or other permanent markers. DO NOT use hubs. PKs may be used when driving a galvanized spike is not practical. If the point lands in a cultivated field, recess the rebar at least 350 mm (14 in.) below the surface of the ground.

   b. Set RPs clear of all construction. Generally, the nearest point should be 6 m (20 ft.) outside the grading limits. Avoid placing Rps at deep cuts or fills. Where possible, locate Rps at cut-to-fill ("daylight") points. Place one reference point on each side of the baseline where possible instead of both on the same side. When you must place two Rps on the same side, space them at least twice the distance apart as the nearest one is to the baseline.

   c. When Rps must be set outside the right-of-way, gain approval of the property owner or tenant before doing so. Use the Area Engineer, if need be, to accomplish this.

d. On curves, set reference points at a maximum of 150 m (500 ft.) apart. On tangents, this may be increased to 300 m (1000 ft.), provided the points are still intervisible.

3. Construction Stake-out Notes

Follow procedures for Centerline Stake-out.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-10 BORING STAKE-OUTS

Revised 11/01

A. GENERAL

Boring stake-outs are performed for the Geotechnical Explorations Division. The location of the boring are marked by this Division on plans using scaled line pluses and offset distances.

B. PROCEDURES

1. Location - Generally, the location of boring points are referenced to a previously established baseline. As boring locations are only approximate locations, boring stakes need not be set exactly. Use of a cloth tape and a pentaprism can meet the required accuracy of point location. A computed angle and distance from any point on the baseline can also be used.

2. Marking of Boring Stakes - The field marker should show the boring number and the ground elevation at the stake. The elevation is shown to the nearest tenth of a foot.

3. Notes - The boring location shall be shown in the baseline survey book at the proper station. The location of the boring is shown by drawing a target symbol at the appropriate spot, either left or right of the baseline, and the plus, offset distance, and ground elevation noted. See Figure 6-10-A for example of field notes.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-11 HYDRAULIC SURVEYS

Revised 11/01

A. GENERAL

For purposes of this MANUAL, hydraulic surveys include hydrographic mapping (soundings), floodplain studies, and wetlands location.

B. PROCEDURES

1. Soundings

   a. General - The surveyor must be aware that the accuracies of soundings are not comparable to land surveys. While the surveyor on land can see the features, the surveyor performing soundings cannot, except in shallow, clear waters.

   b. Using EDM and Weighted Line

      1) Horizontal Control - The sounding line is usually controlled by stations set on both shorelines. The instrument is positioned over one station and keeps the sounding vessel on line as well as measuring the horizontal distance to a prism on the boat.

      2) Vertical Control - The depth of the point below the water surface or sounding must be related to NAVD 88. On ponds or lakes this would merely mean the elevation of the water surface is obtained through normal leveling. All sounding measurements would then be subtracted from the surface elevation to acquire sounding elevations.

         On rivers and bodies of water that have elevation changes and tidal variations, a tide gauge is required to obtain the necessary information during the sounding period. A simple graduated pole, such as an old level rod, is erected with its zero mark below the lowest expected water level. An observer remains with the tide gauge and either informs the note taker when surface elevation changes of 30 mm (0.1 ft.) occur or record the time and gauge readings at specified intervals.

3) Recording Sounding Data - The note taker normally remains with the EDM and notes the horizontal distance to the sounding location. The sounder, using a graduated, weighted line, measures the depth of the water and radios it back to the note taker.

c. Using Echo Sounder - When a large number of soundings are required, the Division has enlisted the aid of the Department of Natural Resources. They supply a boat that is equipped with an echo-sounder along with an operator. The boat is located initially, by an EDM distance and kept on line by an instrument set on the sounding line. The echo sounder provides depth measurements by timing the interval between transmission and reception of an acoustic pulse.

2. Floodplain Studies

a. General - Requests for floodplain surveys are usually from the Office of Bridge Development. Lines to be profiled are shown on a base map. These profile line are normally perpendicular to the stream and are confined by either a horizontal distance or an elevation that the profile is to be run to. The profile lines can be a straight line or have angle breaks on them.

b. Procedures

1) Horizontal Control - A traverse is run to the extent of the floodplain study. This traverse is tied to an existing centerline/traverse line if one exists.

2) Vertical Control - Floodplain surveys are based on NAVD 88 and levels must be brought into the area if no bench marks are available.

3) Ground Profiles - Profiles of the ground on the designated lines can be taken by differential or trigonometric methods. There are no constraints to the distance between ground shots, but all abrupt ground changes should be shown.

4) Note Taking - Sample notes for a Floodplain Study are shown in Figure 6-11-A series.

3. Wetland Location

a. General - Federal regulations require that wetlands destroyed by road construction be replaced in another area. To measure the area of wetlands displaced by road construction, the outline of effected wetlands must be located and referenced to a baseline.

b. Procedures

1) Delineation - The extent of the wetlands to be located are defined in the field by personnel from the Division of Project Development. These personnel visit project sites and determine where wetlands are located. The limits of the wetlands are usually marked by the use of a unique plastic ribbon which is tied to vegetation in the area.

2) Location - As the marked limits of wetlands is at best approximate, great care in locating the ribbons is not necessary. Right angle pluses and distances using a cloth tape of angles and distances measured from a baseline station are sufficient.

3) Note Taking - The location of wetlands are sketched into the book as normal topography would be.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-12 TRAFFIC SIGNALIZATION SURVEYS

Revised 11/01

A. GENERAL

Traffic signalization surveys are requested by the Division of Traffic when traffic signals are to be installed at a road intersection or where the configuration of an existing signal system is to be changed.

B. FIELD PROCEDURES

1. Traverse - A traverse running 90 m (300 ft.) in all directions from the center of the intersection is required unless electronic data collection will be used. Existing survey lines are to be used, if available and can be easily recovered. If not, new lines are established.

2. Topography - Normal topography is to be taken to the back of sidewalks or to the limits of right-of-way, whichever is appropriate. In addition to the features usually located, the following information must be obtained and recorded.

   a. All painted traffic controls, such as stop bars, painted islands, acceleration and deceleration lanes, etc., shall be located.

   b. Distance between ground and all overhead wires in topoed area.

   c. Direction of all wires.

   d. All numbers that appear on utility poles.

   e. Street lights and supporting arms. Also distance above ground.

   f. Signs and their messages.

   g. Any feature that could have an effect on the installation of a traffic signal system.

3. Notes - See Figure 6-12-A series for examples.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-13 BORROW PIT SURVEYS

Revised 11/01

A. GENERAL

Highway construction often necessitates the relocation of earthen material. Where material is to be removed, it is called a "cut" section. Where it is deposited, it is called a "fill" section. When more material is required than can be salvaged from cut sections, material must be obtained from other locations - "borrow" pits. As contractors will be paid by the quantity of dirt removed from the borrow pit, it is important to obtain accurate preliminary and final cross-sections of the borrow pit.

B. PRELIMINARY CROSS-SECTIONS

1. Check with the construction project engineer and/or contractor to determine where the pit limits will be. It is important that no material be removed from this area except that to be used on the project. All topsoil is normally stripped off the surface of the pit and piled out of the area of excavation.

2. Orientation - A detailed narrative description of the location of the borrow pit shall be entered into the survey book. This description should show the route from a major highway, the property owners name, distance from the centerline of the nearest road or lane, the number of the pit, and any other information that would help define the location of the pit.

3. Baselines - Before any excavation takes place, baselines must be established. If the terrain is flat, one baseline should be sufficient. If not, two baselines may be needed. When two baselines are run they are tied together perpendicularly. Skewed lines are not acceptable.

   The baselines may be located in the middle of the pit or along one side as required. A magnetic bearing of the baseline(s) shall be recorded. Baselines are to be staked at 10 meter (25 foot) intervals.

4. Vertical Control - If no bench marks exist in the immediate area of the pit, assumed elevations may be used. A minimum of three bench marks must be established near the pit site.

5. Cross-Sections - Original cross-sections are taken on a 10-meter (25-foot) grid. That is, every 10 meter (25 feet) along the baseline and a rod reading every 10 meters (25 feet) along the cross-section line. Cross-sections are taken at least 20 meters (50 feet) (2 rods) beyond the pit limits. Rods should also be taken at any ground breaks.

6. References - Time should be taken to carefully reference baselines as heavy equipment will be operating in the borrow pit area and may destroy the baseline in whole or in part.

7. Field Notes - Besides the orientation data requirements described above, it should be noted whether the cross-sections were taken before or after topsoil and/or root mat was stripped.

   Sample field notes are shown in Figure 6-13-A series.

C. FINAL CROSS-SECTIONS

1. The borrow pit should be smooth and effectively drained prior to cross-sectioning.

2. Re-stake the baseline, if necessary. Sometimes it may be necessary to set offset lines to facilitate cross-sectioning.

3. Take final cross-sections of the pit in the same manor as the preliminaries with one important difference. Get a distance at the end of each cross-section to "old ground". The rod reading for "old ground" can then be interpolated from the preliminary cross-section data.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-14 ELECTRIFICATION SURVEYS

Revised 11/01

A. GENERAL

Electrification surveys are requested by the Office of Bridge Development when bridges are to be constructed or replaced over AMTRAK facilities. A general sketch of required survey measurements accompanies the request.

B. SURVEY REQUIREMENTS

The required measurements may vary from project to project, but generally contain the following:

1. Survey Measurements

   a. Distance measured along the centerline of track from its intersection with the centerline of the bridge or highway of each catenary structure in each direction of the bridge for a distance of three such full span structures. These measurements are required along each of the outside main tracks owing to the skew of the bridge and possible skewing of the catenary structures.

   b. Distance between centerline of adjacent tracks and between centerlines of outside tracks and adjacent catenary structure column or bridge abutment at the following locations:

      1) At each fascia of each bridge.
      2) At each catenary structure in each direction of the bridge to and including the third full span structure.

   c. Elevation of lowest portion of bridge structure over each track at each fascia of each bridge.

   d. Elevation of both rails of each track at the same locations as item 2 above.

   e. Location of any structures near the bridge which might conflict with foundations for new catenary structures, i.e., manholes, ground signals, etc.

   f. Location of switch and frog point and offsets of sidetrack.

g. Elevations at top of concrete footing for catenary supports.

2. Wire Measurements:

Distance from top of rail to both messenger and contact wires on each track at the following locations:

a. At each fascia of each bridge (including point of attachment to bridge).

b. At approximately midspan between bridge attachments points.

c. At each catenary structure extending to and including the third full span structure in each direction from the bridge.

See Figures 6-14-A and 6-14-B for catenary configuration.

C. SAFETY REQUIREMENTS

Under no circumstances is a Division employee permitted to work on AMTRAK property without receiving the prescribed safety training course conducted by AMTRAK.

After completion of the safety course, Division employees will receive a numbered sticker. This sticker is to be applied to the employee's hard hat and worn when performing electrification surveys.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-15 GEODETIC LEVELING SURVEYS

Revised 11/01

A. GENERAL

The electronic digital level is a new technology instrument using image processing and bar code rods to perform the task of leveling. This technology relieves the observer from actually reading numbers from the level rod or staff.

To take a measurement, all the observer does is level the instrument, point it at a bar code rod, focus, and press the measure button. The level does the rest, resulting in an elevation and a distance to the rod.

Although the measurements can be collected directly to an on-board recording module, the Plats and Surveys Division currently uses a Paravant hand held data collector and the National Geodetic Surveys VERREC program. Please refer to Section 4-03 for specifications for geodetic leveling.

B. GEODETIC LEVELING DEFINITIONS

Backward running - Leveling in the reverse direction the line of levels will be computed.

Collimation check - The process of determining the difference between the line of sight and truly level line.

Forward running - Leveling in the direction the line of levels will be computed.

Imbalance - The backsight distance minus the foresight distance.

Rod constant - For rods with 2 scales, the difference between the 2 scales.

Section - A leveling run between 2 bench marks.

Tie - Checking the elevation difference between two published bench marks within the tolerance specified by the order and class of leveling being performed.

Turning pin - A steel pin driven in the ground to support a level rod.

Turning plate - A steel plate and pin used to support a level rod on hard surfaces.

Vertical refraction - The bending of light rays vertically caused by differences in air densities.

C. WILD 2002 BAR-CODE LEVEL COLLIMATION TEST AND ADJUSTMENT

The collimation error is the angular difference between the line of sight and a truly level line. It is usually expressed in millimeters per meter. For second order class I leveling, this value cannot exceed 0.050 mm/m. It can also be expressed in seconds of arc - 0.050 mm/m is the same as 10 arc seconds.

The NA2002/3003 corrects automatically for the collimation error when electronically measuring the staff reading. As is common place with electronic theodolites, the collimation error can be determined and stored in the digital level. THIS PROCEDURE MUST BE PREFORMED AT THE BEGINNING OF EACH DAY OF LEVELING.

1. Level instrument and turn on by pressing the ON/OFF key in the lower left hand corner.

2. Store data in rec-module: Press the SET key (which is also the #5 key). Using the UP and DOWN arrows (keys #3 and +/-) page to SET RECORD, Then press RUN (which is also the YES key), page to RECORD MODULE and press RUN again. You will now notice ALL in the upper left corner of the screen. THE INSTRUMENT MUST BE IN THIS MODE AT ALL TIMES WHEN RUNNING PRECISE LEVELS.

3. Set the instrument to record in meters: Press the SET key, then page to CONFIG and press the RUN/YES key. Page to UNIT and press the RUN/YES key, the screen will show ft or m (for feet or meters). Page to m and press the RUN/YES key.

4. Press the SET key, then page to SET MEASURE and press RUN. The instrument is now asking how many measurements to take per shot. ALWAYS TAKE 5 MEASUREMENTS PER SHOT WHEN RUNNING PRECISE LEVELS. Press the #5 key and then the RUN key.

5. Set two stable points 45 meters apart. Designate one point A and the other B.

6. Make two marks on line between A and B, a mark 1/3 the total distance from A (1st position) and a mark 1/3 the total distance from B (2nd position).

7. Set the instrument over the 1st position and level. Press the PROGRAM key (which is also the #6 key), then page to CHECK and ADJUST and press the RUN key. The screen will now show MEAS A1 B X A. The instrument is now ready to take a measurement on point A. press the RED measurement button.

8. The instrument is now asking for a measurement on point B. Point the instrument at the rod on point B and press the RED measurement button.

9. The instrument is now ready to be moved to the 2nd position, press the RUN key and move to the second position.

10. Repeat steps 7 and 8, first measuring point B then point A.

11. The instrument is now asking if you want to compute the collimation, press RUN/YES key then store the value displayed by pressing the RUN/YES key again.

12. The instrument is now asking if you want to ADJUST RETICLE, press the CE/NO key and return to PROGRAM.

D. ENTERING PROJECT DATA INTO THE VERREC PROGRAM

The VERREC program was developed by The National Geodetic Survey to record geodetic leveling data. The program was designed for a MSDOS data collector with a small display screen. This is why it displays information in the upper left corner of the Paravant's display screen.
THE PROGRAM DOES NOT MAKE A BACK-UP COPY WHILE RUNNING. Therefor, one should make back-up copies of data each day. If the Paravant has 2 ramcard drives, run the program in the B: drive, otherwise run the program in the A: drive.

1. Key-in VERREC into the data collector and press ENTER. The following is a list of prompts you will see. Note: YOU MUST HAVE THE CAPS LOCK ON FOR THE PROGRAM TO OPERATE CORRECTLY. If you power down the collector while in the program, be sure to hit the CAPS key after power-up.

2. You will be requested to enter a filename:

   Filename : ________

   Use the date for the filename in the form YYMMDD where YY is the Year, MM is the Month, and DD is the day of the month. Ex.: 951105.

3. Enter the appropriate equipment information:

```
Inst.
    Code: 243        (The instrument code)
     S/N: 91767      (The instrument serial number)
 Stadia
    Code: H          (Half stadia)
  Factor: 200        (Stadia factor)
Rod 1
    Code: 396        (Level rod code)
     S/N: 26078      (Rod 1 serial number)
  Const.: 0.000      (Rod 1 constant)
Rod 2
    Code: 396        (Level rod code)
     S/N: 26075      (Rod 2 serial number)
  Const.: 0.000      (Rod 2 constant)
Rod Units: CM        (Centimeters)
Probe Hts.
 Tripod Top: 1.30    (The height in m of the
                     thermometer)
Tripod Bot.: 0.0
  Truck Top: ____
 Truck Mid.: ____
 Truck Bot.: ____
Temp Code  : F       (Fahrenheit)
Time Zone  : Q       (Q-daylight save time, R-Eastern
                     std. time)
Survey
  Ordr/Clas: 21      (Second order, class 1)
Time       : ____    (Enter the time)
Date       : ____    (Enter the date)
Obs. 1     : ___     (Enter the initials of the
                     observer)
Tripd Hgt 1: ____    (Enter the height of the tripod for
                     him/her)
Tripd Hgt 2: ____    (Enter a second tripod height if
                     used)
Obs. 2     : ___     (Enter another observer if
                     necessary)
Tripd Hgt 1: ____    (Tripod height of second observer)
Tripd Hgt 2: ____
Obs. 3     : ___
Tripd Hgt 1: ____
Tripd Hgt 2: ____
Obs. 4     : ___
Tripd Hgt 1: ____
Tripd Hgt 2: ____
F1: Save    F5: Abort:   (Press F1 to save data)
```

E. BEGINNING A SECTION

1. VERREC main menu screen:

```
SELECT ACTIVITY
Change Equipment F1
Begin Section    F2
C-Shot           F3
Review Sections  F4
End Leveling     F5
```

2. Select F2 and key in the appropriate information:

```
     Beginning Information
       Obs.: ___     (Enter the observers initials)
       Rec.: ___     (Enter the recorders initials)
        SSN: ____    (Enter the survey point number)
     Desig.: _______ (Enter the bench mark designation)
      Temp.: ___     (Enter the temp. * 10 - ex. 81 = 810)
       Wind: _       (Enter 0 for calm, 1 for moderate, 2 for
                     strong)
        Sun: _       (Enter 0 for cloudy, 1 for partly, 2 for
                     clear)
       Time: _____   (Enter the correct time)
     Rod on
       Mark: 1       (Press ENTER)
Save Changes  Y      (Enter Y)
   Setup #: 1
 Imbalance:  0.00
  Distance: 0.00     (Press ENTER)
```

3. Program the bar-code level to properly number each set-up and number the bench marks:

   a. Press the PROGRAM key
   b. Page to P START LEV BF, then press RUN
   c. The screen will show START L sure?, press RUN
   d. The screen will show PtNO and a number with the cursor blinking
   e. Enter the SSN number of the bench mark and press RUN
   f. The screen will show INCREM. 1 and the cursor blinking, press RUN
   g. The screen will show GrHT a number and the cursor blinking
   h. Enter a ground height of 0.0000 and press RUN

F. SECTION RUNNING

1. Take a back sight on the backsight and enter the rod reading * 100,000 (move the decimal 5 places to the right) into VERREC. Ex.: If the rod reading is 0.82720, enter 082720

2. To read the stadia, page down and enter the distance * 100 (move the decimal 2 places to the right) into

VERREC. Ex.: If the distance is 1.89 enter 0189, if it is 21.34 enter 2134

```
Backsight
 Elevation:    (Enter the rod reading * 100,000)
 Distance :    (Enter the stadia distance * 100)
Foresight
 Elevation:    (Enter the rod reading * 100,000)
 Distance :    (Enter the stadia distance * 100)

Temp. Top  _______   (Hit ENTER)
  Skip Temp.  Y      (Hit ENTER)
```

G. ENDING A SECTION

After the final rod reading on the closing bench mark is entered, type E to end leveling. NOTE: CAP LOCKS MUST BE ON, If you go to the next Setup and VERREC is asking for the next rod reading you will not be able to enter E. You must first enter F1 to go back to the last Setup, then enter E.

VERREC will now show End Section? N, type Y and press enter.

```
Ending Information
   SSN: ____        (Enter the survey Point Number)
Desig.: _______     (Enter the bench mark designation)
  Temp: ___         (Enter the temperature in degrees
                    Fahrenheit * 10.  Ex.: 810 for 81
                    degrees
  Wind: _           (Enter the wind code)
   Sun: _           (Enter sun code)
  Time: ____        (Enter the time)
```

Save Changes? Yort: Type Y and press Enter

AT THIS POINT YOU HAVE THE OPTION OF BEGINNING ANOTHER SECTION OR ENDING YOUR LEVELING.

CHAPTER 6-00 - TYPES OF SURVEYS

SECTION 6-16 RE-ESTABLISHMENT OF OLD BASE LINES

Revised 11/01

A. GENERAL

Over the last 20 years surveying instruments have greatly improved, both in precision and ease of use. In the 1960's most measurements were taken with 20 second transits and 100 ft steel tapes. Traverse closures were in the range of 1:5000 - 1:10,000. Today angles and distances are measured electronically with total stations. Typical closures range from 1:25,000 - 1:60,000.

This tremendous increase in measurement precision has brought to light unique problems in the establishment of base lines that were done years ago. This section provides policy and direction for this procedure.

B. RECOVERY OF EXISTING CONTROL AND REFERENCE POINTS

The party chief will receive copies of old plans, plats, and survey books for the baseline in question. He should review all material carefully to familiarize himself with the geometry. The field work shall progress as follows:

1. Search for ALL ORIGINAL reference and control points shown in the old survey book. It is important to recover as many ORIGINAL points as possible, especially P.C.'s, P.I.'s, Externals, and P.T.'s. It will usually be necessary to go beyond the limits of the new survey to tie in old base line points.

2. If control or reference points are paved over, and it is appropriate to do so, chop holes in the pavement to locate the original points. Be careful not to destroy the control point by removing to many layers of pavement at one time.

3. If unable to locate sufficient control or reference points, identify any significant topo that was located during the old survey such as house corners, telephone poles, structures, etc.

4. Note in the OLD survey book whether the control points or references were found or not and the date of recovery.

5. Reset base line control points from the references as

shown in the old survey book. If necessary, controls may be set at a convenient offset to facilitate traversing. DO NOT reset control points by measuring from other control points at this time!

6. Identify the stationing to the FOOT ONLY at this time.

C. TRAVERSE

1. If the recovered/reset control points are spaced adequately for the new survey, no new points need to be set.

2. If the spacing is inadequate for new work, set POL's between adjacent found points as necessary. DO NOT attempt to establish them at old stations or even stations.

3. Connect all control points by traverse to GPS control as if it was a random traverse line. If obstructions such as trees, bridge piers, poles, or sign posts prevent sighting between points, establish additional points to traverse around them.

4. Put all NEW work in the new field book. Note the book number and page of the old field book where the control point was found. Show the NEW measured angles and distances between all recovered control and reference points. DO NOT show old distances or old angles in the new field book.

5. Note in the old field book the new field book number and a brief explanation of the new work.

6. Send all data to the office for analysis and adjustment. Data collection may be taken from the traverse points at this time if requested.

D. SET-UP OF BASE LINE

When the data has been analyzed and adjusted in the office, some revision will likely be made to the original geometry. Frequently the tangent alignments (not curve tangent distances) and the degree of curve will be held and all stations and curve data re-computed. Back and Ahead equalities may occur at P.C.'s, P.T.'s. or other points along the base line. New station values for the old control points may also occur.

1. Set the baseline up as directed by the office.

2. Show the new station values in the new field book with a note to the side indicating the old field book and page, and the old station value for the point.

3. Set new references for all control points that do not have original references. Show all references in the NEW field book. If anything is in doubt, call the office for clear direction!

CHAPTER 7-00 - NOTEKEEPING

SECTION 7-01 PURPOSE AND IMPORTANCE

Revised 11/01

A. PURPOSE

Survey field notes are prepared in numerous forms and by various methods to serve as an interpretable, filed record of a survey party's every step in the prosecution of a survey. Implied in the purpose are:

1. A showing of the basis of the survey, new lines, and new points established.

2. A usage by the survey party to monitor its progress and the completeness of the survey.

3. The usage by others to:

    a. Check the accuracy of the survey.

    b. Adjust the survey and derive best values.

    c. Extract data for other surveys, design, traffic, right-of-way, construction, and other uses.

    d. Retrace the footsteps of the survey party.

B. IMPORTANCE

A survey is never completed until field notes are submitted for checking and filing. Field notes are not an accessory to the survey - they are an integral part of the survey!

Field notes often perpetuate a survey when stakes have rotted and monuments are obliterated. Field survey notes are introduced occasionally as court evidence.

C. DEFINITION

Field survey notes are complete graphic, tabular, or written (or combinations thereof) survey records which depict each step of the survey on a suitable form and in a proper format. They show the following to enable knowledgeable persons to interpret and use the survey and its results and retrace the footsteps of the surveyor:

1. Survey location.

2. Pertinent record information and attendant references.

3. Original "raw" values (without any mathematical manipulations and without any corrections for errors) of distance, angle, and elevation.

4. Measurements of pertinent atmospheric conditions.

5. Monuments used and set.

6. Equipment used and its standardization factor(s).

7. Party personnel and their duties.

8. Date(s).

9. Explanatory notes about any condition(s) which might affect the accuracy of result of the survey.

CHAPTER 7-00 - NOTEKEEPING

SECTION 7-02 ELEMENTS OF NOTES

Revised 11/01

A. NOTEBOOKS

The Division has adopted for standard use, numbered survey books, measuring 6-1/4 inches by 8-1/2 inches. The pages are grid paper, with the grid having every fourth line being wider and darker. This book, the standard peg books, and the electronic data collector are used almost exclusively to record field notes.

B. FORMAT

1. Index Page - The index page is the orientation, title, and summary for a set of field notes. The index page should, at the minimum, contain the following:

   a. Book Number (at top of page)
   b. Contract Number
   c. Name of County
   d. Route number or road name of project
   e. Project extremities (from - to)
   f. Type of work
   g. Location of work (between extremities)
   h. Stations of work (from - to)
   i. Pages of work (from - to)
   j. List of books used on project
   k. Date job finished (month, day, year)
   l. Party personnel

   The index page is to be completed in its entirety for each survey. Never note "Same As Above." See Figure 7-02-A for a sample index page.

2. When starting a new field book, pages 1-7 must be reserved for the book index. Start actual field notes on page 8.

3. Orientation Data and Cross References - The Party Chief should make entries into his notes that are primarily for the orientation of the note user. Some of these are:

   a. North Arrow
   b. Direction Arrows (to next town, city or major highway)
   c. Planimetric Features

d. Descriptive Notes
e. Datums Used

The Party Chief should also make cross-references to the origin of any point used in his survey. The word "found" is always used in describing recovered points, but a reference to the origin of the point must always be made.

1 BOOK NUMBER IF NOT STAMPED
2 CONTRACT NUMBER
3 PARTICIPATING (P) OR NON-PARTICIPATING (N)
4 COUNTY(s) NAME
5 PROJECT ROUTE NUMBER AND/OR ROAD NAME
6 PROJECT "FROM"
7 PROJECT "TO"
8 TYPE OF WORK (X-SECTIONS,TRAVERSE,TOPO,ETC)
9 ROUTE NO./ROAD NAME-THEN TYPE WORK
10 "FROM" - "TO" STATIONS
11 PAGE NUMBERS WORK FOUND ON
12 ALL BOOKS USED ON PROJECT
13 BOOK NUMBER JOB CONTINUED IN
14 DATE JOB FINISHED
15 SURVEY PARTY PERSONNEL
16 "RED" LINES TO END INDEXING

NOTE:LINE SPACE AS SHOWN IN SAMPLE

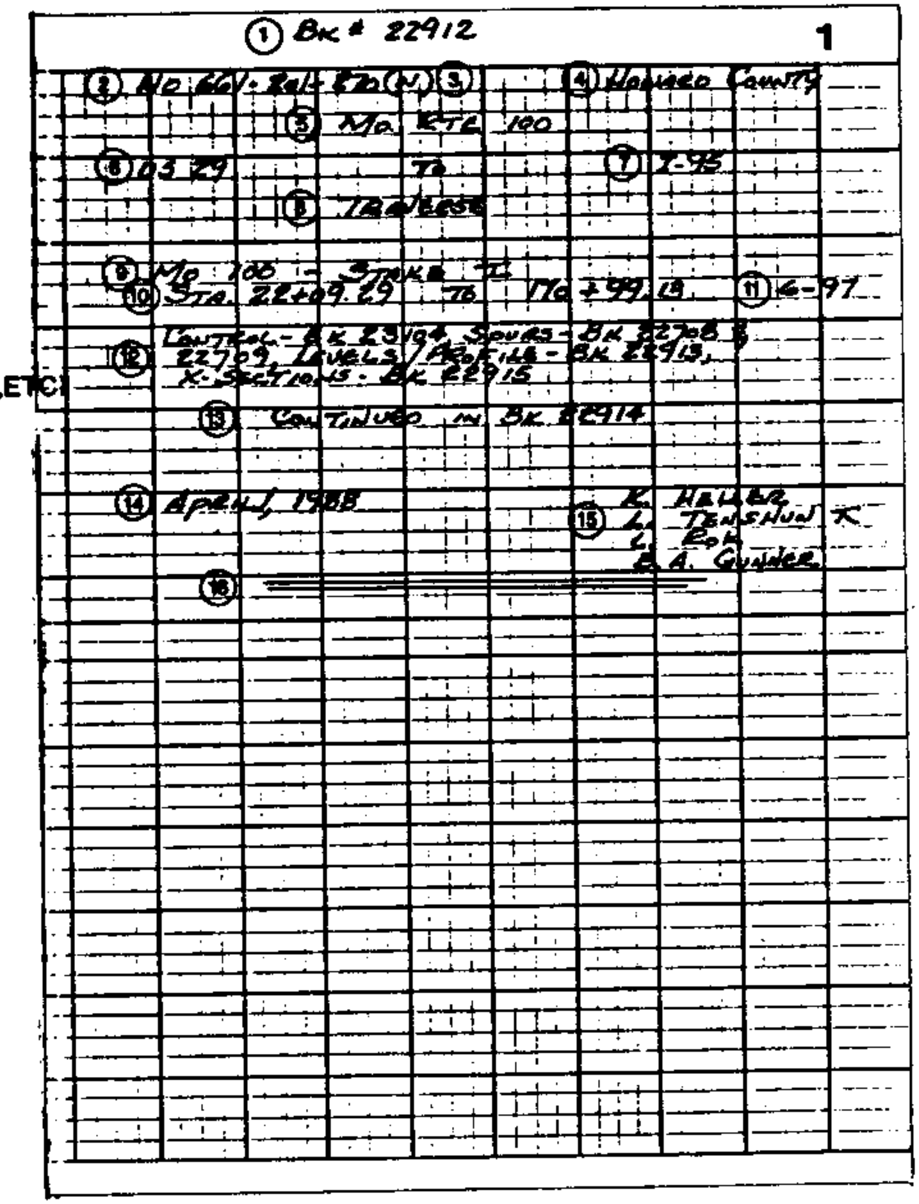


FIGURE 7-02-A SAMPLE INDEX PAGE

CHAPTER 7.00 - NOTEKEEPING

SECTION 7-03 QUALITY OF NOTES

Revised 11/01

A. GENERAL

Do not sacrifice the quality of field notes for expediency. Poor quality notes are not justified because the party is short a man or because the project is a rush job.

The desired qualities in notekeeping overlap and intertwine. They arise from the purpose of notekeeping - "to serve as an interpretable record of a survey party's every step in the prosecution of a survey." To realize this purpose certain qualities must be "built" into each module, each page, and each set of field notes.

B. ACCURACY

Accurate field notes list the exact field data that is measured and gathered. This implies a proper placement of each entry and correlation with all other entries. Accuracy is the prime requisite in notekeeping.

To assure accuracy:

1. Consistently follow the policy of recording "original" field data.

2. Record raw values.

3. Provide for distinctly hearing each call-out from the Instrument Man, Rodman, or Chainman. Two-way portable radios provide great help.

4. Repeat each call-out for verification.

5. Orient the note page to the "ground." Such orientation aids in correct positioning of data on the page. It helps eliminate such notekeeping blunders as recording a rod reading on the wrong side of the station line or showing an angle in the wrong quadrant of an intersection.

6. Have a second person check the notes while the notes are still "warm" and the survey party is still at the job site.

Even though the notekeeper succeeds in accurately recording all data, measurements, and observations, this is not his sole responsibility. The alert notekeeper, with record, calculated, and recorded data in his hands, is usually in the best position to detect blunders. Be alert at all times and do not blindly accept each call-out. To assure survey accuracy be especially alert to obvious inconsistencies.

C. NEATNESS

Neatness in field notes shows the professional attitude of the surveyor. the production of neat field notes requires diligent effort.

Neat notes are obtained through:

1. Proper storage and handling.

    a. Provide a dust proof storage area for forms.

    b. During work breaks, protect unfinished notes from soiling by protecting them.

    c. Use a clip board to prevent "dog-earing."

2. Cleanliness

    a. Use a lead of a hardness which will produce legible and reproducible lettering which will not smear. Etching the paper with very hard leads is not desired: reproduction is difficult.

    b. Minimize contact of hand and forearm with note paper. This is quite important in summer months. A long sleeved shirt or a "sweat-pad" of cloth flagging with help.

D. CLARITY

To possess clarity, notes must be easily understood and be free from ambiguity, confusion, uncertainty, and doubt. Clarity is attained through:

1. Legibility

2. Entries in the proper place or near a related part of a sketch.

3. Orientation data

    a. Line labels ("To" arrows).
    b. Planimetric features.
    c. North arrow.

4. Good delineation

   a. Standard abbreviations. Use those shown in the "Appendix."
   b. Standard symbols.
   c. Blown-up sketches.
   d. Drawing sketches to an approximate scale.
   e. Clustering or tabulating related data.

5. Explanatory notes to clarify apparent inconsistencies as differences between "record" and "measured" or a sketch which is out of proportion.

6. References and cross-references.

E. COMPLETENESS AND INTERPRETABILITY

1. Completeness

   Complete field notes are those which have been field checked, and contain all applicable elements, built in self-checks, and required qualities. The recorder's input must be adequate for satisfying notes users - not just enough to satisfy himself.

   a. Self-Checking - This is data that enables the user to determine that the survey has been properly performed and closed. To ensure this feature:

      1) Show raw values and use only original entries.

      2) Enter data that is the basis for calculations

         a) Coordinates for inversed distances and bearings.

         b) Azimuths or bearings for calculated angles.

      3) Write accurate, detailed descriptions of all record points, especially points of origin and closing points.

      4) Cite references for all record points used.

      5) Review the notes to assure an adequate closure.

   b. Field Checked - Review the notes and the survey for possible omissions or errors. (A set of complete notes does not necessarily guarantee a completed survey.) To aid in the review:

1) If possible, have someone other than the recorder review the notes. His unfamiliarity with the notes will help to test their qualities as well as their content.

2) First, review and survey request to be sure all the request is completed.

3) Mentally review the survey with notes in-hand.

4) If feasible, physically review the survey in the field with notes in-hand.

2. Interpretability

Interpretability results when all the above qualities are included. If a knowledgeable user can take completed notes and retrace the order and the progress of the party's efforts; if the user can understand the information intended to be perpetuated; if correct meanings, without ambiguity, are communicated; if valid values can be calculated and adjusted - the notes are interpretable.

F. LETTERING

Legible lettering is the basic for any method of notekeeping. Select a single-stroke style that is natural and practice until proficient.

Slant - Plain slanted letters are more easily and more quickly formed than vertical letters. A bonus from slant lettering is that irregularities in the individual characters are not readily apparent.

Occasionally, certain data needs emphasis. In such cases, letter vertically to provide the contract that will spotlight a particular entry.

Reinhardt - This single-stroke lettering has proved through years of use to provide the optimum in legibility, speed, and ease of forming. It is simple: void of serifs or curlicues. Use this style as a foundation for your individual style.

Lettering ability can be developed - it is not just a natural trait. The aspiring notekeeper and the poor letterer can become proficient by learning the makeup of letters and by practicing. Figure 7-03-A shows Reinhardt letters and numbers.

Avoid the use of lower case letters. The Division's standard is upper case Reinhardt lettering.

REINHARDT LETTERING

A B C D E F G H I J K L M N O
P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0

FIGURE 7-03-A

GLOSSARY OF LAND SURVEYING TERMS

Abstract - A summary of facts.

Abstract of title - A condensed history of the title to land.

Accessory to corner - A physical object that is adjacent to a corner. An accessory is usually considered part of the monument.

Acclivity - An upward slope of ground.

Accretion - The gradual accumulation of land by natural causes.

Acknowledgment - A declaration by a person before an official (usually a notary public) that he executed a legal document.

Acquiescence - Implied consent to a transaction, to the accrual of a right, or to any act by one's silence (or without express assent).

Adjudication - The giving or pronouncing a judgment or decree in a cause.

Adverse possession - A method of acquiring property by holding it for a period of time under certain conditions.

Affidavit - A written declaration under oath before an authorized official (usually a notary public.)

Alienation - The transfer of property and/or possessions from one person to another.

Aliquot - A portion contained in something else a whole number of times.

Alluvium - Sand or soil deposited by streams.

Appellant - The party which takes an appeal from one court or jurisdiction to another.

Appurtenance - A right, privilege, or improvement belonging to and passing with a piece of property when it is conveyed.

Assigns - Those to whom property is transferred.

Avulsion - A sudden and perceptible change of shoreline by violent action of water.

Bayou - An outlet from a swamp or lagoon to the sea

.

Bed of stream - The depression between the banks of a water course worn by the regular and usual flow of the water.

Bequest - A gift by will of personal property.

Bounty lands - Portions of the public domain given or donated as a bounty for services rendered.

Chain of title - A chronological list of documents which comprise the record history of title of real property.

Civil law - That part of the law pertaining to civil rights, as distinguished from criminal law. Civil law and Roman law have the same meaning. In contradistinction to English common law, civil law in enacted by legislative bodies.

Clear title - Good title. One free from encumbrances.

Cloud on title - A claim or encumbrance on a title to land that may or may not be valid.

Color of title - Any written instrument which appears to convey title, even though it does not.

Common law - Principles and rules of action determined by court decisions which have been accepted by generation after generation, and which are distinguished from laws enacted by legislative bodies.

Consideration - Something of value given to make an agreement binding.

Conveyance - Any instrument in writing by which an interest in real property is transferred.

Covenant - When used in deeds, restrictions imposed on the grantee as to the use of land conveyed.

Crown - The sovereign power in a monarchy.

Cut bank - The water washed and relatively permanent elevation or acclivity which separates the bed of a river from its adjacent upland.

Decree - A judgment by the court in a legal proceeding.

Dedication - An appropriation of land to some public use made by the owner, and accepted for such use by or on behalf of the public.

Deed - Evidence in writing of the transfer of real property.

Deed of trust - An instrument taking the place of a mortgage, by which the legal title to real property is placed in one or more trustees to secure repayment of a sum of money.

Demurrer - In legal pleading, the formal mode of disputing the sufficiency of the pleading of the other side.

Devise - A gift of real property by the last will and testament of the donor.

Easement - The right which the public, an individual, or individuals have in the lands of another.

Egress - The right or permission to go out from a place; right of exit.

Eminent domain - The right or power of government or certain other agencies to take private property for public use on payment of just compensation to the owner.

Encroachment - An obstruction which intrudes upon the land of another. The gradual, stealthy, illegal acquisition of property.

Encumbrance - Any burden or claim on property, such as a mortgage or delinquent taxes.

Equity - The excess of the market value over any indebtedness.

Erosion - The process by which the surface of the earth is worn away by the action of waters, glaciers, wind, or waves.

Escheat - Reversion of property to the state where there is no competent or available person to inherit it.

Escrow - Something placed in the keeping of a third person for delivery to a given party upon fulfillment of some condition.

Estate - An interest in property, real or personal.

Estoppel - A bar or impediment which precludes allegation or denial of a certain fact or state of facts in consequence of a final adjudication.

Et al - An abbreviation for "and others".

Et Mode Ad Hune Diem - An abbreviation for "and now at this day".

Et ux - An abbreviation for "and wife".

Evidence aliunde - Evidence from outside or from another source.

Extrinsic evidence - Evidence NOT contained in the deed, but offered to clear up an ambiguity found to exist when applying the description to the ground.

Grant - A transfer of property.

Grantee - The person to whom a grant is made.

Grantor - The person by whom a grant is made.

Good faith - An honest intention to abstain from taking advantage of another.

Gradient - An inclined surface. The change in elevation per unit of horizontal distance.

Hereditament - An area between two surveys of record described as having one or more common boundary lines with no omission.

Holograph - A will written entirely by the testator in his own handwriting.

Incumbrance - A right, interest in, or legal liability upon real property which does not prohibit passing title to the land but which diminishes its value.

Ingress - The true meaning (from the written words of an instrument).

Intestate - Without making a will.

Judgment - The official and authentic decision of a court of justice.

Leasehold - An estate in realty held under a lease; an estate for a fixed term of years.

Lessee - He to whom a lease is made.

Lessor - He who grants a lease.

Lien - A claim or charge on property for payment of some debt, obligation, or duty.

Lis pendens - A pending suit. A notice of lis pendens is filed for the purpose of warning all persons that a suit is pending.

Litigation - Contest in a court of justice for the purpose of enforcing a right.

Littoral - Belonging to the shore, as of seas and lakes.

Logical relevancy - A relationship in logic between the fact for which evidence is offered and a fact in issue such that the existence of the former renders probable or improbable the existence of the latter.

Mean - Intermediate; the middle between two extremes.

Memorial - That which contains the particulars of a deed, etc. In practice, a memorial is a short note, abstract, memorandum, or rough draft of the orders of the court, from which the records thereof may at any time be fully made up.

Mortgage - A conditional conveyance of an estate as a pledge for the security of a debt.

Muniment - Documentary evidence of title.

Option - The right as granted in a contract or by an initial payment, of acquiring something in the future.

Parcel - A part or piece of land that cannot be identified by a lot or tract number.

Parol evidence - Evidence which is given verbally.

Patent - A government grant of land. The instrument by which a government conveys title to land.

Plat - A scaled diagram showing boundaries of a tract of land or subdivisions. May constitute a legal description of the land and be used in lieu of a written description.

Power of attorney - A written document given by one person to another authorizing the latter to act for the former.

Prescription - Creation of an easement under claim of right by use of land which has been open, continuous, and exclusive for a period of time prescribed by law.

Prima facie evidence - Facts presumed to be true unless disproved by evidence to the contrary.

Privity - The relationship which exists between parties to a contract. Mutual or successive relationship to the same rights of property, such as the relationship of heir with ancestor or donee with donor.

Privy - A person who is in privity with another.

Probate - The act or process of validating a will.

Quiet title - Action of law to remove an adverse claim or cloud on title.

Quitclaim deed - A conveyance which passes any title, interest, or claim which the grantor may have.

Reliction - A gradual and imperceptible recession of water, resulting in increased shoreline, beach, or property.

Relinquishment - the forsaking, abandonment, renouncement, or gift of a right.

Remand - To send a cause back to the same court out of which it came for the purpose of having some action taken upon it there.

Riparian - Belonging or relating to the bank of a river.

Royalty - A share of the profit from sale of minerals paid to the owner of the property by the lessee.

Said - Refers to one previously mentioned.

Scrivener - A person whose occupation is to draw up contracts, write deeds and mortgages, and prepare other written instruments.

Shore - The space lying between the line of ordinary high tide and the line of lowest tide.

Sovereign - A person, body, or state in which independent and supreme authority is vested.

Squatter - One who settles on another's land without legal authority.

Statute - A particular law established by the legislative branch of government.

Statutory - Relating to a statute.

Submerged land - In tidal areas, land which extends seaward from the shore and is continuously covered during the ebb and flow of the tide.

Substantive evidence - Evidence used to prove a fact (as opposed to evidence given for the purpose of discrediting a claim).

Tenancy by entirety - Husband and wife each possesses the entire estate in order that, upon the death of either spouse, the survivor is entitled to the estate in its entirety.

Tenancy, Joint - The holding of property by two or more persons, each of whom has an undivided interest. After the death of one of the joint tenants, the surviving tenant(s) receive the descendent's share.

Tenant - One who has the temporary use and occupation of real property owned by another person (the landlord).

Tenements - Property held by tenant. Everything of permanent nature. In more restrictive sense, house or dwelling.

Testament - A will of personal property.

Testator - One who makes a testament or will. One who dies leaving a will.

Thalweg - The deepest part of channel.

Thence - From that place; the following course is continuous from the one before it.

Title policy - Insurance against loss or damage resulting from defects or failure of title to a particular parcel of land.

To wit - That is to say; namely.

Upland - Land above mean high-water and subject to private ownership (as distinguished from tidelands which are in the state.) Also used as meaning NON-riparian.

Watercourse - A running stream of water fed from permanent or natural sources running in a particular direction and having a channel formed by a well-defined bed and banks (though it need not flow continuously).

Warranty deed - A deed in which the grantor proclaims that he is the lawful owner of real property and will forever defend the grantee against any claim on the property.

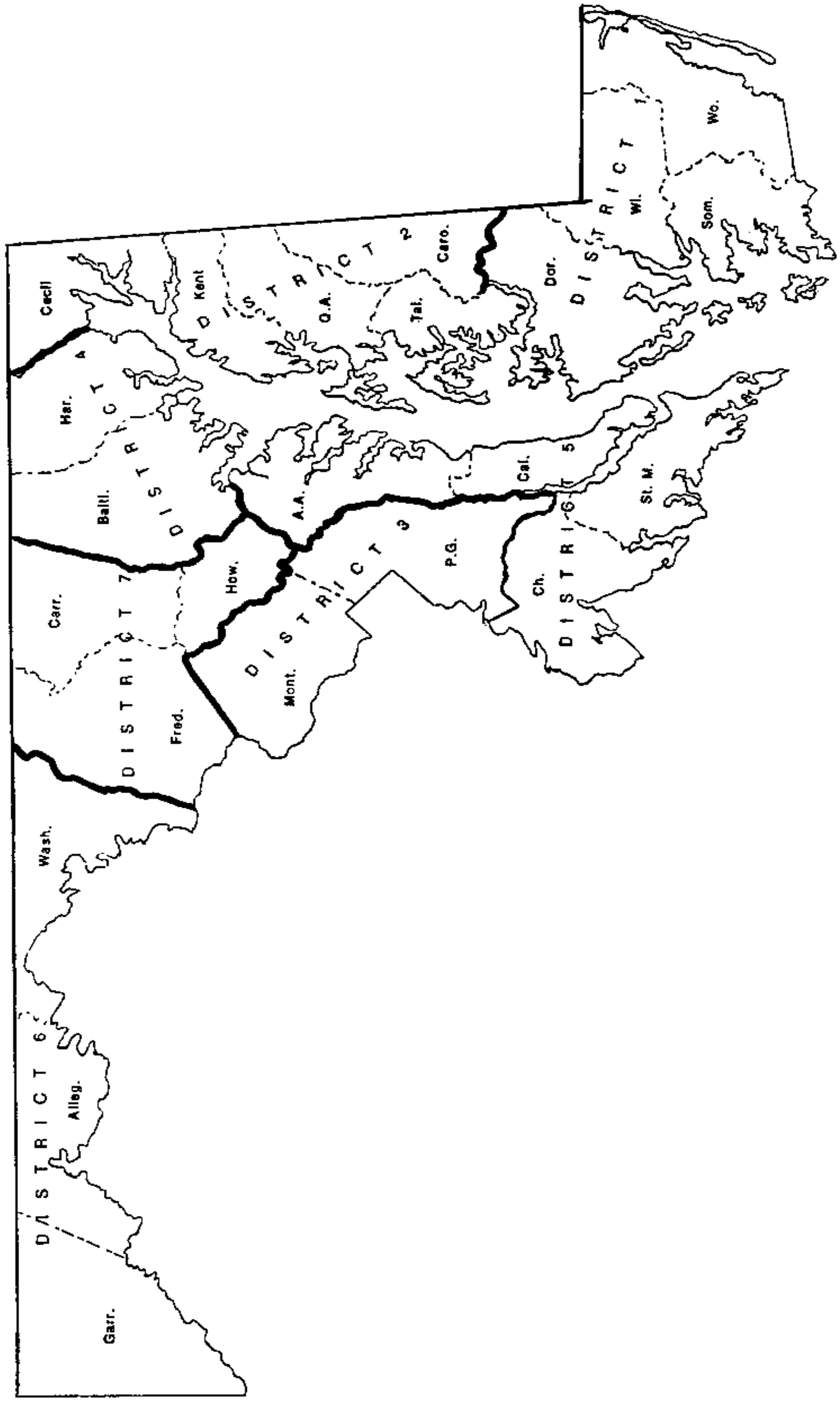
Will - The legal declaration of a person's wishes as to the disposition of his property after his death.

Witness mark - A mark placed at a known location to aid in recovery and identification of a monument or corner.

Writ - A mandatory order issued from a court of justice.

Writ of coram nobis - A common law writ, the purpose of which is to correct an error in a judgment in the same court in which it was rendered.

B. SHA ENGINEERING DISTRICTS



BANK, TOE TOE

C. ABBREVIATIONS

BANK, TOP	TB
BENCHMARK	BM
BILLBOARD	BB
BORING, HOLE	BH
BRIDGE, ABUTMENT	ABUT
BRIDGE, BEAM BOTTOM	BRBM
BRIDGE, DECK	BRDK
BRIDGE, EDGE	EBR
BRIDGE, EXPAN.JOINT	BRJNT
BRIDGE, PAD EDGE	BPAD
BRIDGE, PIER EDGE	PIER
BRIDGE, RR.EDGE	ERRBR
BRUSH LINE	BRLN
BUILDING	BLDG
BUILDING, COMMERCIAL	CBLDG
BUILDING, GARAGE	GBLDG
BUILDING, SHED	SHED
BUSH/SHRUB LINE	BULN
BUSH/SHRUB	BUSH
COMB. TEL./ELECT	T&EP
COMB. TP/EP/STL	TEPL
CULVERT, BOX BOTTOM	BBXC
CULVERT, BOX INSD.TOP	TBXC
CURB, & GUTTER COMB	C&G
CURB, BOTTOM	BC
CURB, DEPRESSED	DEPC
CURB, TOP BACK	TCB
CURB, TOP	TC
DISK BRASS NGS/ST/CO	DISK
DITCH, BOTTOM	BD
DITCH, TOP	TD
DRIVEWAY, CENTER	CLDR
DRIVEWAY, EDGE	DR
DWELLING	DWG
ELECTRIC, MANHOLE	EMH
ELECTRIC, POLE LIGHT	EPL
ELECTRIC, POLE TRFORM	EPT
ELECTRIC, POLE	EP
ELECTRIC, UNGRD.SIGN	EUGSGN
ELECTRIC, WIRE ELE.	EWELV
FENCE, BARBED WIRE	BAFEN
FENCE, BOARD	BDFEN
FENCE, CHAIN LINK	CLFEN
FENCE, CORNER POST	CFEN
FENCE, POST & RAIL	PRFEN
FENCE, POST	PFEN
FIELD, CULTIVATED	CULT
FIELD, MEADOW	MEAD
FIELD, PASTURE	PAST
FIRE HYDRANT	FH
FIRST FLOOR, ELEV	FFELV

C. ABBREVIATIONS

FLOWLINE	FLOW
FOOTING/FOUNDATION	FTG
GAS MANHOLE	GMH
GAS UNDRN. SIGN	GUGSGN
GAS VALVE	GV
GATE, POST	GATE
GRASS	GRASS
GROUND, ORIGINAL	RG
GROUND, SPOT GRADE	SG
GUARD, RAIL CON.ANCH.	GRCAN
GUARD, RAIL DOUB.STEEL	DSGR
GUARD, RAIL STEEL	SGR
GUARD, RAIL(POST&CABLE)	CGR
GUTTER, EDGE	GUT
GUY POLE	GUYP
GUY WIRE (ANCHOR)	GUY
HANDRAIL	HDRL
HEADWALL, BOTTOM	BHDW
HEADWALL, TOP	THDW
HEDGE, ROW	HEDGE
HUB, & TACK	H&T
INLET, (GENERIC)	INL
INLET, DROP EDGE	DI
INVERT	INV
JERSEY WALL, BOTTOM	BJW
JERSEY WALL, TOP	TJW
LAWN	LAWN
LIGHT, POLE	LP
LIGHT, STREET STEEL	STL
LIGHT, STREET WOODEN	WSTL
MAILBOX	MB
MANHOLE, UNKNOWN	MH
MONUMENT, CON.XCUT	CMXC
MONUMENT, CONCRETE	CM
MONUMENT, IRON PIN	CMIP
NAIL, ON LINE	NOL
NAIL, PARK KALON	PK
PARAPET WALL, BOTTOM	BPW
PARAPET WALL, TOP	TPW
PARKING LOT, EDGE	PLOT
PIPE 4IN. UP	PIPE
PIPE, CORRUGATED METAL	CMP
PIPE, IRON PROPERTY	IPP
PIPE, PINCH PROPERTY	IPPP
PIPE, RENINFORCED CON	RCP
PIPE, TERRACOTTA	TCP
PLANTER	PLNT
POOL, EDGE	POOL
PORCH, EDGE	PORCH
PROPERTY, STONE	STONE
RAILROAD, BALLAST TOE	TOEB
RAILROAD, BALLAST TOP	TBAL

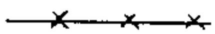
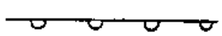
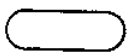
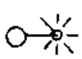
C. ABBREVIATIONS

RAILROAD, CATENARY PL	CATP
RAILROAD, CENTER LINE	CLRR
RAILROAD, CRSS SIGNAL	RRSNL
RAILROAD, INDS.GUAGE	GAUGE
RAILROAD, SWITCH FROG	FROG
RAILROAD, SWITCH	RRSW
RAMP, HANDICAP	RAMP
REBAR, &CAP PROPERTY	PR&C
REBAR, &CAP SHA	R&C
REBAR	REBAR
REFERENCE	REF
RIVER,CL	CLRIV
RIVER, EDGE	RIV
ROAD, ACCEL.LANE EDGE	EAL
ROAD, CENTER	CLRD
ROAD, DECEL.LANE EDGE	EDL
ROAD, EDGE	ER
ROAD, PGL	PGL
S. SEWER CLEAN OUT	CO
S. SEWER FORCE MAIN	SSFM
S. SEWER LINE	SANL
S. SEWER MANHOLE	SSMH
S. SEWER, INVERT	SSINV
SHOULDER, EDGE	ES
SIDEWALK, EDGE	SDWK
SIGN	SIGN
SIGN, COMMERCIAL	CSG
SIGN, CON. BASE OVRHD	OHSGB
SIGN, CON. BASE	SGB
SIGN, STOP	STP
SIGN, YIELD	YLD
SLAB, CONCRETE	CONS
SPIKE, RAILROAD	RRSP
SPIKE, SHA/BOAT	SHASP
SPRING	SPR
STAKE	SOL
STEPS	STEP
STREAM, CONFLUENCE	CONF
STREAM, EDGE	STR
STRM.DRN.CATCH BASIN	CB
STRM.DRN.INVERT	SDINV
STRM.DRN.MANHOLE	SDMH
T.V. LINE ELEVATION	TVL
T.V. PEDESTAL	TVP
TELE., LINE ELEV	TWELV
TELE. UNGRD.SIGN	TUGSGN
TELEPHONE, MANHOLE	TMH
TELEPHONE, PEDESTAL	TPED
TELEPHONE, POLE	TP
TRAF. CABINGET POLE	CABP
TRAF. LOOP DETECTOR	LOOP
TRAF. PAINT STOP BAR.	PSTPB

C. ABBREVIATIONS

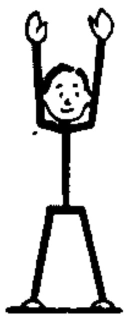
TRAF. SIGNAL POLE	TRSP
TRAFFIC, CABLE WIRE	TRCBL
TRAFFIC LIGHT	TRL
TRANSFORMER	TRN
TREE, CONIFEROUS	EVG
TREE, DECIDUOUS	ORCH
TREE, WOODS LINE	WOOD
WALL, EDGE	WALL
WALL, RETAINING	RETW
WATER, METER	WM
WATER, TOP	TWTR
WATER, VALVE	WV
WELL, STEEL CASING	WELL
WETLAND, BOUNDARY	WETB
WETLAND/SWAMP	SWAMP
WINGWALL, BOTTOM	BWW
WINGWALL, TOP	TWW

D. FIELD NOTE TOPO SYMBOLS

	BUSH
	BUSH OR HEDGE ROW
	CROSS, CHISELED MONUMENT OR STATION
	CONCRETE MONUMENT (DIMENSION)
	FENCE (TYPE AND HEIGHT)
	FIRE HYDRANT
	GUARD RAIL (LABEL TYPE)
	GUY WIRE
	IRON PIPE (SIZE)
	LOOP DETECTOR
	MAN HOLE (TYPE)
	METER OR VALVE (TYPE)
	UNDERGROUND PIPE (TYPE,SIZE, AND DIRECTION OF FLOW)
	POLE-CABINET (OWNER/NUMBER)
	POLE-LIGHT (OWNER/NUMBER)
	POLE-POWER (OWNER/NUMBER)
	POLE-TRANSFORMER (OWNER/NUMBER)
	POLE-TELEPHONE (OWNER/NUMBER)
	TRAFFIC SIGNAL (SHOW DIRECTION)
	TREE (TYPE AND SIZE)

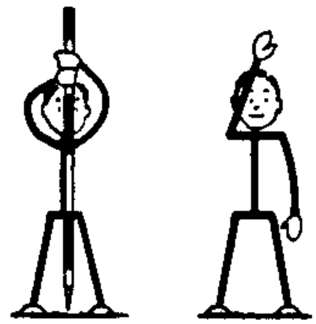
E. STANDARD ARM SIGNALS

LINE



INSTRUMENTMAN WANTS SIGHT ON A POINT OR TO SET A NEW SETUP POINT

WANTS LINE

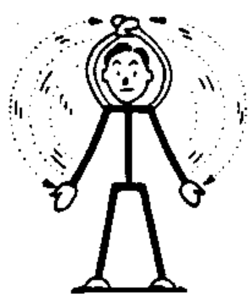


HOLD RANGE POLE, PLUMB BOB, STAKE, OR HAND ABOVE HEAD

MOVE LEFT OR RIGHT

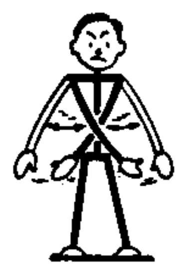
MOVE ONE ARM OUTWARD HORIZONTALLY ON SIDE TOWARD WHICH CHANGE IS DESIRED. SLOW MOTION MEANS A LARGE DISTANCE AND A QUICK MOTION A SMALL DISTANCE

GOOD



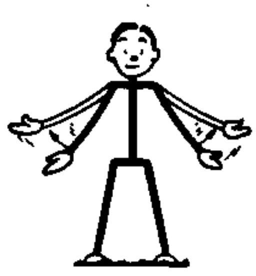
EXTEND ARMS SIDEWARD AND WAVE UP AND DOWN

NO GOOD



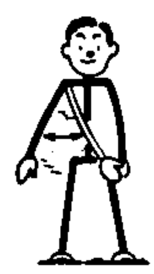
START WITH ARMS OUTWARD AND DOWNWARD; MOVE THEM BACK AND FORTH, CROSSING IN FRONT OF BODY

PICKUP–COME AHEAD



EXTEND ARMS SIDEWARD AND DOWNWARD; RAISE THEM QUICKLY

CLEAR LINE OR CAN'T SEE



START WITH ARM HELD OUTWARD AND DOWNWARD. WAVE BACK AND FORTH IN FRONT OF BODY

E. STANDARD ARM SIGNALS

PLUMB POLE OR ROD

RAISE ARM STRAIGHT ABOVE HEAD AND MOVE SLOWLY IN DIRECTION THAT CORRECTION IS DESIRED

RETURN TO TRUCK

FACE IN OPPOSITE DIRECTION, EXTEND ARMS SIDEWARD AND WAVE UP AND DOWN

CUT

MAKE SLICING MOTION ACROSS THROAT WITH SIDE OF EITHER HAND

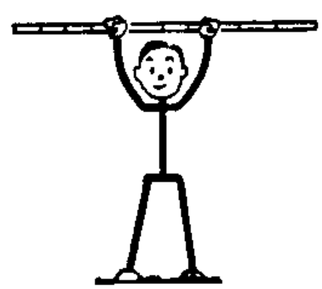
ADD

TAP TOP OF HEAD WITH EXAGGERATED MOTION

TURNING POINT

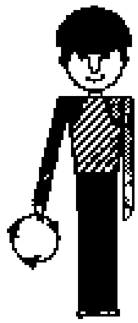
RAISE ARM ABOVE HEAD AND DESCRIBE A CIRCLE IN A HORIZONTAL PLANE

BENCH MARK



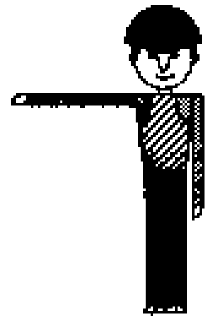
HOLD LEVEL ROD HORIZONTALLY OVER THE HEAD (WITH BOTH ARMS EXTENDED)

E. STANDARD ARM SIGNALS-NUMBERS



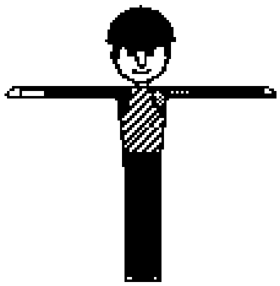
ZERO

MADE BY ROTATING ARM IN A CIRCULAR MOTION



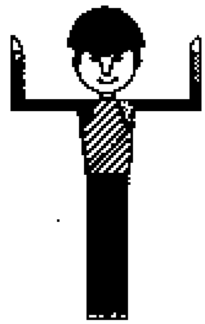
ONE

MADE BY EXTENDING ONE ARM STRAIGHT OUT AND HOLDING OTHER ARM AT SIDE



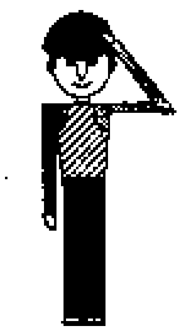
TWO

MADE BY EXTENDING BOTH ARMS OUTWARD



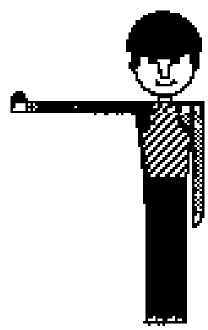
THREE

MADE BY HOLDING ARMS BENT AT ELBOW SKYWARD



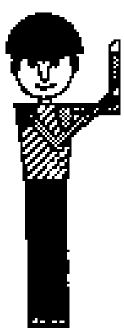
FOUR

MADE BY HOLDING HEAD WITH ONE HAND



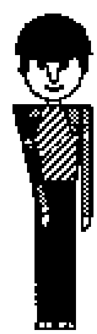
FIVE

MADE BY HOLDING ONE ARM STRAIGHT OUT IN FRONT OF YOU WITH FIVE FINGERS SHOWING



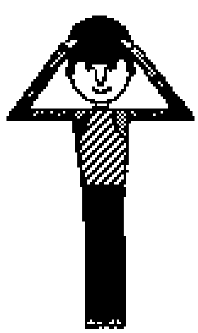
SIX

MADE BY HOLDING ONE ARM WITH OTHER HAND



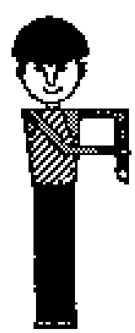
SEVEN

MADE BY PLACING HAND OVER CROTCH



EIGHT

MADE BY HOLDING YOUR HEAD WITH BOTH HANDS

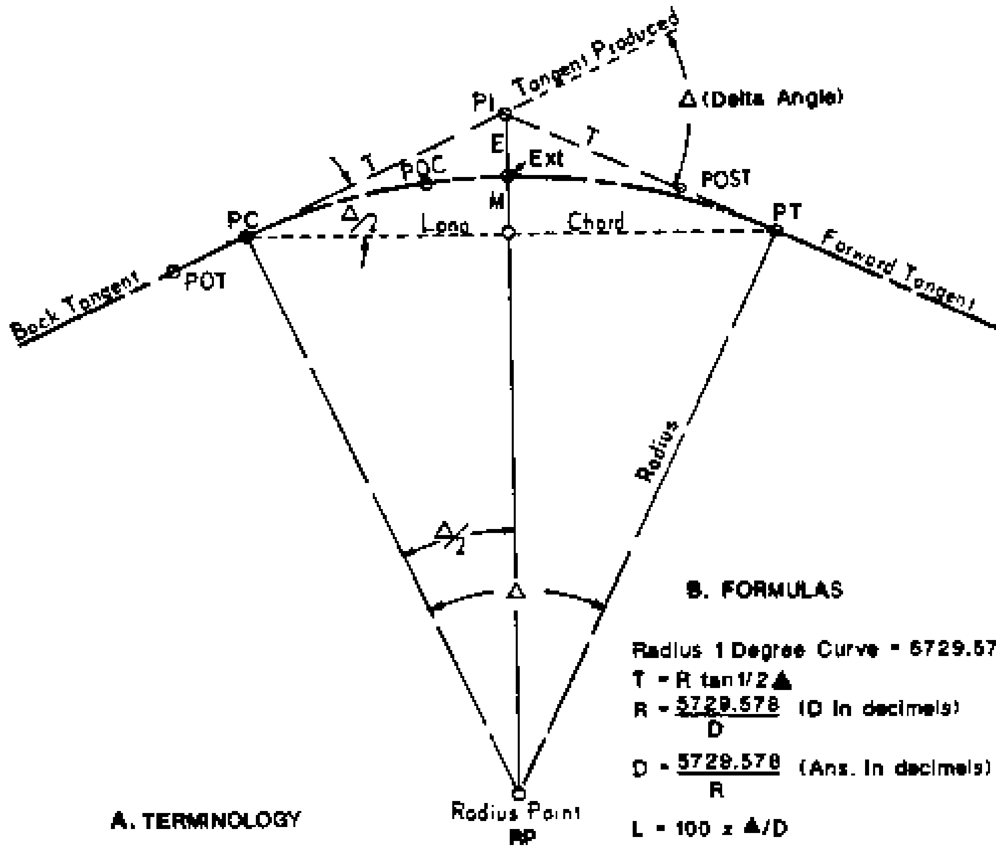


NINE

MADE BY HOLDING ONE ARM DOWNWARDS AND HOLDING IT WITH THE OTHER HAND

F. CURVES

PARTS OF A CIRCULAR CURVE



B. FORMULAS

Radius 1 Degree Curve = 5729.578

$T = R \tan 1/2 \Delta$

$R = \frac{5729.578}{D}$ (D in decimals)

$D = \frac{5729.578}{R}$ (Ans. in decimals)

$L = 100 \times \Delta / D$

$E = T \tan 1/4 \Delta$

$LC = 2R \sin 1/2 \Delta$

$C = 2R \sin DefA$ (DefA in decimals)

$Df = .3 \times D$ (D in decimals–ans. in minutes)

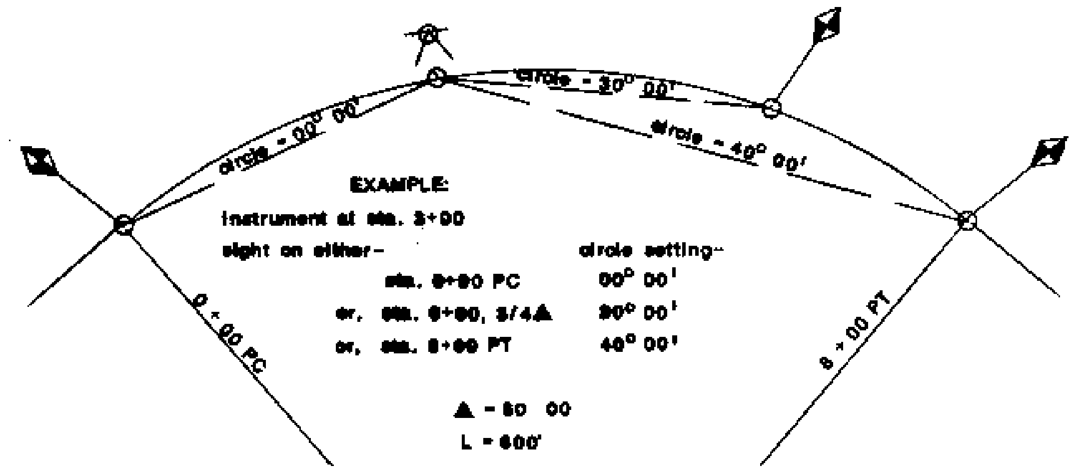
$= \frac{1718.873385}{R}$

$M = R \text{ vers } 1/2 \Delta$

A. TERMINOLOGY

Δ = Central Angle of Curve at RP or deflection angle between back and forward tangents
D = Degree of Curve
R = Radius
T = Semi-Tangent
L = Length of Curve
E = External Distance
LC = Long Chord
PC = Point of Curvature (Beginning of Curve)
PT = Point of Tangency (End of Curve)
Ext = Mid-Point of Curve (External)
PI = Point of Intersection (of back and forward tangents)
POC = Point on Curve
POT = Point on Tangent
POST = Point on Semi-Tangent
C = Chord
RP = Radius Point (center of curve)
DefA = Deflection Angle
Df = Deflection per Foot
M = Middle Ordinate

F. CURVES

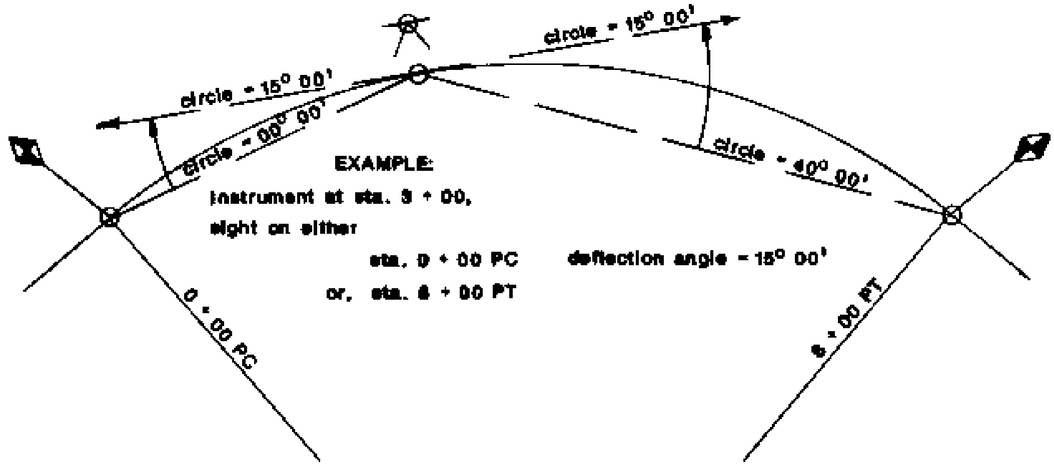


I. SET THE CIRCLE OF THE INSTRUMENT TO "READ" THE DEFLECTION ANGLE OF THE STATION SIGHTED.

II. ON A CURVE TO THE RIGHT USE THE CLOCKWISE CIRCLE.

III. ON A CURVE TO THE LEFT USE THE COUNTER-CLOCKWISE CIRCLE.

c. ORIENTATION OF AN INSTRUMENT AT A POC



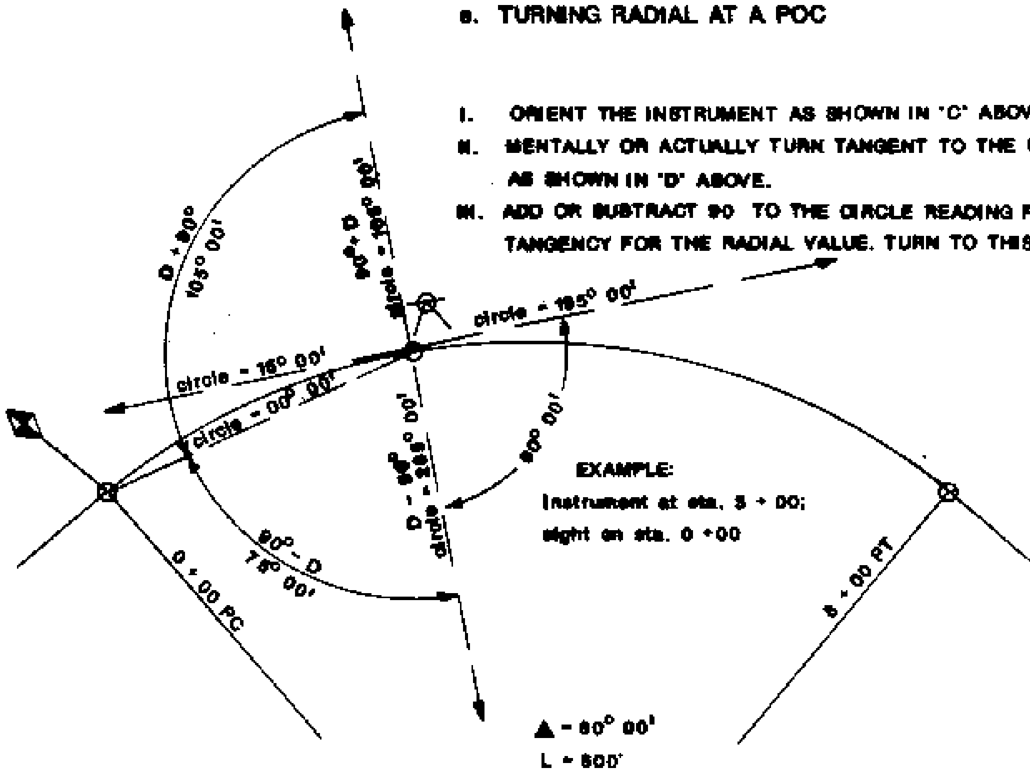
I. ORIENT THE INSTRUMENT AS SHOWN IN "C", ABOVE.

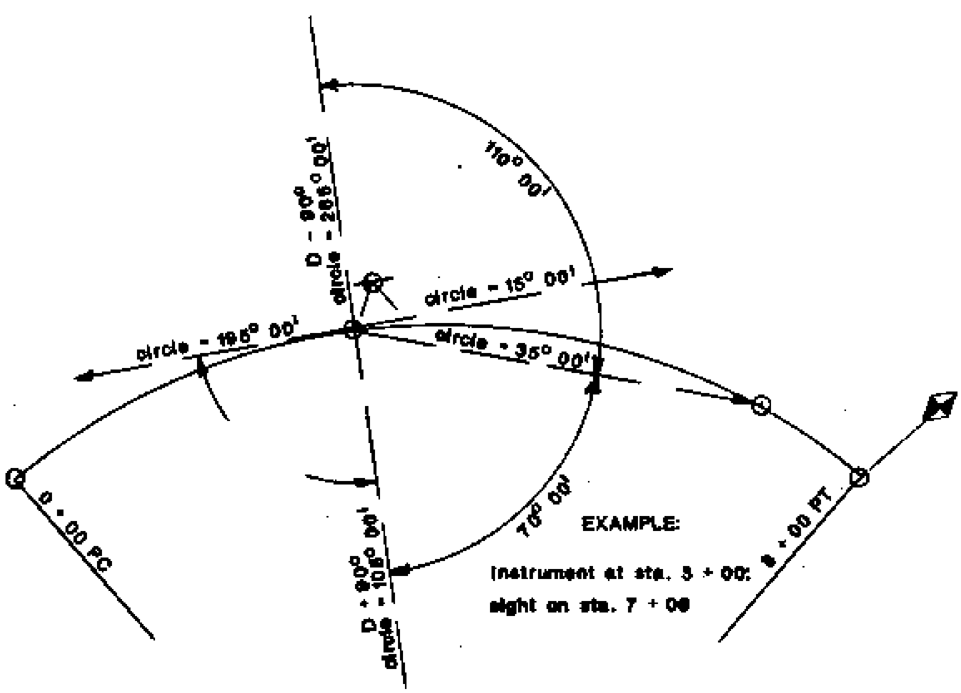
II. TURN TO THE DEFLECTION ANGLE OF THE STATION OCCUPIED.

d. TURNING TANGENT TO THE CURVE AT A POC

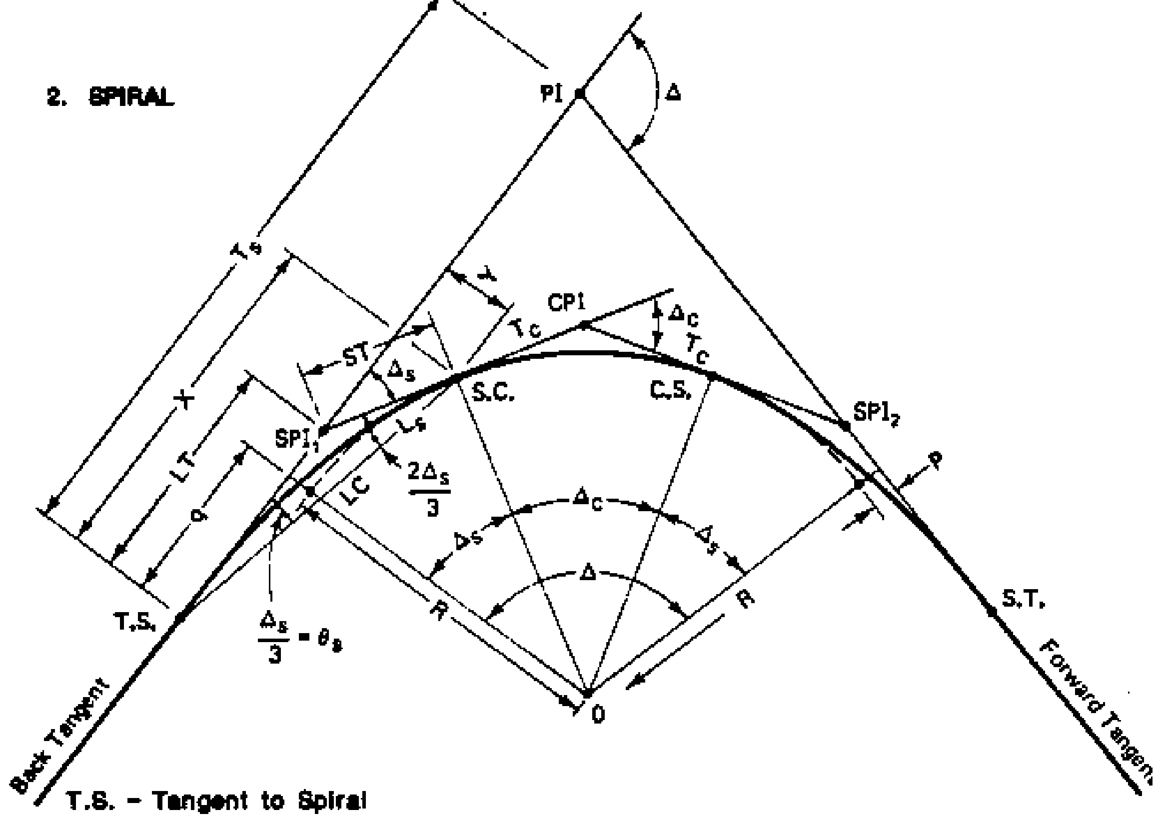
e. TURNING RADIAL AT A POC

I. ORIENT THE INSTRUMENT AS SHOWN IN 'C' ABOVE
II. MENTALLY OR ACTUALLY TURN TANGENT TO THE CURVE AS SHOWN IN 'D' ABOVE.
III. ADD OR SUBTRACT 90 TO THE CIRCLE READING FOR TANGENCY FOR THE RADIAL VALUE. TURN TO THIS VALUE.





2. SPIRAL

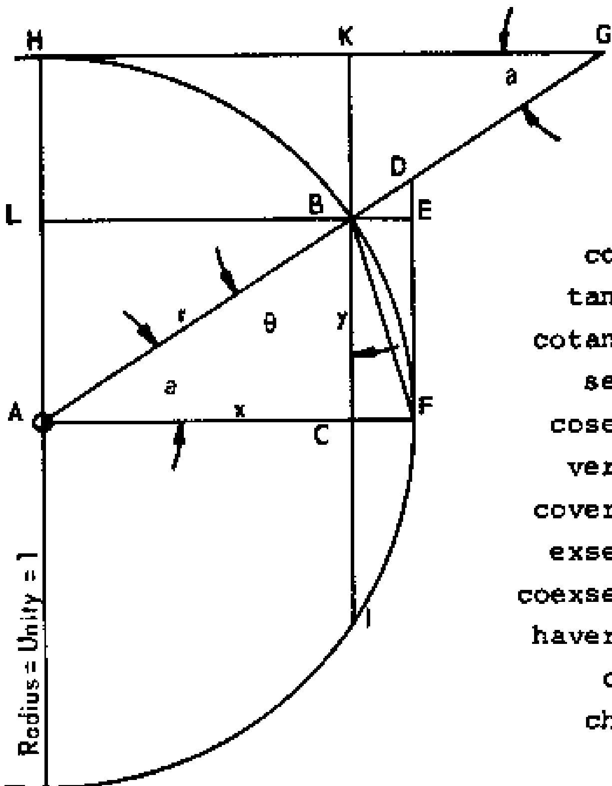


T.S. – Tangent to Spiral
S.C. – Spiral to Curve
C.S. – Curve to Spiral
S.T. – Spiral to Tangent
T_s – Spiral Tangent
X – Distance along Tangent from T.S. to Point at Right Angle to S.C.
Y – Right Angle Distance from Tangent to S.C.
LT – Long Tangent (Spiral)
ST – Short Tangent (Spiral)
L_s – Length of Spiral (Arc)
LC – Long Chord
q – Distance along Tangent to a Point at Right Angle to Ghost PC
p – Distance from Tangent that the Curve (Ghost PC) has been Offset
T_c – Circular Curve Tangent
CPI – Circular Curve PI
SPI – Spiral Curve PI
PI. – Point of Intersection of Curve Tangents
L_c – Length of Circular Curve
L – Length of Curve System–TS to ST

SPIRAL CURVE – GEOMETRY AND SYMBOLS

G. BASIC TRIGONOMETRY

1 UNIT CIRCLE and FORMULAS



Radius = Unity = 1
AF = AB = AH = 1

a = angle BAC
θ = angle ABC

sine a = BC = 1/csc a

cosine a = AC = 1/sec a

tangent a = DF = 1/cot a

cotangent a = GH = 1/tan a

secant a = AD = 1/cos a

cosecant a = AG = 1/sin a

versine a = BE = CF = 1 - cos a

coversine a = BK = HL = 1 - sin a

exsecant a = BD = sec a - 1

coexsecant a = BG = csc a - 1

haversine a = ½ vers a

chord a = BF

chord 2a = 2BC = 2sin a

Hypotenuse of a = AB = r; Adjacent Side = AC = x; Opposite Side = BC = y

$\sin a = y/r = \cos\theta$

$\cos a = x/r = \sin\theta$

$\tan a = y/x = \cot\theta$

$\cot a = x/y = \tan\theta$

$\sec a = r/x = \csc\theta$

$\csc a = r/y = \sec\theta$

$\text{vers } a = \frac{r-x}{r} = 1 - \frac{x}{r} = \text{covers } \theta$

$\text{exsec } a = \frac{r-x}{x} = \frac{r}{x} - 1 = \text{coexsec } \theta$

$\text{covers } a = \frac{r-y}{r} = 1 - \frac{y}{r} = \text{vers } \theta$

$\text{coexsec } a = \frac{r-y}{y} = \frac{r}{y} - 1 = \text{exsec } \theta$

$y = \sqrt{(r+x)(r-x)} = \sqrt{r^2 - x^2}$

$x = \sqrt{(r+y)(r-y)} = \sqrt{r^2 - y^2}$

$r = \sqrt{x^2 + y^2}$

G. BASIC TRIGONOMETRY

2. TRIGONOMETRIC FUNCTIONS in ANY QUADRANT

a Functions in terms of angles in the first quadrant –

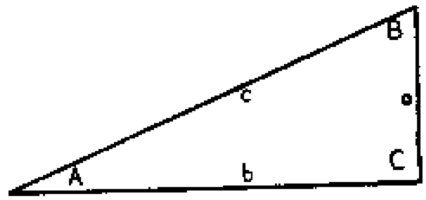
ANGLE / FUNCTION	$90^\circ \pm a$	$180^\circ \pm a$	$270^\circ \pm a$	$360^\circ \pm a$
sine	$+\cos a$	$\mp \sin a$	$-\cos a$	$\pm \sin a$
cosine	$\mp \sin a$	$-\cos a$	$\pm \sin a$	$+\cos a$
tangent	$\mp \cot a$	$\pm \tan a$	$\mp \cot a$	$\pm \tan a$
cotangent	$\mp \tan a$	$\pm \cot a$	$\mp \tan a$	$\pm \cot a$
secant	$\mp \mathrm{cosec}\ a$	$-\sec a$	$\pm \mathrm{cosec}\ a$	$+\sec a$
cosecant	$+\sec a$	$\mp \mathrm{cosec}\ a$	$-\sec a$	$\pm \mathrm{cosec}\ a$

b Signs and value range of functions in all quadrants –

Quadrant	I	II	III	IV	Angle		
Angles	0° to 90°	90° to 180°	180° to 270°	270° to 360°	30°	45°	60°
Functions	Values vary from				Equivalent Values		
Sine	+0 to +1	+1 to +0	−0 to −1	−1 to −0	0.5	$0.5\sqrt{2}$	$0.5\sqrt{3}$
Cosine	+1 to +0	−0 to −1	−1 to −0	+0 to +1	$0.5\sqrt{3}$	$0.5\sqrt{2}$	0.5
Tangent	$+0$ to $+\infty$	$-\infty$ to -0	$+0$ to $+\infty$	$-\infty$ to -0	$1/3\ \sqrt{3}$	1	$\sqrt{3}$
Cotangent	$+\infty$ to $+0$	-0 to $-\infty$	$+\infty$ to $+0$	-0 to $-\infty$	$\sqrt{3}$	1	$1/3\ \sqrt{3}$
Secant	$+1$ to $+\infty$	$-\infty$ to -1	-1 to $-\infty$	$+\infty$ to $+1$	$2/3\ \sqrt{3}$	$\sqrt{2}$	2
Cosecant	$+\infty$ to $+1$	$+1$ to $+\infty$	$-\infty$ to -1	-1 to $-\infty$	2	$\sqrt{2}$	$2/3\ \sqrt{3}$

G. BASIC TRIGONOMETRY

3. RIGHT TRIANGLES

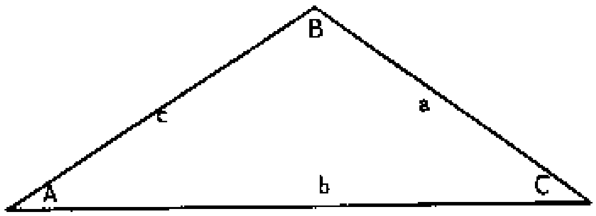


$C = 90^\circ$

GIVEN	TO FIND	FORMULAS
a, c	b A B	$\sqrt{c^2 - a^2}$ $\sin A = a/c$ $\cos B = a/c$
	Area	$\frac{a}{2}\sqrt{c^2 - a^2}$
b, c	a A B	$\sqrt{c^2 - b^2}$ $\cos A = b/c$ $\sin B = b/c$
	Area	$\frac{b}{2}\sqrt{c^2 - b^2}$
a, b	c A B	$\sqrt{a^2 + b^2}$ $\tan A = a/b$; $\cot A = b/a$ $\tan B = b/a$; $\cot B = a/b$
	Area	$ab/2$
A, a	b c B	$a \cot A$ $a/\sin A$ $90^\circ - A$
	Area	$\frac{a^2 \cot A}{2}$
A, b	a c B	$b \tan A$ $b/\cos A$ $90^\circ - A$
	Area	$\frac{b^2 \tan A}{2}$
A, c	a b B	$c \sin A$ $c \cos A$ $90^\circ - A$
	Area	$\frac{c^2(\sin A)(\cos A)}{2} = \frac{c^2 \sin 2A}{4}$

G. BASIC TRIGONOMETRY

4. OBLIQUE TRIANGLES



Law of Sines: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$

Law of Cosines: $a^2 = b^2 + c^2 - 2bc \cos A$

or $\cos A = \frac{b^2 + c^2 - a^2}{2bc}$

GIVEN	TO FIND	FORMULAS
a, b, c	A, B, & C using "s"	Law of Cosines. $\sin \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{bc}}$; $\cos \frac{1}{2} A = \sqrt{\frac{s(s-a)}{bc}}$ $\sin A = \frac{2\sqrt{s(s-a)(s-b)(s-c)}}{bc}$ *NOTE For angles B&C make appropriate substitutions in these formulas* The value "s" = ½(a+b+c)
	Area	$\sqrt{s(s-a)(s-b)(s-c)}$ The value "s" = ½(a+b+c)
a, A, B	b C c	Law of Sines $180^\circ - (A + B)$ Law of Sines ; $\frac{a \sin(A+B)}{\sin A}$
	Area	$\frac{a^2 \sin B \sin(A+B)}{2 \sin A}$
a, b, A	B C c	Law of Sines $180^\circ - (A + B)$ $\frac{a \sin (A + B)}{\sin A}$; Law of Sines
a, b, C	c A B	Law of Cosines $\tan A = \frac{a \sin C}{b-(a \cos C)}$ $180^\circ - (A + C)$
	Area	½ ab sin C
ABC, a	Area	$\frac{a^2 (\sin B)(\sin C)}{2 \sin A}$

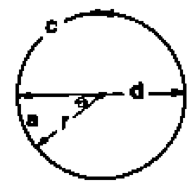
H. PLANE GEOMETRY

1. CIRCLE

a. Linear —

i. Circumference = c
$c = 2\pi$ radius $= 2\pi r$
$c = \pi$ diameter $= \pi d$

ii. Diameter = d
$d = 0.3183c$
$d = c \div \pi$



iii. Radius = r
$r = 0.15915c$
$r = c \div 2\pi$

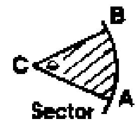
iv. Arc (or curve length) = a
$a = r\theta$ (in radians)
$= \dfrac{\pi r \theta}{180}$

b. Area —

i. Whole circle = A
$A = \pi r^2$
$A = \pi d^2 \div 4 = 0.7854d^2$

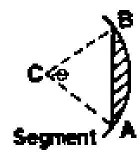
ii. Sector = ASec.
ASec. = $\widehat{CBA}$
ASec. = $\frac{1}{2} r^2\theta$ (in radians)
or $= 0.00872665 r^2\theta$ (in degrees)

$= \dfrac{\pi r^2 \theta}{360}$



iii. Segment = ASeg. (by trigonometry)
ASeg. = $\widehat{BAB}$
ASeg. = ASec. $- \triangle CBA$
ASeg. = $\frac{1}{2} r^2\theta^* - \frac{1}{2} r^2 \sin\theta$
$= \frac{1}{2} r^2 (\theta^* - \sin\theta)$

$^*\theta$ in radians



$= \dfrac{\pi r^2 \theta}{360} - \dfrac{r^2 \sin\theta}{2}$

2. POLYGON — A closed plane figure bounded by straight lines (or sides).

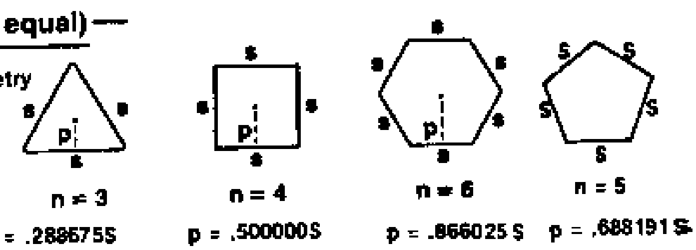
a. Interior angles, sum —

sum = S = (180°) (number of sides − 2)
S = (180°) (n − 2)

b. Area of regular polygon (all sides equal) —

Area = A = $\frac{1}{2}$ n s p ; or by trigonometry

$= \frac{1}{4} n s^2 \cot \dfrac{180}{n}$

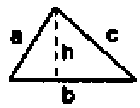


H. PLANE GEOMETRY

3. TRIANGLE — A 3-Sided polygon

a. Area = A

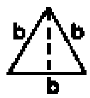
I. $A = \frac{1}{2} bh$



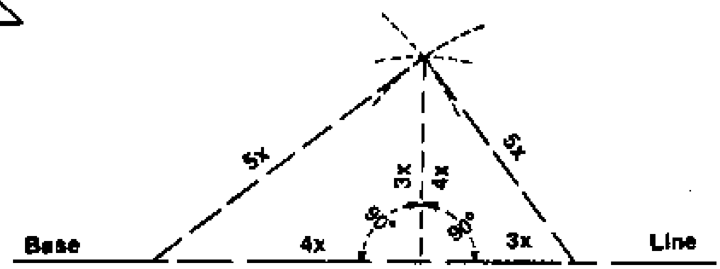
II. $A = 0.433013b^2$

by trigonometry

$= \frac{\sin 60° b^2}{2}$



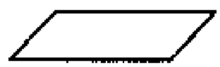
b. 3-4-5 triangle (for laying o perpendicular) —

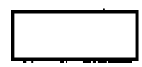


4. QUADRILATERAL — A 4-sided polygon (see formulas below).

5. PARALLELOGRAM — A quadrilateral with opposite sides equal and parallel.

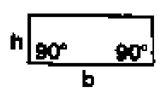
See formulas below





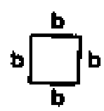
6. RECTANGLE — A parallelogram with 90° angles.

Area = A = bh



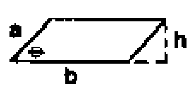
7. SQUARE — An equal-sided rectangle.

Area = A = b^2



8. RHOMBOID — A parallelogram having all angles different than 90°.

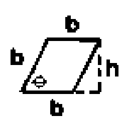
Area = A = bh



by trigonometry
$A = ab \sin \theta$

9. RHOMBUS — An equal-sided rhomboid.

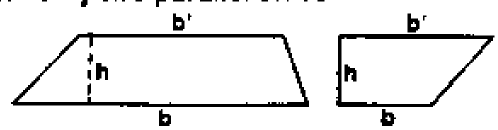
Area = A = bh



by trigonometry
$A = b^2 \sin \theta$

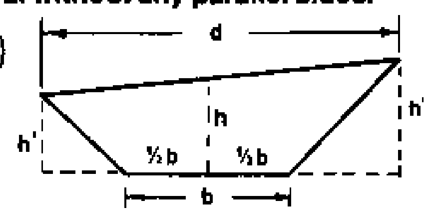
10. TRAPEZOID — A quadrilateral with only two parallel sides.

Area = A = $\frac{1}{2}h\,(b+b')$



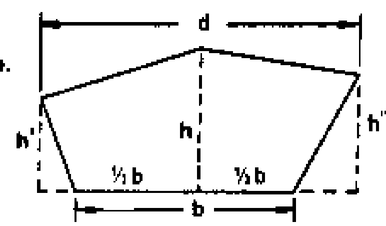
11. TRAPEZIUM — A quadrilateral without any parallel sides.

Area = A = $\left[\frac{1}{2}d\,h\right] + \left[\frac{1}{2}b\,(h' + h'')\right]$



12. PENTAGON, IRREGULAR

For Area, A, use
the trapezium formula, above.

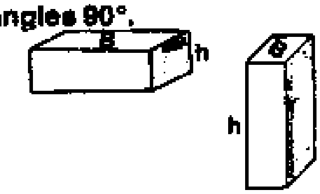


I. VOLUME

1. PARALLELOPIPEDS — A six sided solid; all sides are parallelograms and opposite sides are parallel.

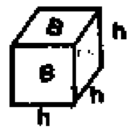
a. Right rectangular prism — a parallelopiped with all angles 90°.

Volume = Bh where, B = area of base
h = height



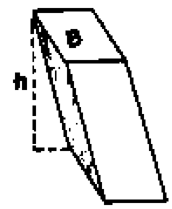
b. Cube — An equal-sided right rectangular prism.

Volume = Bh = (h x h) h
V = h^3



c. Rhombic prism — A parallelopiped without any 90° angles.

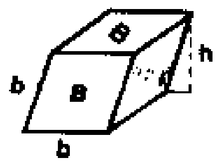
Volume = Bh



Note : "h" = Perpendicular distance between opposite faces.

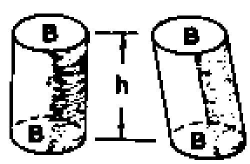
d. Rhombohedrom — An equal-sided rhombic prism.

Volume = Bh



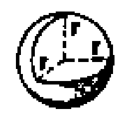
2. CYLINDER

Volume = Bh
= $\pi r^2 h$



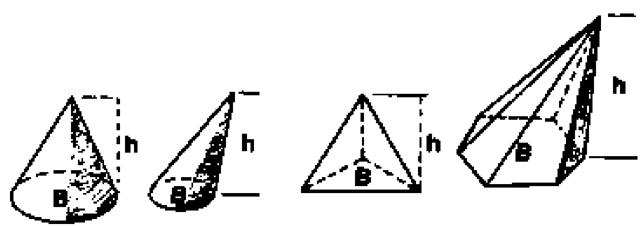
3. SPHERE

Volume = $4/3\ \pi r^3$



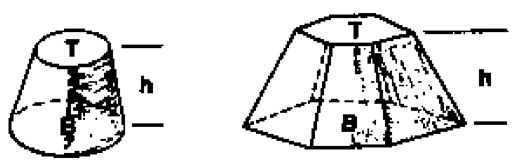
4. PYRAMID and CONE

Volume = ⅓ Bh



5. FRUSTRUMS
(with base & top parallel)

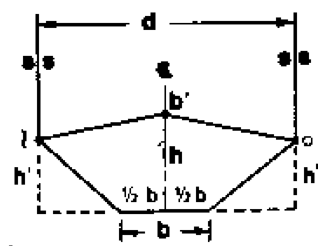
Volume = ⅓ h (T + B + $\sqrt{TB}$)



6. PRISM — A solid whose two ends are parallel, similar, and equal, and whose sides are parallelograms. (A parallelopiped is a prism.)

Volume = Bh

7. EARTHWORK ("Three-Elevation" Sections) —



"Three-elevation" with elevations at each slope stake, *l* and o, and at centerline, b'.

a. Volume by "Average End Areas" (approx.) —

i. **End areas in square feet (approx.) —**

$$\text{Area} = A = \left[\tfrac{1}{2} dh\right] + \left[\tfrac{1}{4} b\,(h' + h'')\right]$$

ii. **Volume in cu. yds. —**

$$V' = \frac{L(A_1 + A_2)}{27}$$

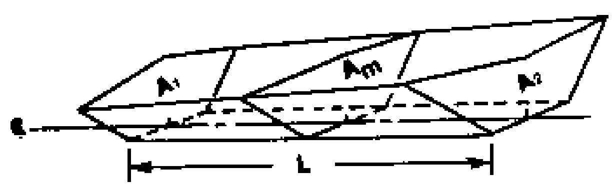
where, L = Distance between end areas, A_1 and A_2, in feet.

iii. **Volume correction in cu. yds. —**

$$V_c = \frac{L}{324}(h_1 - h_2)(d_1 - d_2)$$

iv. **Corrected volume —**

$$V = V' - V_c$$



The area of A_m is calculated by using formula 7ai., above. The values used for d, h, b, h', and h'' are derived by averaging the corresponding values of end sections A_1 and A_2.

b. Prismoidal formula (exact) —

$$V = \frac{L}{6}(A_1 + A_2 + 4A_m)$$

J. CONSTANTS AND USEFUL DATA

1. PI, π — The number which denotes, "the ratio of the circumference of a circle to its diameter".

a. <u>Approximate</u>

$\frac{22}{7}$ or 3.14

b. <u>More exact</u>

3.1415926536

2. RADIAN — The central angle of a circular arc which is equal, in length, to the radius of the arc.

$$\frac{180^\circ}{\pi} = 57.29577951^\circ = \text{One Radian}$$

3. EARTH'S MEAN RADIUS

a. <u>Feet</u> — 20,906,000
b. <u>Miles</u> — 3959.5
c. <u>Kilometres</u> — 6372

4. TEMPERATURE CONVERSION

	F	C
Freezing	32°	0°
Boiling	212°	100
Ratios	1°:0.55° C	1°:1.8°F
C to F	$\frac{9}{5}$ C + 32°	
F to C	$\frac{5}{9}$ (F − 32°)	

5. LENGTHS of ARCS of the EARTH'S SURFACE per DEGREE of ARC

LAT.	Along Meridian	Along Parallel
32°	68.901 st. mi.	58.716 st. mi.
33°	68.912 "	58.071 "
34°	68.923 "	57.407 "
35°	68.935 "	56.725 "
36°	68.946 "	56.027 "
37°	68.958 "	55.311 "
38°	68.969 "	54.579 "
39°	68.981 "	53.829 "
40°	68.993 "	53.063 "
41°	69.006 "	52.281 "
42°	69.018 "	51.483 "
43°	69.030 "	50.669 "

K. SURVEYOR'S MEASURES

1. ABBREVIATIONS

a. U.S. — linear —

Inch	=	in. or "
Link	=	lk.
Foot	=	ft. or '
Yard	=	yd.
Fathom	=	fm.
Rod	=	rd.
Pole	=	pl.
Chain	=	ch.
Furlong	=	fur.
Mile	=	mi.

b. Metric — linear —

Micron	=	μ
Millimetre	=	mm
Centimetre	=	cm
Decimetre	=	dm
Metre	=	m
Decametre	=	dkm
Hectometre	=	hm
Kilometre	=	km
Myriametre	=	mym

c. Square measure — U.S. and metric —

Preface the linear abbreviation with "sq.", as "2 sq. mi.", or add the exponent, "2", as "2 mi^2". Do not confuse these two terms which indicate an area of 2 square miles with the term, "2 miles squared " which indicates an area of 4 square miles.

d. Land area terms — U.S. and metric —

Acre	=	A	Centare	=	ca
Section	=	S	Are	=	a
Township	=	T	Hectare	=	ha

2. LINEAR — U.S.

a. Links —

1 lk.	=	7.92 in.
25 lk.	=	16½ ft. = 1 rd.
100 lk.	=	1 ch.

b. Chains —

1 ch.	=	66 ft. = 100 lk. = 4 rd.
10 ch.	=	1 fur. = ⅛ mi.
80 ch.	=	1 mi.

c. Rods, or poles —

1 rd.	=	16½ ft. = 25 lk.
4 rd.	=	1 ch.
40 rd.	=	1 fur.
320 rd.	=	1 mi.
1 rd.	=	1 pl.

d. Inches, feet, and yards —

12 in.	=	1 ft.
3 ft.	=	1 yd.
5½ yds.	=	1 rd.
5280 ft.	=	1 statute mi.
6076.1033 ft.	=	1 nautical mi
6 ft.	=	1 fm.

K. SURVEYOR'S MEASURES

3. LINEAR — METRIC

a. Metres —

0.001 m	=	1 mm
0.01 m	=	1 cm
0.1 m	=	1 dm
10 m	=	1 dkm
100 m	=	1 hm
1000 m	=	1 km
10000 m	=	1 mym
1852 m	=	1 nautical mi.

b. Millimetres —

1 mm	=	1000 μ
10 mm	=	1 cm
100 mm	=	1 dm
1000 mm	=	1 m

4. AREA — U.S.

a. Acre —

1A	=	43,560 ft^2
1A	=	160 $rd.^2$
1A	=	10 ch^2
640A	=	1 mi^2
640 A	=	1 section, S

b. Square miles —

1 mi^2	=	6400 ch^2
1 mi^2	=	640 A
1 mi^2	=	1S
36 mi^2	=	1T

5. AREA — METRIC

a. Square metres —

1 m^2	=	1 ca		
100 m^2	=	1 dkm^2	=	1a
10,000 m^2	=	1 hm^2	=	1 ha
1,000,000 m^2	=	1 km^2	=	100 ha
100,000,000 m^2	=	1 mym^2		

b. Land area terms —

1 ca	=	1 m^2
1 a	=	100 m^2
1 ha	=	100 a
1 km^2	=	100 ha
1 mym^2	=	10,000 ha,

6. CONVERSIONS — LINEAR, based on, "1 metre = 39.37 inches, exactly"*

a. U.S. to metric —

0.001 ft.	=	0.000304800610 m
0.01 ft.	=	0.00304800610 m
1 in.	=	0.0254000508 m
0.1 ft.	=	0.0304800610 m
1 lk.	=	0.201168402 m
1 ft.	=	0.304800610 m
1 yd.	=	0.914401829 m
1 fm.	=	1.82880366 m
1 rd.	=	5.02921006 m
1 pl.	=	5.02921006 m
1 ch.	=	20.1168402 m
1 frl.	=	201.168402 m
1 mi.	=	1609.34722 m = 1.60934722 km

b. Metric to U.S. —

1 mm	=	0.03937 in. (exact)	= 0.00328083333 ft.
1 cm	=	0.3937 in. (exact)	= 0.0328083333 ft.
1 dm	=	3.937 in. (exact)	= 0.328083333 ft.
1 m	=	3.28083333 ft.	
1 dkm	=	32.8083333 ft.	
1 hm	=	328.083333 ft.	
1 km	=	0.621369949 mi.	
1 mym	=	6.21369949 mi.	

In 1959 the Foot System was redefined in relation to the International Metre. But, the values, "One International Metre=39.37 inches, exactly", is the basis for the American Survey Foot, ASF. The ASF is still used by NGS for all horizontal and vertical control nets. Therefore, the ASF is the standard for MD SHA.

7. CONVERSIONS — AREA

a. U.S. to metric —

1 in.^{2}	=	6.45162581 cm^2		
1 ft.^{2}	=	929.034116 cm^2		
	=	0.0929034116 m^2 = 0.0929034116 ca		
1 yd^2	=	0.836130705 ca		
1 rd^2	=	25.2929538 ca		
1 ch^2	=	404.687261 ca	= 4.04687261 a	
1 A	=	40.4687261 a	= 0.404687261 ha	= 4,046.87261 ca
1 mi^2	=	258.999847 ha	= 2.58999847 km^2	

b. Metric to U.S. —

1 cm^2	=	0.15499969 in.^{2} (exact)	
1 ca	=	10.7638674 ft.^{2}	
1 a	=	1076.38674 ft.^{2}	
1 ha	=	107,638.674 ft.^{2}	= 2.47104393 A
1 km^2	=	247.104393 A	= 0.386100614 mi.^{2}
1 mym^2	=	38.6100614 mi.^{2}	

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