

Survey Manual

Chapter 2

General Procedures

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2.1 Equipment Checking and Calibration

2.1.1 General

Equipment must be properly maintained, regularly checked, and calibrated for accuracy at the beginning of any survey project to ensure that the equipment is operating properly. Errors due to poorly maintained or malfunctioning equipment will not be accepted. If any equipment errors are found to exist they must be reported to the Region Survey Coordinator prior to the start of the survey. These errors will need to be verified and eliminated prior to performing any survey. For surveys lasting longer than six months, the checking, and calibration of equipment shall be repeated once every six months to show that the equipment is staying within acceptable tolerances.

Any variation from the specifications shall have the prior approval of the Region Survey Coordinator.

2.1.2 Equipment

Equipment is defined as any and all types of survey and or office survey equipment used to perform the functions of land surveying. The specifications and procedures as stated in this chapter shall apply to any and all makes and models of equipment. The specific maintenance, adjustment, care, use and, repair information is contained in the owners/operating manual for your instrument. If a particular brand or model of equipment is not specifically addressed within this chapter the manufacturers owners/operating manual shall be consulted for instructions on the care for the equipment.

For GPS equipment see Chapter 3 – GPS Surveys, for additional information.

2.1.3 Equipment Abuse

Any CDOT employee who misuses or abuses any surveying equipment is subject to adverse action in accordance with the policies and procedures of CDOT. Misuse or abuse includes taking CDOT surveying equipment without prior authorization of the Region Survey Coordinator, damaging or losing equipment due to lack of care, or using equipment for personal business.

2.1.4 Electronic Survey Instruments Adjustments, Calibration or Repairs

All electronic survey instruments shall be repaired, adjusted, or calibrated only by an authorized equipment vendor or manufacturers service department.

2.1.5 Equipment Types

There are many types of equipment used to perform the functions of land surveying for CDOT. The types of equipment currently used at CDOT include but are not limited to the following:

1. Global Positioning System receivers, antennas, cables, poles, height rods, etc.
2. Electronic total stations with on-board data collectors
3. Hand-held data collectors
4. Electronic theodolites
5. Electronic digital bar-code levels (First and Second Order)
6. Automatic levels
7. Electronic distance meters
8. Bar code level and automatic level rods
9. Hand-held calculators

10. Lap-top computers
11. Cellular telephones
12. Battery chargers
13. Cables / accessories
14. Tribrachs
15. Prisms
16. Steel and fiberglass tapes
17. Adjustable and fixed height tri-pods
18. Chaining pins, poles, plumb-bobs, right angle prisms
19. Prism poles
20. Magnetic locators
21. Power tools such as saws, grinders, jackhammers, etc.
22. Hand tools such as sledge hammers, shovels, drivers etc.
23. Hand-held two way radios
24. Cameras
25. Barometers / thermometers
26. Traffic control devices
27. First aid kits
28. Vehicles

2.1.6 Survey Crew Responsibilities

The survey crew chief is responsible for the crew's equipment and shall assure that all members are trained to properly care for the equipment and shall delegate the responsibilities accordingly. The crew chief shall also see that the equipment is used for its intended purpose. Members of a crew must understand the absolute necessity of using the proper equipment, in the proper condition, for the given tasks. Proper care and respect for all equipment is required of every survey crew member.

2.1.7 Equipment Care and Protection

For the care and protection of equipment the following rules shall be observed:

1. Care shall be taken when moving survey instruments. Manufacturer's recommendations shall be followed.
2. Instruments such as total stations or theodolites should never be lifted by the standard or horizontal axis, rather by their base or handle.
3. When equipment is being moved to or from its case or tripod, it should be lifted by the base or handle.
4. Never point an instruments telescope directly at the sun as the sun's rays will damage the diodes in the EDM, and may also result in permanent eye damage of the user.
5. Never carry an instrument on its tripod over your shoulder except as indicate by the instruments owners/operating manual.
6. When equipment is being set up, the leveling screws should never be tightened any more than necessary to eliminate looseness. Over tightening damages the fine threads of the leveling screws, and sets up stresses that makes observations erratic and often will deform vital parts of the instrument.

7. Instruments shall be protected from rapid change in temperature. Instruments shall be allowed to acclimatize prior to use in accordance with the manufacturers requirements.
8. All equipment is designed to withstand use in a wide range of weather conditions, but will not withstand forces that stress the parts beyond their elastic limit. Care needs to be taken to not overstress equipment beyond the intended use.
9. Electronic equipment should not be subjected to extended periods of time in wet weather due to possible damage to the electronics.
10. Equipment left set up during rain showers will be covered with a waterproof covering. Equipment that becomes wet shall be allowed to dry prior to storing in its case.
11. Equipment should never be left unattended in areas where it might be knocked over or disturbed by pedestrians, animals, motor vehicles, wind, falling rocks, tree limbs or other causes.
12. Whenever possible, select instrument setup locations to minimize the exposure of the instrument operator, other members of the crew, and the instrument to danger. Select stable ground for the tripod feet.
13. All instruments shall be stored in a safe, secure area when not in use.

2.1.8 Routine Instrument Maintenance

Before using any survey instrument, visually inspect it for damage. Check all machined surfaces including the polished faces of lenses and mirrors. Snug up all clamps and check tangent motions for smooth operation. These should move freely with the absence of binding or gritty sounds.

Clean the instrument exterior frequently. Accumulation of dirt and dust can scratch or mar machined polished surfaces and cause friction and sticking in the motions. Remove dust with a camel's-hair brush and clean soiled non-optical parts with a soft cloth or with a clean chamois. Clean the external surfaces of lenses with a fine lens brush. If necessary, use lens tissue. Do not use silicone treated tissue that can damage coated optics. Do not use any liquids other than pure alcohol. Take care not to scratch lenses or their coating. Never touch optical glass with your fingers. Always use a lens cover when storing in the instrument case. Do not loosen or attempt to clean the internal surface of any lens.

If any instrument or equipment has become wet, unpack it at the end of the day and after wiping it dry with a soft towel or cloth, leave the instrument and any of its accessories outside of the case to dry. Also leave the case open to dry. If the foam inserts for the case are wet, also remove them for drying. Do not replace the instrument in the case until completely dry.

For GPS equipment see Chapter 3 - GPS Surveys, for additional information.

2.1.9 Equipment Maintenance

At the beginning of any survey all survey equipment needed to perform the survey shall be checked and adjusted by the professional land surveyor in responsible charge of the survey under his/her direct supervision and/or checking. All survey equipment shall be checked once every six months thereafter and as needed during the course of the survey, whichever comes first.

Checks shall include but are not limited to the following:

1. GPS equipment – No cracks or visible signs of damage to the receivers or any cabling.
2. Electronic Total Stations and Distant Meters/ Theodolites – No cracks or visible signs of damage. Leveling screws and tangent screws are in adjustment and operate smoothly. Level bubbles are in adjustment and operational. Optical sights are clear, clean, not cracked or chipped. Optical plummet is in adjustment. Bottom of base mount is smooth and not damaged. Horizontal and vertical columniations shall be checked daily adjusted as needed.
3. Electronic / Automatic Levels – No cracks or visible signs of damage. Leveling screws and tangent screws are in adjustment and operate smoothly. Level bubbles are in adjustment and operational. Optical sights are clear, clean, not cracked or chipped. Two Peg test or other test as recommended in the manufacturers owners/operating manual should be performed and adjustments made as needed. (See Chapter 5 – Preliminary Surveys, for additional information.)
4. Level Rods - 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.
5. Prism Poles - Level bubbles are checked and are in adjustment, rod is not bent or damaged, height of rod is correct as reportedly measured, and adjustable rod height clamps are secure.
6. Tribrachs - Optical plummet is in adjustment, level bubble is in adjustment, no lose legs, no loose or missing screws, bottom head is flat and not damaged.
7. Adjustable Leg Tripods - Nuts and bolts are tight, no loose or broken legs, tripod head is tight, flat, and not damaged. A tripod is the base on which your instrument sits and should be kept in good condition so that the instrument can be depended on for the accuracy that it was built to obtain. When the tripod is not in use, the tripod head cap should be used to protect the tripod head.
8. Fixed Height Tripods - Level bubbles are in adjustment, rod is not bent or damaged, height of rod is correct as reportedly measured, legs are secure.
9. Collimators - Level bubble is in adjustment, top and bottom heads are both flat with no damage.
10. Cables - No cuts, breaks, pinch marks or damage.
11. Steel Tapes (Chains) - A steel tape is a precision tool manufactured under rigid specifications and should be treated as such. The steel tape should never be pulled around a post, stake, or wound on a reel so tightly that the tape will stretch beyond the elastic limit. Vehicles should not be allowed to run over steel tapes. The kinks and bends that result will make the tapes inaccurate. Wet or muddy steel tapes should be wiped dry and clean, oiled lightly, and dried again.
12. Hand Levels - The hand level should be kept in adjustment per manufactures guidelines.
13. Power and hand tools such as hammers, shovels, picks, axes, brush hooks, hatchets, etc., should be kept sharp, clean, and the handles in good repair. Broken or cracked handles are to be replaced. Mushroomed heads on chisels and punches must be ground off as flying pieces of steel can cause serious, even fatal injuries. Each member of the survey crew shall assure that all miscellaneous tools are returned to the vehicle and put in their proper place prior to leaving the work site.

14. Vehicles - The care, organization, and general housekeeping of a vehicle are good indications of the attitude of the entire crew. Keep the cab and passenger compartment 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." Vehicles must be kept in good running condition. A regular maintenance program for the vehicle is essential. Needed repairs should be taken care of as soon as possible. Driving in a safe and defensive manner is required of employees operating state vehicles and of contract consultant survey crews.

For GPS equipment see Chapter 3 - GPS Surveys, for additional information.

2.2 Calibrations

2.2.1 General

A calibration check on all types of electronic survey instrumentation is essential to obtain and maintain the tolerances required in this manual. At the beginning of any survey all survey equipment needed to perform the survey shall be calibrated by the professional land surveyor in responsible charge of the survey under his/her direct supervision and/or checking. All survey equipment shall be calibrated once every six months thereafter and as needed during the course of the survey, whichever comes first.

For GPS equipment see Chapter 3 - GPS Surveys, for additional information.

2.2.2 Federal Published Calibration Baseline Check

The National Geodetic Survey (NGS) conducts a cooperative program that provides surveyors with a means for checking and calibration of errors in electronic distances meters (EDM). Publications are available for the procedures for checking of EDM against a Federal Calibrated Baselines from NGS. The unadjusted baseline length accuracy tolerances shall meet or exceed the manufacturers ratings for the equipment used when checked against a calibrated baseline length for both horizontal and vertical.

The checking and calibration of an EDM involves the determination or verification of instrument constants and the assurance that the measured distances meet required accuracy specifications. Although it is not necessary to utilize a measured distance to determine or verify instrument constants, the verification effort is reduced when an accurately measured distance can be used. However, to assure that the measuring capabilities of an instrument have not significantly deteriorated, a known distance of high accuracy or, preferably, a sequence of distances forming a calibration range or base line is required. Experience shows that a base line consisting of four on-line monuments spaced at intervals of 150 m, 400 to 430 m, and 1000 to 1400 m will meet the needs of users for the checking and calibration of EDM.

NGS/NOAA

<http://www.ngs.noaa.gov/CBLINES/calibration.html>

The above link provides information and downloads of Federal Published Calibrated Baselines.

For GPS equipment see Chapter 3 - GPS Surveys, for additional information.

2.2.3 Practical Use and Application of a Calibrated Baseline

- I. The primary purpose for comparing a total station's EDM over a calibrated base line is to make sure it is performing within the manufacturer's stated accuracy. Secondly, it is to determine the instrument constants. The constants should be applied to measured distances only after a sufficient history of baseline comparisons have been made. This assumes the optical plummets and plate levels of the equipment are in good adjustment.

The optical plummet in the alidade or tribrach needs to be checked before going out to the baseline. An adapter is available for adjusting tribrachs in the office, but a plumb bob can be used to check a tribrach in the field to look for gross errors. This is a very important adjustment and care should be used in doing this adjustment by following the instructions in the manual or with the adapter. Check the tribrach for missing screws or for looseness from wear. Clean the tribrach optics so you can better see the point the instrument is supposed to be over.

The weather equipment should be in good condition and adjusted. The barometer should be set for uncorrected pressure, not corrected to sea level as given on the radio. The thermometer should also be checked. There should be no air bubbles where the mercury is in the thermometer. The local weather station can check the barometer and thermometer in five or ten minutes for free. If only a dry bulb thermometer is at hand, just record that information.

Remember to record the height of instrument and prism to the center of the instrument and the prism and measure this carefully. This is the least accurate part of this operation, but if done with care the highest level of accuracy can be achieved. While on the Base Line a Meter tape is to be used, because all differences in elevation Mark to Mark are in Meters. Conversion can be made after you finish by the factor derived from: one meter = 3937/1200 Feet. Also all distances should be taken in Meters and Feet to check the internal workings of the Total Station Instrument.

Most baselines have supports for the feet of the tripod to insure that the instrument or any of the reflectors won't settle off the mark causing erroneous readings. If there are not supports provided, stakes should be driven into the ground and the legs of the tripods set on these. This is also recommended in the field especially while doing control work. The saying "A building is no better than the foundation it set upon," is especially true in precision surveying.

The bull's-eye bubble that comes on tribrachs is at best a good way to get close to the point, for precision a vial bubble that attaches to the tribrach should be used. This gives the tribrachs the same accuracy as the total station that has a vial bubble to level with. This should also be used on all control surveys to achieve the desired accuracy.

For a total station the instruments EDM should be checked not only directly to the calibrated baseline itself, but also in conjunction with the methods that will be used to perform the survey such as with a data collector and downloading the data into a survey processing surveying program. The primary purpose for comparing a total station's EDM over a calibrated base line is to make sure it is performing within the manufacturer's stated accuracy. Secondly, it is to determine the instrument constants. The constants should be applied to measured distances only after a sufficient history of baseline comparisons have been made. This assumes the optical plummets and plate levels of the equipment are in good adjustment.

II. A comparison can only be achieved if the "operator" induced errors are minimized. These include:

1. Leveling instruments and reflectors.
 2. Centering or plumbing instruments and reflectors.
 3. Applying meteorological (weather) observations.
1. Leveling instruments and reflectors - on the surface this would appear inconsequential, but accumulatively, it is not. Assume the instrument plate bubble is 20" of arc per division. Also assume the target level used for setting up the reflector is 60" of arc per division. If the instrument and reflector are at a height of 1.5 meters (4.92 ft.) over the marks and one division out of level, then the equipment can be off the point by 0.14 mm (0.0005 ft.) and 0.43 mm (0.0014 ft.) respectively, or a total of 0.57 mm (0.0019 ft.).
 2. Centering or plumbing the instrument should be done with care. In calm conditions, the instrument can be plumbed over the mark to within 0.02 mm (0.00007 ft.) using a plumb bob. Most equipment today utilizes optical plummets, which should be good to within 0.500 mm (0.0016 ft.). Optical plummets should be checked regularly to ensure they are in adjustment, otherwise considerable error can be introduced.

3. If not taken with care, meteorological observations can induce a significant error in distance measurements. A good rule of thumb is that an error of 1 degree Celsius (1.8 deg. f.) will induce a 1 PPM or 1 mm per 1000 m (0.0033 ft.) error in the measured distance. For microwave instruments the error is even greater. Therefore, to ensure good results, the thermometers should be of a quality to give at least 1 deg. accuracy. Equally critical are the barometric pressure observations. An error in pressure of 0.1 in. of mercury will result in the same 1 PPM error in the measured distance.
4. Each of the above errors is small when considered individually, but assuming the following situation and combining them indicates the necessity to do all operations as accurately as possible.
 - a. Leveling error of instrument (1 div.) 0.140 mm = 0.0005 ft.
 - b. Level error of reflector (1 div.) 0.430 mm = 0.0014 ft.
 - c. Optical plummet (adjusted) 0.500 mm = 0.0016 ft.
 - d. Temp. error 1 deg. C. (1000 m line) 1.000 mm = 0.0033 ft.
 - e. Pres. error 0.1 in Hg. (1000 m line) 1.000 mm = 0.0033 ft.

Total possible error ± 3.070 mm = 0.0101 ft. (Nearly half of the single measurement rejection limit of ± 0.02 ft. on any individually measured distance.)

III. The basic observation procedures are outlined as follows:

1. Raw observations are collected on either a Calibrated Baseline Worksheet (See Appendix Calibrated Baseline Worksheet) or in a hardbound fieldbook labeled Total Station Log Book along with the instrument's serial number.

For a hardbound fieldbook, the normal baseline uses 12 pages for each complete test. If you allow 20 pages for each test, there will be room for analysis, recommendations, and where, when and why the instrument was sent to the manufacturer or a service center for cleaning, adjustment and or repair.

2. Setup the instrument and reflectors over all the marks using care to minimize centering and leveling errors. This allows you to apply the method of forced centering in your calibration. This method allows you to move the total station throughout the course without resetting any tripods. This will enable you to distinguish operator problems from equipment problems.
3. Measure and record instrument and reflector heights above the marks.
4. Let the instrument acclimatize in accordance with manufacturer's instructions prior to making any measurements.
5. Observe and record meteorological observations. Since ambient meteorological conditions have a direct bearing on the results of distance observations and the near topography atmosphere is the most turbulent, all precautions should be taken to secure accurate data. When making temperature observations, the thermometer should be kept in the shade. Leaving it in the sun will cause significant error. Likewise pressure observations are raw pressure altitude data, not corrected to sea level. Ideally, meteorological observations are made along the entire line, but this is not feasible so the second most desirable method is to make simultaneous observations on each end of longer lines, so the data as observed at the instrument site, and reflector can be averaged.
6. Record the instrument model number, serial number and manufactures specifications, and the reflector model and offset constant, also any instrument constants.

7. Record general weather conditions (*i.e.* clear, overcast, partly cloudy, rain, wind, etc).
8. Record any unusual or problematic conditions (*i.e.* frozen ground, muddy, dusty, loud traffic noise, etc.)
9. Observe and record two (2) sets of forward and reverse measurements to and from all stations, so that a mean and standard deviation can be derived for all measurements, including slope distance, horizontal distance, and vertical difference.

The zenith angle is to be recorded for both face 1 and face 2 observations to determine that the culmination is correct. The forward and reverse readings totaled should equal 360 Degrees. For a complete calibration test, the recommended procedure is to perform both forward and backward observations over each section of the base line on separate days. This is a recommendation of NOAA and is not a requirement but might be done prior to setting or resetting NOAA markers.

- IV. After all observations are completed and the data is recorded it may be worthwhile to make a comparison set on a long and near distance with a zero weather setting or zero PPM correction dialed in and calculate the corrected slope distance and convert to horizontal distance or mark to mark distance utilizing the instrument and reflector heights and the station elevations as compared with those taken in the calibration test.
- V. The first step in analyzing the results is to compute the differences between the published and observed distances. These differences should then be compared to the manufacturers accuracy statistic, which is given in terms of standard error, or one-sigma, this value is used to test whether your instrument is in true adjustment. The results should also be compared to three-sigma, or three times the manufacturers accuracy specifications.

Prior to continuing, a little background is in order to understand what we are doing. One-sigma means that statistically 68.3% of the differences between a "true value" and the observed value should fall within these limits. However, this is only true for large samples and for known standard errors. Rarely are both of these criteria satisfied. By using the value of one-sigma as a limit for rejecting observations, it is possible that a valid observation may be rejected. To reduce this possibility, a limit of three-sigma is selected to decide if an observation is acceptable or not. Theoretically, 99.7% of the differences should fall within this limit. Most equipment accuracy is stated something like $\pm (5\text{mm} + 5\text{ppm})$. What the latter term refers to is an additional error dependent upon the distance measured; or in this case the slope error is an additional $5\text{ mm} + 5/1,000,000 \times$ the length measured.

Getting back to analyzing the observational results, once the difference, one-sigma, and three-sigma are plotted, it is a matter of simple computations. If 68.3% of the differences fall within the manufacturer's stated accuracy, one-sigma, and 99.7% fall within three-sigma, the instrument can be accepted as working accurately and reliably. If this is not the case then the baseline should be run again, using care to minimize the errors, and the results computed and analyzed. If the results are similar to the first time, then there are two options available. Preferably return the instrument to the manufacturer, (a service center), or through a least square analysis compute the new instrument corrections.

- VI. The conclusions that can be drawn from the foregoing are:

1. In order to get a valid base line comparison, the human induced errors have to be minimized.
2. If the results meet the sigma and three-sigma tests, then the instrument is working accurately and

reliably.

3. If the results do not meet the sigma and three-sigma tests then before doing anything with the instrument, re-run the base line. If the results are similar, then the first thing is to check with other users to see if there is a problem in the base line. If not, it is recommended to return the instrument to the manufacturer or a service center. This is also assuming that all the tribrachs used on the base line are in adjustment. This can be tested by switching the tribrachs to different stations during the second run of the base line.
 4. The above develops a history for the instrument as well as the base line. This is necessary before computing any new constants through least squares analysis.
- VII. Procedures on the calibration base lines are more complex than just taking a total station, setting it up, and taking the distances the machine gives out. Several problems may exist with the equipment the total station sits upon. The tripod is an important part of observations at any time, yet is so often abused and out of adjustment that it is amazing any survey works out. The critical areas of the tripod are the head, the dowels (legs), the hinges/clamps, and the shoes. The head of the tripod should be flat, so an instrument set on it does not rock back and forth. The wooden legs should not be broken and should bear the weight of the instrument without moving. The hinges and clamps should be tight and doing the job of moving yet holding the tripod together. The shoes should be holding the legs and the instrument in the ground without any movement. A test of the tripod will give some indication of any problems it might have. First set up and level the instrument, then point to a well defined point over 500 feet away. Second, twist the tripod head both ways and sight, if the horizontal angle changes after pointing, the tripod needs adjusting, repairing, or replacing.

2.2.4 NGS Calibrated Baseline Program CALIBRAT

This program is available through NGS and is used to determine the scale and constant corrections for electronic distance measuring instruments by making measurements over previously determined base lines. The formulas used in the program are found in NOAA Technical Memorandum NOS NGS-10, "Use of Calibration Base Lines."

NGS CALIBRAT

http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml#CALIBRAT

The above link provides for downloading of NGS CALIBRAT program.

2.3 Error Sources in Surveying

2.3.1 General

Although measurement errors in surveying can never be completely eliminated, through proper planning, procedures redundant checks, and common sense errors can be isolated, identified, and kept to a minimum. The ultimate responsibility for providing surveys that fulfill required Minimum Horizontal and Vertical Accuracy Tolerances remains with the field personnel. To meet this responsibility, the survey crew chief and members of the crew must understand the various types and sources of errors, the effect of possible errors upon each surveying task, and the procedures that will eliminate or minimize errors. The use of the term "errors" is included in many surveying textbook. This term has some unfortunate negative connotations but is used throughout the industry.

The two sources of inaccuracies in surveying are:

1. Blunders
2. Errors

2.3.2 Blunders / Human Errors

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. All blunders must be eliminated prior to correcting and adjusting a survey for errors. Blunders are caused by carelessness, misunderstanding, confusion, haste, or poor judgment.

Examples of blunders are:

1. Transposition of two numbers
2. Neglecting to level the instrument
3. Misplacing the decimal point
4. Misunderstanding a call to be "7" when it is "11"

2.3.3 Detection of Blunders

Blunders are detected and eliminated, for the most part, by the following:

1. Standard procedures
2. Redundancy of measurements
3. Independent checks
4. Proper checks of recorded and calculated data
5. "Closing" each survey
6. Electronic equipment and data files
7. Crew and individual alertness / awareness
8. Common sense and good judgment

2.3.4 Errors

An error is the difference, after blunders have been eliminated, between a measured or calculated value of a quantity and the true established value of the quantity. The true value is the actual value existing in nature, which is seldom known except when fixed by mathematics or by authority. The observed value is generally called the reading in surveying. It is what is read directly or accumulated on the scales of the equipment.

From the above definition, the following simple equation can be written:

$$\text{Error} = \text{Reading} - \text{True Value}$$

Errors are of two general types:

1. Systematic
2. Accidental.

2.3.5 Systematic Errors

A systematic error is an error, which will always have the same magnitude and same algebraic sign under the same conditions. Also known as cumulative errors, they can be computed and their effects eliminated by applying corrections. In most cases, systematic errors are caused by physical and natural conditions that vary in accordance with fixed mathematical or physical laws. 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.

Some examples of systematic errors are:

1. Thermal contraction and expansion of steel tape
2. Refraction
3. Failure to equalize foresights and backsights when leveling
4. Failure to consider slope in measuring horizontal distances
5. Failure to calibrate measuring devices such as rods, tapes, theodolites and EDM
6. A particular chain person's tendency to always slightly over pull a tape

It is imperative that each operation of a survey and any imperfections or instability of equipment be thoroughly considered. 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 effects can be minimized. Using correct procedures will automatically eliminate many systematic errors.

Some examples of procedures to follow that will eliminate systematic errors are:

1. Balance foresights and backsights when leveling.
2. Turn angles the required number of direct and reverse (face 1 and face 2) pairs to achieve the required accuracy for the type of survey being performed so that a mean and standard deviation can be calculated.
3. When using an EDM, measure the distances from both ends of the line with enough repetitions so as to achieve a mean and standard deviation of the distance.
4. Use standardized tapes.
5. Regularly calibrate all instruments.

2.3.6 Accidental Errors

An accidental error is an error, which does not follow any fixed relation to the conditions or circumstances of the observation. These errors are produced by irregular, complex causes that are beyond the control of

the observer. Their occurrence, magnitude, and algebraic sign cannot be predicted and each is truly random. In theory 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 errors will not totally compensate for one another. According to the mathematical theory of probability, accidental errors tend to increase in proportion to the square root of the number of opportunities for error. Thus, if the accidental error in turning one angle were $\pm 2''$ the chances would be equal that the total accidental error due to measuring 100 angles would not exceed $\pm 20''$ ($\pm 2 \times \sqrt{100}=20''$). A systematic error of the same magnitude would produce a total error of $3' 20''$ ($200''$) ($2 \times 100 = 200$). Accidental errors to a small degree remain in the inability to point a theodolite exactly or setup exactly over a point. However, if personal habits make one consistently point off to the same side of the sight line, this error becomes a systematic error. Corrections cannot be computed for accidental errors as for systematic errors.

In more precise surveys, the least squares method shall be used for adjustment of accidental errors. All blunders and systematic errors must first be eliminated because this method of adjustment is applicable only to truly random accidental errors. Any standard survey textbook can further explain the principles of "Least Squares adjustments".

No adjustment of any survey data is to be performed in the field.

2.3.7 Sources of Errors

There are three general sources of errors:

1. Personal
2. Instrumental
3. Natural.

2.3.8 Personal Errors

Personal errors are caused by the observer's lack of knowledge, failure to apply knowledge, physical limitations, and personal habits. They can be either systematic or accidental. Each observer, whether he/she believes it or not, makes personal errors of a small degree on each individual observation. Exact, correct observations are impossible because of the human limitation of sight and touch. Fortunately, such errors are minimized by proper procedures.

Examples of personal errors are:

1. Inability of a chain person to observe and hold a plumb bob over the point
2. Inaccurate mathematical calculations
3. Poor instrument sighting of a point
4. Erroneous readings of scales, tapes, rods and verniers
5. Failure to hear, understand or record verbally stated data
6. Use of improper methods

Continually practicing careful, conscientious survey techniques will substantially reduce personal errors. Several hours spent training inexperienced help is worth the time and effort in the reduction of errors. When the work is knowingly done haphazardly, costly errors will occur.

2.3.9 Instrumental Errors

Instrumental errors are caused by imperfections in the design, construction, and adjustment of instruments and other equipment. Most instrumental errors are eliminated by using standard 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. This can be accomplished by maintaining a regular program of periodically checking and calibrating instruments and other equipment. Whenever new or used instruments or equipment are initially assigned, they must be checked and calibrated prior to using them.

2.3.10 Natural Errors

Natural errors, or external errors, result from natural physical conditions, such as atmospheric pressure, temperature, humidity, gravity, wind, atmospheric refraction, and type of soil the instrument is being set up on. 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. Sometimes the effect of natural errors can be eliminated by using certain procedures, such as setting stakes for the tripod to set on due to thawing conditions or even in other unstable soils that occur all year long such as blow sand or swamps.

2.3.11 Detection of Errors

The accuracy of all survey work shall be checked by a closure to detect any errors that are greater than the stated Minimum Horizontal and Vertical Accuracy Tolerance.

This is to be done mathematically with the use of statistical analysis. All checks are to be made before errors are carried ahead to other work. When checks are neglected, erroneous information and costly errors usually result. In most cases it is economical and practical to apply methods that will result in near perfect results. The first return trip to the project to correct sloppy and careless work will pay for the initial proper procedures having been used. This is especially true if the initial control is lost and the whole survey has to be redone.

2.3.12 Mathematical Checks

Traverse, triangulation, and level work have definite requirements for closures. The determination of the error of closure requires a great deal of calculation not usually done as fieldwork progresses. There are, however, many mathematical and geometric checks that shall be used as the work progresses. Too often simple checks are not made as the work progresses, and result in the necessity of returning to the field for clarification.

Checks are to include but not limited to the following:

1. Sufficient redundant and repeat measurements shall be made to determine if the Minimum Horizontal and Vertical Accuracy Tolerance as stated for the survey are being met at the ninety five percent (95%) confidence level (See Chapter 5 - Preliminary Surveys, Minimum Horizontal Accuracy Tolerance Table and Minimum Vertical Accuracy Tolerance Table for additional information).
2. Instrument horizontal and vertical columniations shall be checked daily and adjusted as needed.

3. Level two peg test or other test as recommended in the manufacturers owners/operating manual shall be performed daily and adjustments made as needed.
4. The sum of the horizontal angles around a point should equal 360 degrees within the horizontal accuracy tolerance of the instrument. This is achieved by the operation commonly referred to as "Closing the Horizon" when an angle right and an angle left are used to find the sum of the total angle.
5. The mean and the standard deviation shall be calculated on all multiple measurements, and compared to the 3 sigma values of the instruments being used before moving to the next instrument location.
6. In a closed polygon, the sum of the interior angles equals 180 degrees times the number of sides minus two (Required degrees = $180(n-2)$)
7. The hypotenuse of a right triangle is equal to the square root of the sum of the squares of the other two sides.
8. In leveling, the algebraic sum of foresights and backsights should equal the difference in elevation between the starting point and closing point.
9. The zenith or vertical angle of the forward sighting and the zenith or vertical angle of the reverse or inverted sighting shall equal 360 degrees within the vertical accuracy tolerance of the instrument.

2.3.13 Visual Checks

Visual checks shall be made, by observing such things as disturbed control monuments. Control monuments shall be checked before final values or positions based on them are established.

2.4 Field Notes

2.4.1 General

Field notes are prepared to record all pertinent information, measurements, calculations, sketches, and observations made by the surveyor during the course of a survey. These notes become the permanent record of the survey. The continuous practice of keeping good field notes is imperative. Notes should be examined and checked for accuracy, legibility, completeness, and clarity before leaving the field. They must be recorded in such a way that someone outside the original crew could clearly understand how, when, where, for what purpose and by whom the original survey was done.

The individual recording the field notes may not be the same person reading the field notes at a later date. The notes must be taken so that individuals with similar technical backgrounds can properly interpret the notes, correctly read the numbers, and understand their meaning. The Region Survey Coordinator will reject any field notes found to be unacceptable.

2.4.2 Types of Field Notes

CDOT accepts three types of field notes as follows:

1. Handwritten field notes in hardbound survey fieldbooks.
2. Electronically recorded field notes printed in a fieldbook format and bound in three-ring binders or similar books.
3. Electronically recorded field notes copied onto a CD ROM(s) in an ASCII text fieldbook format that is compatible for the files to be read in a standard word editor program (this option may only be used when approved in advance by the Region Survey Coordinator).

2.4.3 Survey Fieldbook / Electronic Field Notes Submittal

All field notes shall be taken in accordance with the Survey Manual. All field notes if not taken electronically, shall be recorded in standard hardbound survey fieldbooks. All electronically generated field notes shall be printed in a fieldbook format conforming to this Survey Manual and bound in a three-ring binder or similar book. The electronic field notes may be copied onto a CD ROM in an ASCII text fieldbook format that is compatible for the files to be read in a standard word editor program only if approved in advance by the Region Survey Coordinator.

Original field notes and/or unedited electronic notes are the permanent record of the survey and shall become the property of CDOT. All original hardbound survey fieldbook and/or electronic field notes taken by either CDOT or contract consultant survey crews shall be submitted to the Region Survey Coordinator at the end of the project or at the time as specified. These books shall be included with the project files and/or cataloged in a fieldbook database for future reference.

Before submittal of fieldbooks and/or electronic field notes to CDOT, the surveyor should make copies for inclusion into their own project files. If it becomes necessary for either CDOT or contract consultant surveyors to obtain original survey fieldbooks the Region Survey Coordinator should be contacted and arrangements made.

2.4.4 Survey Fieldbook Database

Each Region shall maintain a database of hardbound fieldbooks for reference and retrieval of the fieldbooks. This will expedite the process of providing fieldbooks when request are made.

Such request may come from the following sources:

1. Attorney General's office
2. Court summons
3. Condemnation court cases
4. Contract consultant records research
5. CDOT records research
6. Private survey records research
7. Open records request made in accordance with 244-72-101 CRS, to 4-72-402 CRS.

2.4.5 Survey Fieldbook / Electronic Field Note Indexing

Survey fieldbooks and electronic field notes shall be indexed individually for each element of a project and shall contain only that particular portion of the survey that pertains to the fieldbook as indexed. It is generally the responsibility of the survey crew chief to index the fieldbooks upon completion of each survey or each appropriate element of the survey.

The following survey elements of a project shall be indexed by fieldbooks and/or electronic field notes:

1. Horizontal Control (Primary and Secondary)
2. Vertical Control, *i.e.* Bench Books (Primary and Secondary)
3. Property Pin Ties (*i.e.* Right of Way, Public Land Survey System, easement and boundary monuments)
4. Alignment
5. Grading
6. Slope staking
7. Minor structures
8. Major structures
9. One book for each work category as shown on the Survey Tabulation Sheet.

See Chapter 6 - Construction Surveys, for additional information.

2.4.6 Original Field Notes

Original notes are those recorded at the time the measurements are being taken. Time must be taken during the survey to record neatly and accurately all notes. Transcribing originally recorded field notes and measurements from peg books or other sources shall not be accepted by CDOT. This practice causes mistakes, omissions and makes them inadmissible as trial court evidence. In addition, it is an unnecessary duplication of work.

2.4.7 Erasures

Erasures are not permitted in fieldbooks. If an item has been recorded incorrectly, draw a single line through it without destroying its legibility and record the correct item directly above. If an entire page is to be omitted, draw diagonal lines across the page from opposite corners and write "VOID" conspicuously across the page. When changing data onto new field pages, the corrected data and the voided data must be

referenced back to each other. State the date and crew information on the corrected data as if it were original data.

2.4.8 Calculations

Field calculations should be included on the appropriate pages in the notes. Book covers or flyleaves should never be used for calculations, notes, additions, etc. If the possibility of error arises, the computations for the survey can then be easily retrieved for checking.

2.4.9 Electronic Field Notes

Electronic field notes gathered using electronic survey equipment should have the same credibility as field notes taken in a fieldbook. Electronic field notes may be substituted for fieldbook notes called for elsewhere in this manual if the electronic notes contain all the information specified. The same care and procedures used with hardbound fieldbooks shall be followed with electronic field notes. The major advantages of electronic field notes are that mistakes in reading and recording measurements in the field are eliminated and the time to process, display, and archive the notes is reduced.

All electronically generated field notes shall be printed in a fieldbook format conforming to this Survey Manual and bound in a three-ring binder or similar book. The electronic field notes may be copied onto a CD ROM in an ASCII text fieldbook format that is compatible for the files to be read in a standard word editor program only if approved in advance by the Region Survey Coordinator.

2.4.10 Original Electronic Field Notes

The information gathered in the unedited electronic field notes are the original field notes, and shall not be changed at any time. Copies of all original notes shall be forwarded to the Region Survey Coordinator for review and approval. Sketches and additional information should be included in fieldbooks if it will help to clarify the notes in the collector. These sketches should be referenced in the collector and in the fieldbook.

Just as with fieldbooks, the date, crew, weather, and project description must be included at the start of each file. This should be done in the electronic notes prior to the start of the job. Notes should be kept in the collector if they will help in the explanation of the data.

2.4.11 Electronic Field Notes Downloaded Daily

At the end of the day the raw data from the collector shall be downloaded into a survey processing software program for editing and processing. At this time a hard copy of the non-edited raw file should be acquired and signed by the survey crew chief. This will help with the legality of the survey should a problem arise. A copy of the non-edited file should be made to a disk, then both disk and hard copy should be archived for future use. The original file should never be edited. It should be kept just like an original fieldbook. If problems or questions arise over the use of the collector, contact the Region Survey Coordinator for clarification.

2.4.12 Electronic Filed Note Indexing

Electronic field notes shall be index in accordance with this Survey Manual. Electronic field notes shall printed in a Fieldbook format conforming to this Survey Manual and bound in a three-ring binder or similar type of binder. Electronic fieldbooks shall be indexed individually in the order of the survey for each element of a project and shall contain only that particular portion of the survey that pertain to the electronic filed notes as indexed.

2.4.13 Field Note Check List

The following is a checklist of important procedures to follow in note keeping for both fieldbooks and/or electronic field notes. It is advisable to review this from time to time to insure good habits of taking field notes.

1. Always enter data directly into the fieldbook. Never use scrap paper for recopying later.
2. Include sketches whenever in doubt as to the clarity of the tabulated information.
3. Sketches can be drawn in general proportion, rather than exactly to scale.
4. Exaggerate details on sketches if more clarity is needed.
5. Always avoid overcrowding. Keeping the number of fieldbooks to a minimum is not important. The cost of fieldbooks is inexpensive compared to the value of the information they contain.
6. Sketches and descriptions should be carefully lined up on the right hand page with the corresponding numerical data on the left hand page.
7. Always use explanatory notes wherever needed.
8. Use customary symbols and signs when possible to conserve space.
9. Tabulated figures should be kept inside the column rulings with the digits and decimal points in line vertically.
10. For number less than one, a zero must be placed before the decimal point. For example, record 0.15 instead of .15.
11. Always record significant zeroes to show precision of measurements. For example, record 6.40 instead of 6.4 if actually measured to hundredths.
12. All possible checks on the notes should be done and recorded before leaving the field.
13. All possible ratios of errors and closures should be computed before leaving the field.
14. Include all essential computations with field notes, so they can be easily checked later.
15. The person performing the computations shall initial the field computations on the lower right hand side of the page.
16. All field computations shall be checked by a second person and initialed by the person who performed the check on the lower right hand side of the page.
17. Repeat out loud the numbers given for recording. For example, before recording a measurement of 97.48 feet, call out "nine, seven, point, four, eight" for verification by the tape person who submitted the distance.
18. Try to make a mental estimation of all measurements before receiving them, to eliminate large errors.

19. Lettering should be neat and printed.
20. Carry a straight edge in the survey vehicle for ruling lines.
21. Do not erase. Draw a single line through an erroneous value and record the correct value above it.
22. Begin each day's work on a new page.
23. Record date, weather, and crewmembers' names and duties at the top of the right hand page.

2.4.14 Setting Up Fieldbooks

The first fourteen pages of all fieldbooks used for CDOT surveys shall be set up as in accordance with this section. Although it is not readily apparent, the proper setting up of fieldbooks greatly aids in the cataloging of fieldbooks and for records research for performing retracement surveys after fieldbooks have been cataloged. Examples are shown on the following pages and shall be followed as nearly as possible. It is the survey crew chief's responsibility to see that the fieldbooks are set up accurately and maintained throughout the survey and/or project.

New fieldbooks shall be set up as follows:

1. Contact information shall be contained immediately inside of the book's front cover stating the CDOT region, region address, Region Survey Coordinator and phone number. If the book is for a contract consultant survey the consultant information shall also be included for the consultant company name, address and phone number. If the book is lost, the finder will then know whom to contact to return it to. This also provides CDOT with an immediate record for consultant contact information for cataloging and records research. (See Figure 2-1)
2. All pages in a book shall be numbered before the work begins. Only the right-hand pages in the upper right-hand corner shall be numbered. (Figure 2-1 through 2-16)
3. Page 1 shall contain the title page showing the following (See Figure 2-2):
 - a. CDOT Project Number
 - b. CDOT Project Code
 - c. State highway number and highway and mile post
 - d. Location
 - e. County
 - f. Type of fieldbook
 - g. Units of measurement (International survey feet or US survey feet)
 - h. Starting and ending dates of the survey
 - i. State of Colorado Map Number (such as F-17 for the location of Colorado's State Capital building)
4. Page 2 shall contain a roster of the persons who worked on the survey along with their titles and initials. (See Figure 2-3)
5. Page 3 shall contain an index of all the project fieldbooks denoting the general kind of notes contained in each book for the survey elements for each particular portion of the survey (See Figure 2-4)

6. Pages 4 through 7 shall contain a table of contents for the book along with the appropriate page numbers. The table of contents should be kept current daily. (See Figure 2-5 through 2-8)
7. Pages 8 and 9 shall be reserved for general explanations or other remarks. If no other remarks are made the pages should remain blank except for the remarks title at the top of the page. (See Figure 2-9 through 2-10)
8. Page 10 through 13 shall be reserved for the survey equipment and instrument identification used to perform the survey such as brand, model and serial number along with statements of certification that the instruments, tribrachs, tripods and any other surveying equipment have been successfully checked against a calibrated baseline and regularly checked, maintained and adjusted in accordance with this manual. (See Figure 2-11 through 2-2-14)
9. Pages 14 shall be reserved for the Surveyor's Certification statement as to the accuracies of the survey. This is to be accompanied by the professional land surveyors seal and original signature of the surveyor in responsible charge. (See Figure 2-15)
10. Page 15 is the first page for the recording of the actual survey field notes. (See Figure 2-16)

<p>Colorado Department of Transportation REGION 2 905 ERIE AVE PUEBLO, CO. 80011 MARK LANE 719-546-5442</p>	<p>Projects _____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>Survey Consultant Information (INSERT COMPANY NAME HERE) (INSERT COMPANY ADDRESS HERE) (INSERT COMPANY PHONE NUMBER HERE)</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p>
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Figure 2 – 1

						P. 1											
						PROJECT NO: CXBRF 36-0071-13											
						PROJECT CODE: 15586											
						SH 71 MP 31 - 42											
						4.3 MILES N. OF SH 96											
						CROWLEY COUNTY											
						HORIZONTAL CONTROL											
						UNITS: US SURVEY FEET											
						SURVEY START DATE: 1/15/86											
						SURVEY END DATE: 2/14/86											
						MAP NO L-22											

Figure 2 – 2

						P. 3
						INDEX OF FIELDBOOKS
						BOOK NO
						DESC
						1
						HORIZONTAL CONTROL
						2
						VERTICAL CONTROL
						3
						PROPERTY PIN TIES
						4
						ALIGNMENT
						5
						GRADING
						6
						SLOPE STAKING
						7
						MINOR STRUCTURES
						8
						MAJOR STRUCTURES

Figure 2 – 4

		P. 4
		TABLE OF CONTENTS:
PAGE NO	DESC	
1	TITLE PAGE	
2	CREW ROSTER	
3	INDEX OF FIELDBOOKS	
4	TABLE OF CONTENTS	
5		
6		
7		
8	GENERAL REMARKS	
9	" "	
10	EQUIPMENT CERTIFICATION	
11		
12		
13		
14	SURVEYOR'S CERTIFICATION	
15	CONTROL COORDIANTE LIST FROM REGION 2	
16	CONTROL MP 35.2 CHECK	
17	CM 35.6 CHECK	
18	CM 35.8, 40.2, 40.4 CHECKS	
19	CM TIES	

Figure 2 – 5

TABLE OF CONTENTS:	
PAGE NO	DESC
20	CM 42.4 SKETCH
21	CM 42.6 SKETCH
22	TRIANGULATION SKETCH
23	TRIANGULATION CALCS FOR SEARCH COORDS OF CM 35.8
24	CM 35.8 SKETCH
25	CM 35.8 TIES
26	}
27	
28	

Figure 2 – 6


	P. 8
	GENERAL REMARKS:
	CONTROL COORDINATES USED ARE FROM SH 71 AND SH 96 CONTROL FILES PROVIDED BY REGION 2.
	SINGLE SIDE SHOTS ARE TAKEN FOR A CHECK ONLY ON GPS BASELINES.

Figure 2 – 9

<table border="1"> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td></td><td></td></tr> </table>																																																																																																																			P. 10
EQUIPMENT CERTIFICATION:																																																																																																																			
INSTRUMENT TYPE: TRIMBLE 5700 WITH GEODETTIC ANTENNA																																																																																																																			
INSTRUMENT SERIAL NUMBERS:																																																																																																																			
0220264927																																																																																																																			
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0220262789																																																																																																																			
0220262101																																																																																																																			
DATE CHECKED: 1/05/86																																																																																																																			
CALIBRATED BASELINE: PUEBLO																																																																																																																			
CHECKED BY: LARRY LUCAS LORÉLEI WARD																																																																																																																			

Figure 2 – 11

	P. 12				
	EQUIPMENT CERTIFICATION:				
	TRIBRACHS AND RODS CHECKED				
	ON 1/25/86 BY LL				
	RODS CHECKED ON 2/07/86 BY LL				
	RODS CHECKED ON 2/8/86 LW				
	TRIBRACHS CHECKED ON 2/12/86 LL				

Figure 2 – 13

						P. 13																																																																																																													
						EQUIPMENT CERTIFICATION:																																																																																																													

Figure 2 – 14

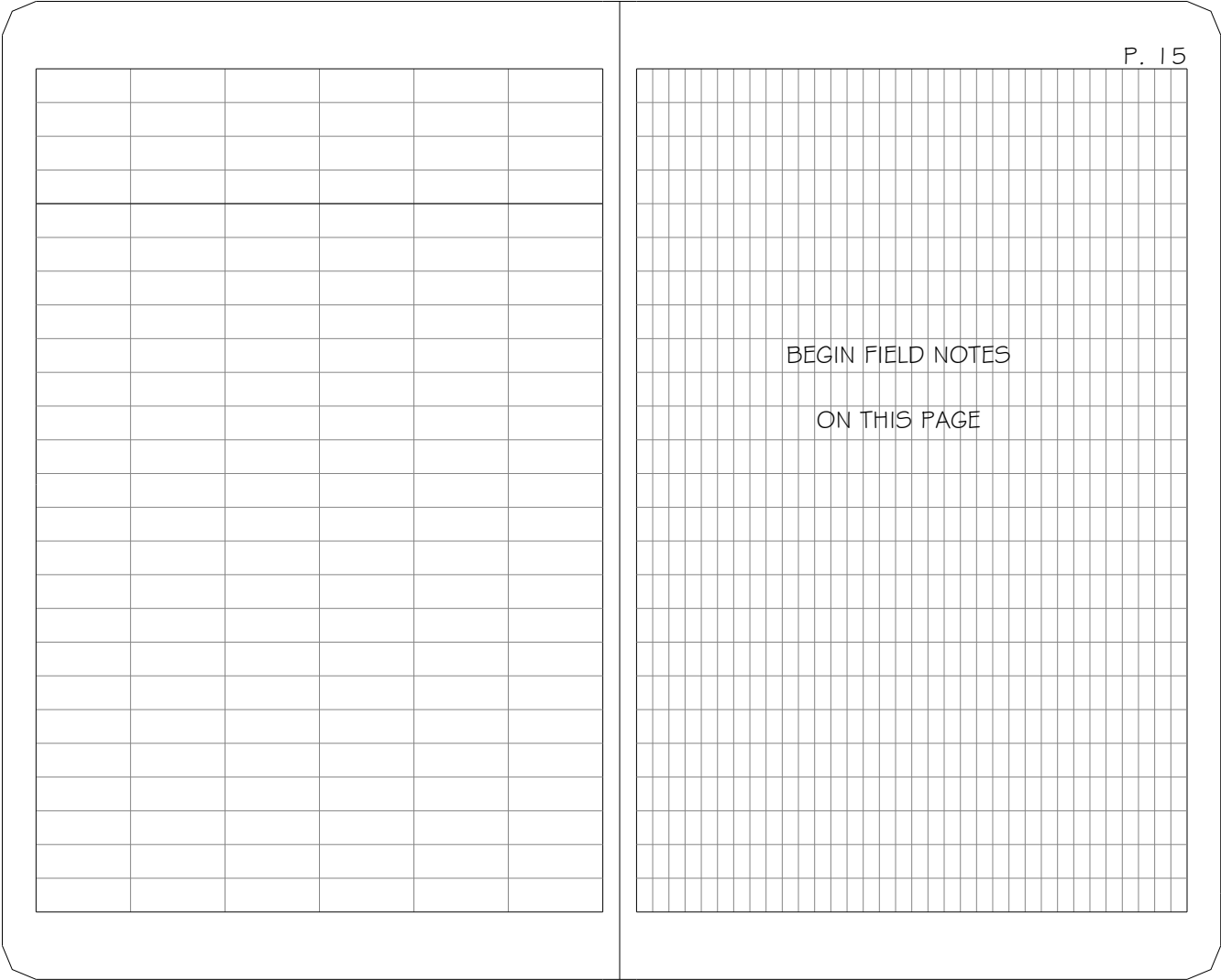


Figure 2 – 16

2.4.15 Daily Field Notes

For each day of the survey, the date, weather conditions, unadjusted barometric pressure, any unusual conditions such as wind, dust, or fog, instrument number, names of the crew and their duties shall be recorded on the upper right hand page.

The left page is normally ruled in six columns and is normally used for tabulations only. Column headings should be placed between the first and second horizontal line and should follow from left to right in the anticipated order of reading and recording. A title of the work being performed and recorded should be noted at the top of the left hand page.

2.5 Preliminary Survey Scope Form 1217a

2.5.1 General

Any request for survey activities shall be coordinated through the region Right of Way Manager, and/or the designated Region Survey Coordinator by issuing a Preliminary Survey Scope Form 1217a.

All possible improvements should be anticipated when the project scope is being prepared. It is prudent to include all identified deficiencies when preparing the Preliminary Survey Scope Form 1217a, so that enough information is gathered to allow the designer the ability to analyze the data, and decide if changes are needed to the final design

<http://www.coloradodot.info/library/forms/cdot1217.pdf/view>

2.6 Presurvey Conference

2.6.1 General

Prior to any survey work being performed a presurvey conference shall be held. Any known problems or oversight issues with the proposed plans or specifications shall be discussed at the presurvey conference. The presurvey conference shall include at a minimum the appropriate Presurvey Conference Form for the type of survey being performed as follows:

1. Presurvey Conference – Aerial Survey
2. Presurvey Conference – Preliminary Survey
3. Presurvey Conference – Construction Survey

2.6.2 Presurvey Conference – Aerial Survey

A Presurvey Conference – Aerial Survey shall be held prior to the beginning of the following types of aerial surveys as defined in Chapter 4 – Aerial Surveys:

1. Aerial Photogrammetric Mapping
 - a. Layout of panel points
 - b. Aerial photo control survey
 - c. Photography

2.6.3 Presurvey Conference – Preliminary Survey

A Presurvey Conference – Preliminary Survey shall be held prior to the beginning of the following types of preliminary surveys as defined in Chapter 5 – Preliminary Surveys:

1. Reconnaissance Survey
2. Control Survey
 - d. Horizontal
 - e. Vertical
3. Right of Way Survey
4. Topographic Survey
 - f. TMOSS
 - g. Aerial
5. Drainage Survey
6. Utility Survey
7. Staking for appraisal

The presurvey conference at a minimum shall include a Presurvey Conference Form for Preliminary Survey, CDOT Standard Specifications for Road and Bridge Construction, Section 629 – Survey Monumentation, Subsection 629.02 – Materials and Subsection 629.03 - Construction Requirements shall be included as part of this presurvey conference.

See Chapter 5 – Preliminary Surveys, for additional information.

2.6.4 Presurvey Conference – Construction Survey

A Presurvey Conference – Construction Survey shall be held prior to the beginning of any construction survey as defined in Chapter 6 – Construction Surveys for the following sections of CDOT Standard

Specifications for Road and Bridge Construction as deemed pertinent for the project by the Region Survey Coordinator:

1. Section 625 – Construction Surveying
2. Section 629 – Survey Monumentation

The presurvey conference at a minimum shall include a Presurvey Conference Form for Construction Survey. CDOT Standard Specifications for Road and Bridge Construction, Section 625 – Construction Surveying and Section 629 – Survey Monumentation shall be included as part of this presurvey conference.

See Chapter 6 – Construction Surveys, for additional information.

2.7 Special Use Permit Form 1283a

2.7.1 General

Private surveyors or contract consultant firms working in the existing CDOT Right of Way shall obtain a Special Use Permit Form 1283a, with the survey option completed.

<http://internal/centralfiles/FormsCatalog.htm>

2.7.2 Contact Information

To obtain a Special Use Permit contact the following for the appropriate region:

<http://www.coloradodot.info/business/permits/utilitiesspecialuse/program-contacts/all-contacts.html#Advisors>

2.8 Manual on Uniform Traffic Control Devices (MUTCD)

2.8.1 General

All work performed in or near to any traveled roadway shall follow the latest Manual on Uniform Traffic Control Devices (MUTCD).

MUTCD

http://mutcd.fhwa.dot.gov/kno-millennium_12.28.01.htm

The above link provides information and download of the latest MUTCD.

CDOT Work Zone Safety, Guidelines for Municipalities, Utilities, and Contractors, October 2002, also provides information directly from the MUTCD for surveying along the centerline of a low and high volume road and is available at the following:

See Chapter 7 – Safety, for additional information.

2.9 Permission to Enter Property Form 730a

2.9.1 General

A property owner or occupant shall be contacted before a survey crew enters the property. The purpose of this contact is to inform the owner or occupant that an entry is required, to explain what survey activities are to be performed, to indicate the duration of the survey and any effect it may have on the property, and to obtain Permission to Enter Property Forms in writing. This form should be filled out in order that survey crews will have permission for performing their assigned functions. The owner or occupant at this time are to be advised of their rights and allowed to use section “Conditions requested by Owner” of the permission form to place certain restrictions on the activities (*i.e.* time limitations, where vehicles may drive, cutting of brush, digging holes or if notice needs be given before entering property).

<http://internal/centralfiles/FormsCatalog.htm>

2.9.2 Exception to Criminal Trespass

18-4-515 CRS contains an exception to the trespass laws for boundary survey evidence investigation and to utilize such evidence.

See Appendix Exception to Criminal Trespass, for additional information.

2.10 Underground Utility Locates Prior to Installing Monumentation

2.10.1 General

Colorado SB 93-155 requires that anyone that engages in any type of excavation must provide advance notice to the underground facility owners. The notice must be at least two business days, not including the day of the call, prior to any excavation. A precise definition of excavation is included in the state law as follows: “Excavation” means any operation in which earth is moved or removed by means of any tools, equipment, or explosives and includes augering, backfilling, boring, ditching, drilling, grading, plowing-in, pulling-in, ripping, scraping, trenching and tunneling.

After monumentation sites are identified on the ground for installation of monuments each site shall be marked with a lath, and white paint and/or flagging and underground utility locates shall be called for. The lath should be marked as “Utility Locate” with it’s appropriate Milepost, and radius necessary for the area of the utility locate. Underground utility locates shall be called for by contacting the following:

Utility Notification Center of Colorado:
12600 W. Colfax Ave. Ste: B310
Lakewood, Colorado 80215
Phone: 1-800-922-1987
Fax: 303-234-1712
<http://www.uncc2.org/>

The above utility locate contact number is primarily for the front-range area only. This may not be the only number you will need to call to obtain utility locates. For additional information on utility locates in your area contact your local utility companies and/or municipalities.

Utility locates for design engineering work may be difficult to obtain. Private utility locate companies may need to be contracted with for performing these types of locates in a reasonable amount of time. The following link provides a statewide list of private utility companies:

http://www.uncc2.org/uncc/middlepages/private_locate_companies.htm

2.10.2 Information Needed to Provide for Utility Locates

When calling in your utility locates the following information will be helpful to provide to the utility locate company or municipality with the information necessary for each point:

1. Your contact information
2. Alternate contact information
3. Description of the monument rod length and diameter to be set
4. No explosives will be involved
5. Installation method (hand or power tools)
6. Utility locate to be performed by a 30 foot radius around the marked point
7. Description of how the point is marked
8. Highway number and mile post
9. County and/or City
10. Distance and cardinal direction to the nearest intersection
11. Distance and cardinal direction to the nearest town or city
12. Distance and cardinal direction from edge of asphalt or concrete of the highway to the point
13. Section, Township, and Range

If the description of the points to be located are confusing to the utility locate company or if there are many points to be located a meeting with the surveyor and the utility locate company may be needed to allow the surveyor to assist the utility locator with finding the points.

2.10.3 Utility Locate Color Codes and Tolerance

See Figure 2-17 for information on underground utility color codes:

COLOR CODE FOR MARKING UNDERGROUND UTILITY LINES	REQUIRED LOCATION REQUEST INFORMATION
 PROPOSED EXCAVATION	<u>PHONE#</u>
 TEMPORARY SURVEY MARKINGS	<u>NAME OF CALLER</u>
 ELECTRIC	<u>WORK BEING DONE FOR</u>
 GAS-OIL-STEAM	<u>TYPE OF WORK</u>
 COMMUNICATION CATV	<u>COUNTY</u> <u>CITY</u>
 POTABLE WATER	<u>ADDRESS OR JOB LOCATION</u>
 IRRIGATION, RECLAIMED WATER, SLURRY LINES	<u>EXTENT OF WORK</u>
 SEWER	<u>TOWNSHIP</u> <u>RANGE</u> <u>SECTION</u>
Dig Safely.	
BEFORE YOU DIG CALL:	
1-800-922-1987 <small>www.uncc.org</small>	
<small>UTILITY NOTIFICATION CENTER OF COLORADO</small>	
Dig Safely. CALL UNCC	
<small>THREE WORKING DAYS BEFORE YOU DIG</small>	
1-800-922-1987 <small>www.uncc.org</small>	
<small>UTILITY NOTIFICATION CENTER OF COLORADO</small>	

Figure 2 – 17

See figure 2-18 for information on underground utility locate tolerance zone:

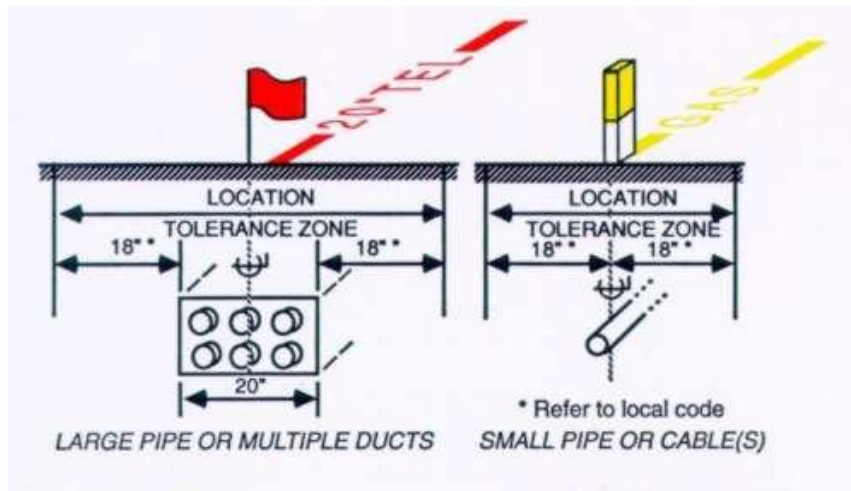


Figure 2 – 18

2.11 References

CDOT Survey Manual – CDOT, 1992

CDOT Right of Way Manual – CDOT, 2002

CDOT Standard Specifications for Road and Bridge Construction – CDOT, 1999

Board of Registration for Professional Engineers and Land Surveyors, Land Surveying Laws and Board Rules – July, 2002

<http://www.dora.state.co.us/aes/index.htm>

National Geodetic Survey – June 21, 2002

<http://www.ngs.noaa.gov/>

Colorado Statute Manager – Version 2.50 July, 2002

<http://www.michie.com/colorado/lpext.dll?f=templates&fn=main-h.htm&cp=>

Manual on Uniform Traffic Control Devices (MUTCD) –

http://mutcd.fhwa.dot.gov/kno-millennium_12.28.01.htm

CDOT Work Zone Safety Guidelines for Municipalities, Utilities, and Contractors – October, 2002

<http://www.dot.state.co.us/>

Survey Equipment - California Department of Transportation, Survey Manual, Chapter 3, January 1998