Survey Manual

Chapter 6

Construction Surveys

Colorado Department of Transportation
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Chapter 6 – Construction Surveys

6.1 General

6.1.1 Construction Surveys

Construction surveying must be given special consideration to assure that cost efficient and expedient methods are used, and appropriate accuracy and tolerances are maintained.

The engineer and the Region Survey Coordinator at the presurvey conference shall review the proposed methods and procedures of the surveyor for conformity with this manual. It is the responsibility of the surveyor to perform all survey work in conformance with the specifications, methods, and tolerances as set forth in this manual.

Any variation from the specifications shall have the prior approval of the engineer and the Region Surveyor Coordinator.

6.1.2 Construction Work

Construction work shall not be performed until adequate lines and grades have been established CDOT or by the contractor.

See Appendix Standard Specifications for Road and Bridge Construction – Section 105.08, Construction Stakes, Lines and Grades, for additional information.

6.1.3 Surveyor

When the term "surveyor" is used throughout this chapter, it shall mean the contractor's surveyor or CDOT's surveyor.

6.1.4 Specifications and Special Provisions

The Project Special Provisions, Standard Special Provisions, Detailed Plans, Standard Plans, Supplemental Specifications, and the CDOT Standard Specifications shall take precedence over this Survey Manual. In case of a discrepancy the order of precedence shall be in accordance with Section 105.04 of CDOT Standard Specifications for Road and Bridge Construction as follows:

1. Special Provisions
    a. Project Special Provisions
    b. Standard Special Provisions
2. Plans
    a. Detailed Plans
    b. Standard Plans (calculated dimensions will govern over scaled dimensions)
3. Supplemental Specifications
4. Standard Specifications
5. Survey Manual

When the term "Survey Manual" is referenced on the plans and specifications, it shall mean the entire CDOT Survey Manual.

6.1.5 CDOT Standard Specifications for Road and Bridge Construction – Sections 625 & 629

CDOT Standard Specifications for Road and Bridge Construction is to be used on contract work awarded by CDOT. These may be supplemented or modified to suit specific contracts by way of Special Provisions.

Section 625 – Construction Surveying (See Chapter 1 – General, for additional information.)

Section 629 – Survey Monumentation (See Chapter 1 – General, for additional information.)

6.1.6 Presurvey Conference – Construction Survey

Prior to beginning any construction survey activities a Presurvey Conference - Construction Survey shall be held. Any known error or oversight on the plans or specifications shall be discussed at the presurvey conference. The project manager shall notify all parties listed below at least two weeks prior to the presurvey conference. The following individuals shall attend the Presurvey Conference for Construction Survey:

1. Region Survey Coordinator or designee
2. Right of Way Plan Coordinator or designee (if Right of Way is being acquired)
3. Construction Engineer or designee
4. Contractor's Superintendent
5. Construction Survey Crew Chief
6. Any appropriate subcontractor personnel

The surveyor in responsible charge for the survey work shall have the following reference materials at the Presurvey Conference - Construction Survey:

1. Project Plans
2. Project Special Provisions
3. CDOT Standard Specifications
4. CDOT Standard Specifications for Road and Bridge Construction
5. CDOT Standard Plans (M & S Standards)
6. CDOT Survey Manual
7. Manual of Uniform Traffic Control Devices (MUTCD)
8. Computer generated cross sections

The presurvey conference at a minimum shall include a Presurvey Conference - Construction Survey Form for the following two Sections of CDOT Standard Specifications for Road and Bridge Construction:

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

If Section 625 - Construction Surveying is a contract bid item, the surveyor shall submit in writing his proposed work schedule, man-hour estimate of office and field time for each item, and methods statement to the engineer for all work specified on the survey tabulation sheet and any additional staking which may be required by the contractor.

If Section 625 - Construction Surveying is not part of the contract, the contractor shall direct all requests for surveying in writing to the engineer.

If Section 629 – Survey Monumentation is a contract bid item, the surveyor shall submit in writing his proposed work schedule, man-hour estimate of office and field time for each monumentation item, and methods statement to the engineer for all work specified on the survey tabulation sheet and any additional monumentation which may be required by the contractor.

If Section 629 – Survey Monumentation is not part of the contract, the contractor shall direct all requests for survey monumentation in writing to the engineer. The Region Survey Coordinator requires two weeks written notice to reference, relocate, and/or replace any survey monuments.

See Appendix Presurvey Conference – Construction Survey Form, for additional information.

6.1.7 Survey Tabulation Sheet

The survey tabulation sheet is the Survey Tabulation Plan Sheet. The information CDOT intends to provide for the construction of the project and the work to be performed by the surveyor is tabulated on the survey tabulation sheet. Whenever the survey tabulation sheet is referred to in this chapter it shall mean the Survey Tabulation Plan Sheet.

See Appendix Survey Tabulation Plan Sheet, for additional information.

6.1.8 Monuments Listed on the Survey Tab Sheet for Replacement

Survey monuments (*i.e.* primary control and boundary monuments) that need to be relocated and/or replaced due to construction shall be listed on the survey tabulation sheet. The surveyor shall recover, reference and after construction is complete relocate and/or replace those monuments listed on the survey tabulation sheet.

6.1.9 Coordination of Construction Surveys

The surveyor shall coordinate with the contractor to assure the survey work is performed in a timely manner and there is adequate staking to avoid project delays. Survey work should begin immediately after the start of contract time to avoid delays to the project. The contractor shall allow the surveyor sufficient time to perform the survey work without being rushed. The surveyor shall be available to review work, resolve problems, and make adjustments with the approval of the engineer, in a timely manner so no delays are experienced by the project. The engineer will inspect the survey work and advise the contractor of any corrections and necessary revisions.

The construction phasing may require multiple trips to the field by the surveying crew and should be considered in any analysis for manpower scheduling or cost estimating.

6.1.10 Checking and Calibration and of Survey Equipment

Checks and calibrations on all types of electronic survey equipment are essential to obtain and maintain the Minimum Construction Horizontal and Vertical Accuracy Tolerances required in this chapter. 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 in accordance with Chapter 2 – General Procedures, and Chapter 3 – GPS Surveys. 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 engineer and 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.

Legible certified copies of all records documenting the equipment checks and calibrations shall be provided to the engineer and become part of the project records. Certifications shall consist of a signed and sealed statement by the surveyor in responsible charge that the equipment is operating within the tolerances as specified in this chapter.

See Chapter 2 - General Procedures, and Chapter 3 – GPS Surveys, for additional information.

6.1.11 Project Control Diagram

All staking shall utilize the primary control monuments and the corresponding coordinates shown on the approved CDOT Project Control Diagram (PCD). The Project Control Diagram shall be included in the CDOT construction plans.

See Chapter 5 - Preliminary Surveys, for additional information.

6.1.12 Land Survey Control Diagram

Right of Way, Public Land Survey System (PLSS), boundary, and easement monuments located during the preliminary survey are shown on the Land Survey Control Diagram (LSCD). The Land Survey Control Diagram shall be included in the CDOT construction plans and serves as notice for the location of these monuments. These monuments should be tabulated on the survey tabulation sheet. The contractor is responsible for preserving these monuments during construction and for replacing any that are disturbed by construction activities unless stated otherwise during the presurvey conference.

In some instances a Land Survey Control Diagram may not be required for a construction project (*e.g.* no additional Right of Way will be acquired). In these instances any Right of Way, Public Land Survey System, boundary, and easement monuments located during the TMOSS portion of the preliminary survey may be shown on the Project Control Diagram and shall serve as notice for the location of these monuments. These monuments should be tabulated on the survey tabulation sheet. The contractor is responsible for preserving these monuments during construction and for replacing any that are disturbed by construction activities unless stated otherwise during the presurvey conference.

See Chapter 5 - Preliminary Surveys, for additional information.

6.1.13 Control Monument Checks

Primary control monument checks shall be performed prior to any construction staking to ensure the primary control monuments have not been disturbed and are within their original CDOT Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class A – Primary survey.

Secondary control monument checks shall be performed prior to any construction staking to ensure the secondary control monuments have not been disturbed and are within their original CDOT Minimum Construction Horizontal and Vertical Accuracy Tolerance for the item being staked.

It is the responsibility of the surveyor to check all control monuments used and to verify and document their accuracy tolerance prior to using them for any construction surveying control work. The surveyor shall document checking of the control monuments and notify the engineer in writing of any discrepancies prior to using the monuments.

6.1.14 TMOSS Surveys

Topography MOdeling Survey System (TMOSS) is developed by CDOT to automate the collection of surveying and aerial survey data. TMOSS is a survey system that provides a nine digit coding format that facilitates the use of CDOT Project Item Coding System (PICS) software.

TMOSS codes shall be used when survey data is collected to create the raw survey data file in accordance with this manual. This data file is then processed to produce plan drawings and survey data input for CDOT approved design software programs.

TMOSS Code Manuals are available through CDOT Bid Plans by contacting the following:

Colorado Department of Transportation
4201 E. Arkansas Ave., Room 117
Denver, CO 80222
(303) 757-9313

CDOT TMOSS:
http://www.dot.state.co.us/Publications/publications.htm
The above link provides information on obtaining TMOSS Code Manuals.

CDOT PICS:
http://www.dot.state.co.us/ECSU/Download.asp
The above link provides for downloading of CDOT PICS software.

See Chapter 5 - Preliminary Surveys, for additional information.

6.1.15 Survey Records

All survey field notes shall be taken in accordance with this manual. All field notes if not taken electronically, shall be recorded in standard hardbound fieldbooks. All electronically generated field notes shall be printed in a fieldbook format conforming to this 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 when approved in advance by the engineer.

Field notes for a particular phase of construction may be requested for inspection, and no work on that phase will be allowed to proceed until the inspection is complete. All original field notes shall become the property of CDOT. The engineer or inspector shall have the right to inspect the field notes at any time for completeness, accuracy, form, and proper technique. The surveyor shall sign and affix his Colorado professional seal to the survey field note records as each element is completed.

The surveyor shall provide the original field notes in fieldbooks and office computations for each of the following elements:

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 and Boundary monuments)

4. Horizontal Alignment - If there are several alignments, separate alignment books for each shall be used. Deflection angles for curves shall be calculated such that a maximum staking interval of 50 ft is produced. The computations and coordinates shall be recorded in the survey records. Smaller staking intervals may be required depending on the radius of the curve, visibility, or other factors.

5. Grading

6. Slope Stakes

7. Minor Structures

8. Major Structures, (*e.g.* bridge structure, sign bridge structure). Includes the horizontal and vertical locations for construction staking and as-constructed substructure survey for each of the required structural components. (See As-constructed Substructure, for additional information.)

9. One book for each of the major work categories as shown on the survey tabulation sheet.

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 engineer will reject any field notes found to be unacceptable.

See Chapter 2 - General Procedures, for additional information.

6.1.16 Staking by Coordinates

When the project is staked or data is collected using coordinates, it shall be accomplished by using the primary control monuments and the corresponding coordinates shown on the approved CDOT Project Control Diagram in either Meters or U.S. Survey Feet as determined by the engineer during the presurvey conference.

6.1.17 Survey Staking, Review and Checks

Survey work consists of performing computations and staking necessary for the construction of all elements of the project. The surveyor shall review and check the plans, specifications, standards, memoranda of agreement, and this chapter thoroughly before staking begins. Field checks shall be performed to verify plan data at the vertical and horizontal tie-in(s) to existing features. Field checks shall be performed to verify plan data when the plans are based on photogrammetry or interpolated data. The contractor may be held responsible for all costs associated with corrective actions if the engineer is not immediately notified in writing that plan errors were discovered during staking.

6.1.18 Preservation of Stakes

(Reference Section 625.08 and 105.08 of the CDOT Standard Specifications)

When staking a project, the surveyor shall keep in mind the operations of the contractor for the preservation of stakes. Communication between the surveyor and the contractor is necessary to avoid destroying stakes and reference locations. Lath and/or stakes with the appropriate colored flagging or paint in accordance with this chapter shall be used to mark offset stakes and references. Stakes should be placed in locations where the normal operations of the contractor will not disturb them.

The contractor's personnel and other subcontractors should be made aware that the stakes are time consuming and expensive to replace. This issue should be discussed during on site project meetings so all project personnel are aware of the impacts to the project when the stakes are disturbed.

Stakes that are damaged, destroyed, or made inaccessible by the progress of construction shall be replaced, transferred, or re-established at the contractor's expense, except for those noted on the survey tabulation sheet.

6.2 Control Monumentation

6.2.1 Performed by Professional Land Surveyor

The Memorandum of Understanding (MOU) between CDOT and the State Board of Registration for Professional Engineers and Professional Land Surveyors requires that control surveys from which the Right of Way or any land boundary will be calculated, described or monumented, be performed under the direction and control of a Colorado Professional Land Surveyor.

See Chapter 1 – General, for additional information.

6.2.2 Primary and Secondary Control Monuments

Most CDOT construction projects have previously established primary control monuments that were established during the preliminary survey for the project. For projects where primary control monuments have not been established and are a necessary requirement for construction of the project, a CDOT primary control survey shall be performed in accordance with this manual.

CDOT primary control monuments and the monuments used as reference for the establishment of the primary control monuments are considered primary control. Any additional control set from these primary control monuments shall be considered secondary control.

See Chapter 5 – Preliminary Surveys, for additional information.

6.2.3 Setting of New Primary Control Monuments

When a primary control monument is disturbed or destroyed, a new primary control monument shall be set by either GPS or conventional survey methods in accordance with this manual. The primary control spacing shall not exceed 0.2 mile (1000 feet) from other primary control monuments. The monument spacing shall not exceed the primary control monument spacing. The new monument shall have a new and unique point number assigned to it in order to identify it from the old monument that is being replaced (*e.g.* if the disturbed primary control monument's point number was 5231 for mile post 252.31, the newly established primary control monument's point number may be 5232 for mile post 252.32). The point number of the old monument must not be used again as the new monument is a different monument and has different horizontal and vertical control data. Care needs to be taken to ensure that primary control monument point numbers will not interfere with any TMOSS or any other point numbers that may be needed. The point's new coordinate and elevation data shall be established before any staking is performed in the area governed by the new primary control monument.

After the monumentation sites are identified for installation of new primary control monuments, each site shall be marked and utility locates called for. (See Chapter 2 – General Procedures, for additional information.)

Primary control monuments shall have a witness post installed within 2 ft and facing the monument, or as approved by the engineer. Primary control monuments and witness posts material shall be furnished by CDOT in accordance with M & S Standards M-629-1. (See Chapter 1 – General, for additional information.)

A supplemental or amended Project Control Diagram shall be prepared in accordance with this manual by the surveyor in responsible charge of resetting the monument and submitted to the engineer and the Region Survey Coordinator at the end of the construction phase. It is important to note that the

supplemental or amended Project Control Diagram includes a diagram prepared to scale showing the location of the monument in relationship to the improvements and topography. A list of control data associated with the new monument is not an acceptable substitute for a Project Control Diagram.

Setting of primary control monuments shall meet the Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class A – Primary survey. (See Chapter 5 - Preliminary Surveys, for additional information.)

6.2.4 Setting of Secondary Control Monuments for Construction

Any permanent or temporary secondary control monument set for construction shall be set by either GPS or conventional methods in accordance with this manual. The secondary control monument spacing shall not exceed the primary control monument spacing. All secondary control monuments shall be set solidly into the ground and shall consist of a material that will hold the required Minimum Construction Horizontal and Vertical Accuracy Tolerance as required in this chapter for the entire time the monument is to be used for construction and as-built surveys. If a cap is placed on the secondary control monument it should be stamped "Work Point" along with it's identifying point number, and be punched marked with a point not larger than 0.01 ft. If a reinforcing bar is used, the point shall be punched in the steel. See Chapter 5 - Preliminary Surveys, for additional information.

Any secondary control monuments set for construction shall meet the same Minimum Construction Horizontal and Vertical Accuracy Tolerance required for the item being staked in accordance with this chapter.

6.2.5 Benchmarks

Benchmarks for CDOT projects consist of the primary control monuments and their corresponding elevation data shown on the Project Control Diagram.

CDOT primary control monuments and benchmarks are typically one of the same.

Vertical control in construction surveying consists of locating the existing benchmarks set during the preliminary survey, verifying their accuracy, correcting errors if necessary, moving benchmarks to new locations to prevent conflict with construction, and adding new benchmarks as needed. The surveyor shall document checking of project benchmarks and notify the engineer in writing of any discrepancies prior to using the benchmarks.

6.2.6 Setting of new Primary Control Benchmarks

Primary control benchmarks shall be set in accordance with this manual, and set in locations that will not be disturbed by or conflict with construction activities. The primary control benchmark spacing shall not exceed 0.2 mile (1000 feet) from other benchmarks. The benchmark spacing shall not exceed the primary control monument spacing. Primary control benchmarks shall have a witness post installed within 2 ft and facing the benchmark, or as approved by the engineer. Primary control benchmarks and witness posts materials shall be furnished by CDOT in accordance with M & S Standards M-629-1. (See Chapter 1 – General, for additional information.)

CDOT Primary Control Monuments and Benchmarks are typically one of the same.

Differential leveling is the CDOT approved process for determining and establishing elevations of any primary control benchmark. Only closed level circuits will be allowed for primary elevation control.

The control benchmark spacing requirement is based on the limitations of leveling equipment. The spacing requirement may be varied only if the leveling procedure, such as differential leveling, trigonometric leveling, or GPS established elevations, produces acceptable results in tolerance and is approved by the engineer with the concurrence of the Region Surveyor Coordinator. Proof that required tolerance has been attained shall be documented in the field notes.

Setting of new primary control benchmarks shall meet the Minimum Vertical Accuracy Tolerance of a CDOT Class A – Primary survey in accordance with Chapter 5 – Preliminary Surveys.

6.2.7 Setting of Secondary Control Benchmarks

Secondary control benchmarks shall be set in accordance with this manual in locations that will not be disturbed by or conflict with construction activities. Secondary control benchmark spacing shall not exceed 0.1 mile (500 feet) from other benchmarks. Secondary control benchmarks shall be set solidly into the ground and consist of a material that will hold the required Minimum Construction Vertical Accuracy Tolerance for the item being staked as required in this chapter for the entire time of construction.

Differential leveling is the CDOT approved process for determining and establishing elevations of any secondary control benchmark. Only closed level circuits will be allowed for secondary elevation control. EDM methods shall only be used when approved in advanced by the Region Survey Coordinator.

The control benchmark spacing requirement is based on the limitations of leveling equipment. The spacing requirement may be varied only if the leveling procedure, such as differential leveling, trigonometric leveling, or GPS established elevations, produces acceptable results in tolerance and is approved by the engineer with the concurrence of the Region Surveyor Coordinator. Proof that required tolerance has been attained shall be documented in the field notes.

Setting of secondary control benchmarks for construction shall meet the same Minimum Construction Vertical Accuracy Tolerance required for the item being staked in accordance with this chapter.

6.2.8 Setting Project Benchmarks on Bridges

The practice of setting project benchmarks on bridges (normally a brass cap set in the curb) ended in the mid 1990's due to the following:

1. Good information as to how the benchmark elevations were determined was not being provided.

2. They were not always correctly set (*e.g.* in the curb) directly over the bridge abutment.

3. The bridge guardrail was typically installed directly over the benchmark, making use of the benchmark impractical.

6.2.9 Preservation of Control Monuments and Benchmarks

CDOT has shared responsibility with the National Geodetic Survey (NGS), the United States Geological Survey (USGS) and other federal and local government agencies for mark (monument) maintenance in the State of Colorado. Every effort shall be made to protect control monuments and benchmarks set by CDOT or any other governmental agency such as city, county, state, or federal. The surveyor shall work closely with the contactor and CDOT to identify as early as possible any such monuments that will be

destroyed or disturbed in any manner. When the surveyor or contractor becomes aware that any such monument will be destroyed, the engineer and region survey coordinator shall be notified. The contractor will be required to pay for the cost to relocate and/or replace any monuments destroyed by his actions (except those identified for replacement on the survey tab sheet) unless proper notice is given and/or noted otherwise by the engineer and/or the region survey coordinator.

If proper notice is given, the monument will be referenced and relocated at no cost to the contractor. If CDOT references and/or relocates the monument, the Region Survey Coordinator requires a minimum two weeks advance notice. Additional time may be needed if the monument will be referenced and/or relocated by a contract consultant.

If proper notice is not given for referencing and/or relocating the monument, the cost will be billed to the contractor by deducting the replacement cost from the pay estimate.

See Chapter 1 – General, and Chapter 5 - Preliminary Surveys, for additional information.

6.3 Boundary Monumentation

6.3.1 Performed by Professional Land Surveyor

The Memorandum of Understanding (MOU) between CDOT and the State Board of Registration for Professional Engineers and Professional Land Surveyors requires that Right of Way surveys and boundary monumentation be performed under the direction and control of a Colorado Professional Land Surveyor.

See Chapter 1 – General, for additional information.

6.3.2 General

The work necessary for boundary monumentation under this section shall only be performed under the responsible charge of a Colorado Professional Land Surveyor (PLS) registered in the State of Colorado. The registration number of the professional land surveyor in responsible charge of setting the monument shall be stamped on the monument. All such work shall be performed and certified to in accordance with the following:

1. Laws of the State of Colorado applicable to the practice of land surveying.

2. Rules of the State Board of Registration for Professional Engineers and Professional Land Surveyors (State Board).

3. Memorandum of Understanding between CDOT and the State Board.

4. CDOT Procedural Directive – Land Surveys.

5. CDOT Standard Specifications for Road and Bridge Construction Section 629 – Survey Monumentation.

6. CDOT Survey Manual.

7. CDOT Right-of-Way Manual.

See Chapter 1 – General, and Chapter 5 – Preliminary Surveys, for additional information.

6.3.3 Boundary Monumentation

When the term “boundary monument” is used throughout this chapter it shall mean the following:

1. Right of Way Monuments
2. Public Land Survey Monuments
3. Property Boundary Monuments
4. Easement Monuments
5. Installing or adjusting monument boxes
6. Referencing and/or resetting of any of the above listed monuments

6.3.4 Right of Way Monuments

Right of Way (ROW) monuments are monuments set to mark CDOT Right of Way boundaries. Surveys of adjacent properties are not completed by CDOT and any discrepancies observed are not adjusted or resolved. ROW monuments are NOT set to delineate the property boundary lines of adjacent landowners.

The setting of final ROW monumentation and witness posts shall be coordinated with the engineer only after the needed ROW has been purchased, or immediate possession of the property being acquired has been granted, and the construction is at or near completion. The surveyor in responsible charge of setting the ROW monuments shall work closely with the engineer and contractor to ensure that the monuments and witness posts will be set at a time that will not be disturbed by future construction activities. When monumenting ROW, it is the surveyor's responsibility to verify the latest set of ROW plans are being used. Witness posts when required shall be set within 2 ft and facing the ROW monument, or as approved by the engineer.

Right of Way monuments shall be set at the following locations:

1. All points as designated on the Right of Way Plans.

2. All angle points or changes of direction.

3. At the beginning and ending of curves.

4. At the points of change of direction or changes of radius of any boundary defined by circular arcs.

5. Not to exceed 1400 feet apart along any straight boundary line.

6. All other points identified by the Region Survey Coordinator.

Right of Way monuments and witness posts materials shall be furnished by CDOT in accordance with M & S Standards M-629-1. (See Chapter 1 – General, for additional information.)

All Right of Way monuments set shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey. (See Chapter 5 - Preliminary Surveys, for additional information.)

6.3.5 PLSS Aliquot Monuments

Public Land Survey (PLSS) monuments are those monuments set as the result of a government (*i.e.* federal, state or municipal) survey or resurvey and are shown on General Land Office (GLO) or Bureau of Land Management (BLM) plats and filed notes and may include other survey monumentation documented in "Public Record". The surveyor in responsible charge of setting the Public Land Survey monument shall work closely with the engineer and contractor to ensure that the monuments will be set at a time that will not be disturbed by future construction activities. Witness post shall be set within 2 ft and facing the Public Land Survey monument, or as approved by the engineer.

CDOT as well as contract consultants performing work for the department shall strictly adhere to the restoration and upgrading of monuments, and filing of monument records.

Public Land Survey monuments and witness posts materials shall be furnished by CDOT in accordance with M & S Standards M-629-1. (See Chapter 1 – General, for additional information.)

All Public Land Survey System monuments set shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey. (See Chapter 5 - Preliminary Surveys for additional information.)

See Chapter 5 – Preliminary Surveys, for additional information on Reference Monuments (*i.e.* 2-Point, 3-Point, and 4-Point).

6.3.6 Boundary Monuments

Boundary monuments are monuments set to mark CDOT property boundaries (*e.g.* uneconomic remnants, excess Rights-of-Way or maintenance sites) when a land survey has been performed to locate such boundaries. Witness posts when required shall be set within 2 ft and facing the boundary monument, or as approved by the engineer.

Un-surveyed boundaries such as uneconomic remnants, excess Rights of Way, or maintenance sites are not required to be monumented when no land survey has been performed to determine their boundary. If the boundaries of uneconomic remnants, excess Rights of Way, or maintenance sites are determined by a boundary survey the boundaries shall be monumented.

CDOT is not required to monument remainder tracts.

Boundary monuments and witness posts materials shall be furnished by CDOT in accordance with M & S Standards M-629-1. (See Chapter 1 – General, for additional information.)

All boundary monuments set shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey. (See Chapter 5 - Preliminary Surveys, for additional information.)

6.3.7 Easements Monuments

Easement monuments are those monuments set to mark CDOT easement boundaries (*e.g.* permanent easements, slope easements, utility easements, railroad easements) when a land survey has been performed to locate such boundaries. Easements that parallel a monumented Right of Way do not require monumentation. Monumenting of easements is a professional decision made by the Region Survey Coordinator based each project's circumstances to protect the public.

Easements to be monumented shall be identified on the Right of Way Plans and by the Region Survey Coordinator at the presurvey conference. Witness posts when required shall be set within 2 ft and facing the easement monument, or as approved by the engineer.

CDOT does not monument temporary easements.

CDOT is not required to monument un-surveyed easements.

Easement monuments and witness posts materials shall be furnished by CDOT in accordance with M & S Standards M-629-1. (See Chapter 1 – General, for additional information.)

Easement monuments set shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey. (See Chapter 5 - Preliminary Surveys, for additional information.)

6.3.8 Installing or Adjusting Monument Boxes

This work consists of installing or adjusting monument boxes for new or existing monuments for the following:

1. Installing new monuments that require a monument box (*e.g.* CDOT Type A monuments).

2. Upgrading of existing monuments that require a monument box.

3. Adjusting existing monument boxes due to project overlaying of asphalt or concrete, or other circumstances when no new monument is set.

Monument boxes shall be furnished by CDOT in accordance with M & S Standards M-629-1. (See Chapter 1 – General, for additional information.)

6.3.9 Preservation of Boundary Monuments

The preservation of survey monuments is mandatory and affects all governmental agencies including CDOT. Once a monument is destroyed the cost of replacing the monument is significantly increased and if it has to be reset at its original position, the positional accuracy of the re-established monument is degraded. When it is known that a monument is in danger of being destroyed by or will interferer with construction activities the engineer and the Region Survey Coordinator shall be notified. The monument datum must be preserved. (See Chapter 1 – General, and Chapter 5 - Preliminary Surveys, for additional information.)

When it becomes known that a survey monument of any kind is going to be destroyed by construction and is not listed on the survey tabulation sheet for replacement, the engineer and Region Survey Coordinator shall be notified and a determination made as to if replacing the monument is required or not, (*e.g*. an existing Right of Way monument or boundary monument may not require replacement if additional Right of Way is being purchased in the same area where the monument is located).

If it is determined that replacing of the monument is required an additional contract bid item shall be prepared and submitted for replacing of the monument. If no contract bid item is prepared the cost of replacing the monument shall be the responsibility of the contractor. If CDOT replaces the monument the replacement cost will be billed to the contractor by deducting the replacement cost from the pay estimate.

6.3.10 Referencing and/or Replacing of Boundary Monuments

Every effort shall be made to protect boundary monuments. The surveyor shall work closely with the contractor and the engineer to identify as early as possible any such monuments that will be destroyed or disturbed in any manner. If the surveyor or contractor becomes aware that any such monument will be disturbed or destroyed the engineer and Region Survey Coordinator shall be notified. The contractor will be required to pay for the cost to relocate and/or replace any monuments destroyed by his actions (except those identified for replacement on the survey tabulation sheet) unless proper notice is given and/or noted otherwise by the engineer and/or the Region Survey Coordinator.

If proper notice is given, the monument will be referenced and relocated at no cost to the contractor. If CDOT references and/or relocates the monument, the Region Survey Coordinator requires a minimum two weeks advance notice. Additional time may be needed if the monument will be referenced and/or relocated by a contract consultant.

If proper notice is not given for referencing and/or relocating the monument, the cost will be billed to the contractor by deducting the replacement cost from the pay estimate.

When a boundary monument is slated for replacement the monument shall be referenced, prior to being disturbed, in a manner that the stated precision of the monument is minimally degraded. The position of the monument replaced shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey. (See Chapter 5 - Preliminary Surveys, for additional information.)

The replacement monument shall bear the registration number of the Colorado Professional Land Surveyor in responsible charge of setting the monument in addition to any other required monument stamping. (See Chapter 1 – General, for additional information.)

6.4 Minimum Construction Horizontal and Vertical Accuracy Tolerance

6.4.1 Construction Accuracy Tolerance

Construction items staked shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance for each specific item in accordance with this chapter. No hubs, tack points nails or secondary control monuments shall vary from line and grade by more than the specified tolerance for the item being staked.

The Minimum Construction Horizontal and Vertical Accuracy Tolerance is a local tolerance within itself and does not include the Minimum Horizontal and Vertical Accuracy Tolerance of the primary control monuments from which the construction staking is tied and referenced to as described in Chapter 5 – Preliminary Surveys.

For example, when staking a bridge or other structure the location of the centerline of the load bearing structure shall be positioned for alignment and grade meeting the required Minimum Horizontal and Vertical Construction Accuracy Tolerance. If the contractor, while performing the double checks required for structures discovers that the angles and distances calculated from the control monuments do not produce the required tolerances then the contractor is to adjust the stakes to produce the required tolerances. The adjustment method chosen must ensure that the overall alignment and grade of the structure fits the roadway while at the same time ensuring that the individual structural components called for on the plans all fit together. The contractor should plan on using the appropriate survey methods to verify that the structural components will all fit together (*e.g.* double measuring with a steel chain or tape and setting elevations with a rod and level).

6.4.2 Adjustments

No adjustment of the survey field data will be permitted without the written consent of the engineer and concurrence of the Region Survey Coordinator. If it is determined that an adjustment is necessary, a weighted least squares adjustment method is recommended.

6.4.3 Primary Control Benchmark Minimum Vertical Accuracy Tolerance

Setting of primary control benchmarks shall meet the Minimum Vertical Accuracy Tolerance of a CDOT Class A – Primary survey as required in Chapter 5 – Preliminary Surveys as the square root of the total horizontal distance of the level loop in miles multiplied by 0.035 feet.

$$0.035\, ft\sqrt{d}$$

The results of this evaluation shall be recorded in the field book for each differential level loop. At least two established benchmarks on the same or mathematically related datum shall be used to verify that the starting mark has not been disturbed. No adjustments of the data used for this evaluation will be allowed.

6.4.4 Secondary Control Benchmark Minimum Vertical Accuracy Tolerance

Setting of secondary control benchmarks for construction shall meet the same Minimum Construction Vertical Accuracy Tolerance required for the item being staked in accordance with this chapter.

6.4.5 Two Peg Test for Levels

Leveling equipment shall be checked and adjusted regularly as specified in this manual using the "Two Peg" test.

See Chapter 5 - Preliminary Surveys, for additional information.

6.5 3D Engineered Construction Surveying (3DECS)

6.5.1 General

CDOT first addressed the use of automated construction machine control by Revision of 625 Survey Control of Grading by GPS or RTS Methods, issued on November 3, 2008. This revision was later replaced by Revision of 625 3D Engineered Construction Surveying (3DECS) on February 18, 2016.

6.5.2 3DECS Defined

3DECS is the use of Global Positioning System (GPS) and/or Robotic Total Station (RTS) instruments to guide construction equipment operations by comparing 3D model information in real time. For 3DECS, either the construction equipment is fed modeling information and makes automatic adjustments (automated machine control) or the equipment operator is fed the information and makes manual adjustments.

3DECS may be used to supplement construction staking in order to reduce the amount of staking needed for construction. Alignment control points are required to be staked at a minimum of 500 foot intervals to allow for construction inspection and the checking of the contractor's equipment and work. Revision of 625 3D Engineered Construction Surveying details the requirements the contractor shall follow whenever 3DECS is used.

6.5.3 3DECS Contractor's Use

The Contractor may use 3D model information provided by CDOT, or as generated by the contractor in conjunction with construction equipment controlled by GPS and/or RTS instruments to guide the equipment during construction operations of specific items such as subgrade, subbase, base course and other roadway structure materials, ditches and other planned excavations and embankment of the project.

6.5.4 3DECS Minimum Horizontal and Vertical Accuracy Tolerance

Whenever the contractor uses 3DECS, the Minimum Construction Horizontal and Vertical Accuracy Tolerance for the specific item being constructed shall be met as specified in this chapter.

Whenever GPS or RTS equipment is used to control construction equipment, the contractor shall provide a method of equipment checks, inspection, and field verification per the requirements of Revision of 625 3D Engineered Construction Surveying that verifies the equipment meets the Minimum Horizontal and Vertical Accuracy Tolerance for the specific item being constructed as specified in this chapter.

6.6 Staking

6.6.1 General

The surveyor is required to perform all staking indicated on the survey tabulation sheet in accordance with the Standard Specifications for Road and Bridge Construction and in accordance with this Manual. Minimum staking requirements for the various construction items are described in detail in the Minimum Staking Requirements of this chapter. If staking details are not specified in this manual or on the plans, the staking placement interval and details shall be determined prior to the start of the work. The coordination required between the surveyor, contractor, and engineer to perform all survey related tasks shall be considered subsidiary to Item 625 - Construction Surveying. Survey work beyond the original project scope will be paid according to the CDOT Standard Specifications for Road and Bridge Construction.

Items shall be staked a minimum of 48 hours prior to any construction work being performed to allow for field inspection, unless otherwise approved in writing by the engineer.

6.6.2 Staking Color Codes

Type of Stake and/or Monument	Color Flagging, Paint, Etc.
Primary Control, Right of Way (ROW), Boundary, Public Land Survey System (PLSS)	Orange
Secondary Control, Structure Control	Yellow
Benchmarks (Primary and Secondary)	Blue
Easements (Permanent and Temporary)	Florescent Lime or Green
Alignment Centerline (Permanent and Temporary)	Red
Alignment Reference	Red and White
Slope Stakes	White
Structure Reference (Major and Minor)	Yellow and White
Test Holes (Geotechnical)	Pink
Utility Locates	White

Table 6-1

6.6.3 Required Reference Material

The surveyor shall have the following reference materials at the project site:

1. Project Plans
2. Project Special Provision
3. Computer generated cross sections
4. CDOT Standard Plans (M & S Standards)
5. CDOT Survey Manual
6. CDOT Standard Specifications for Road and Bridge Construction
7. CDOT Standard Specifications
8. Manual of Uniform Traffic Control Devices (MUTCD)

6.6.4 Checking for Plan Errors

The elevations, dimensions, and horizontal alignment of structures, earthwork, and roadways shall be checked for plan errors, compatibility, and consistency with existing field conditions. If any discrepancy is discovered, the engineer shall immediately be informed in writing. New grades shall be established from the plan profile with adjustments to match existing roadway features and approved by the engineer.

6.6.5 Centerline Staking

The project centerline control points, i.e. POT, POC, PCC, PC, PT, TS, ST, SC and CS, or the engineer approved offset line shall be established from primary control monuments and their assigned coordinates as shown on the plans. Staking for the project centerline shall be established from the project centerline control points as shown on the plans. The maximum staking interval for the project centerline shall be 100 ft on tangents and 50 ft on curves or as specified on the survey tabulation sheet. All project centerline control points as shown on the plans shall be staked. Additional project centerline points should be established by the surveyor and referenced to provide convenient and timely recovery of the centerline when required during construction. Once the project centerline or the engineer approved offset line has been established, all POT and any other centerline control points shall be immediately referenced to prevent loss and provide for easy recovery. Referencing such points can avoid delays if a portion of the project is re-staked. Care shall be taken when establishing these reference points to assure the accuracy of the centerline control points and prevent disturbance during construction.

Equation stations are occasionally encountered on a projected line. An equation station is a point on a line which is assigned two station numbers, *e.g.* Sta. 122+410.320 (back) = Sta. 122+418.490 (ahead). Equations stations are placed on an alignment to eliminate adjusting the length or to accommodate a revision in part of the alignment.

Centerline control points, or their reference marks, set in soil are to be monumented by a piece of reinforcing steel with an aluminum cap. When set in existing roadway, a large hinge nail may be countersunk in a chiseled square 0.03 ft below grade. When temporary centerline control points or their reference marks are set in soil, wood stakes are used. The temporary centerline control points are witnessed by crossed lath and identified with red flagging.

Station markers when set at any interval are wood laths clearly marked with the station and offset, if applicable. The stations are marked on the lath with a paint pen or with a stake pencil.

The planned horizontal alignment, centerline, or offset line, shall be established, referenced, and

maintained during construction.

6.6.6 Adequate Staking

Staking for Right of Way fence shall be based on the primary control monuments. In the case where no monumentation exists and no new Right of Way has been acquired, the existing fence shall be referenced and the new fence, if required, set from the reference data.

After the excavation and embankment are completed, all ditches shall be checked by the surveyor to assure proper drainage without ponding. This check shall be recorded in the survey records. Where the grade is 2% or less, the ditch centerline shall be staked.

Grade stakes are required for the top of all subgrades and the top of each layer of aggregate base course. A minimum of three grade stakes are required per each typical section or as specified on the survey tabulation sheet. The maximum transverse spacing is 15 ft.

Stakes for curb and gutter, and pipes over 50 ft in length, shall be placed at a maximum of 25 ft spacing.

6.7 Minimum Staking Requirements

6.7.1 General

Stationing shall be placed at a 100 ft maximum interval on tangents and 50 ft maximum interval on curves or as specified on the survey tabulation sheet. All staking should be placed where it will not be disturbed by the normal operations of the contractor. Check with the contractor prior to setting stakes since replacement is at the expense of the contractor.

Whenever a spacing interval is given in this section it shall be the maximum spacing unless otherwise specified.

Within this chapter, for the reason of consistency, the term grade stakes shall be used for either grade stakes or blue tops.

The date when a stake is placed or a mark is made shall be included in the survey records. Color-coding for the identification of the various types of stakes shall be in accordance with this chapter.

The following staking requirements are the minimum. In no case will the minimum staking requirements be reduced without a Contract Modification Order (CMO) or Minor Contract Revision (MCR). The engineer shall approve all field adjustments. All staking should be placed where it will not be disturbed by the normal operations of the contractor. Check with the contractor prior to setting stakes to minimize stake replacement.

6.7.2 Clearing and Grubbing

(Reference Section 201 of the CDOT Standard Specifications)

The majority of clearing and grubbing on a project is done within the area bounded by the slope stakes plus any area required for slope rounding. Any items to be cleared or grubbed outside the slope staked area or items to be protected shall be clearly marked according to an engineer approved plan. Items that are to remain in place and are in an area of removal activity shall be clearly marked and protected to prevent accidental removal prior to the start of any construction operation.

1. Tolerance and Interval

Stakes shall be set at 50 ft intervals and meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical. The vertical tolerance may be waived by the engineer.

2. Stakes and Documentation

Clearing and grubbing may be marked with lath, flagging, or paint as appropriate and documented by stationing and offset distance or project coordinates as necessary for area determination.

6.7.3 Removal of Structures and Obstructions

(Reference Section 202 of the CDOT Standard Specifications)

All marking shall be done prior to any removal work. Materials to be salvaged shall be clearly marked to avoid damage to the item.

1. Tolerance and Interval

Staking shall meet the tolerance and interval specified on the plans or specifications, which varies depending on the item.

2. Stakes and Documentation

All removals and partial removals included in this item shall be clearly marked such that no markings are left on remaining portions after removals are completed. Only changes to plan specified removals require documentation.

3. Reset Items

Staking is usually not required for the removal of a reset item but may be required to place items that are to be reset such as light poles, signs and minor structures as the item may not be put in the same place it occupied prior to construction. Refer to the section in this manual for the item to be reset for tolerances and intervals required as well as for stakes and documentation requirements. For example, if the item is sign refer to the section on signs for the requirements. (See Reset Structures, for additional information.)

6.7.4 Excavation and Embankment

(Reference Section 203 of the CDOT Standard Specifications)

Slope stakes shall be located using CDOT generated cross sections as a reference in accordance with this chapter.

Borrow areas shall have a minimum of three secondary control monuments set and have the terrain data collected using TMOSS methods and PICS software, or be cross sectioned from a baseline. Other terrain modeling methods which allow CDOT to create cross sections for verification of quantities from field data taken before and after excavation may be approved by the engineer prior to construction. A printed copy of the terrain data and a computer disk with the electronic data shall be submitted to the engineer.

All as staked earthwork quantities shall be computed and plotted from terrain data generated by CDOT TMOSS methods and PICS software showing the actual catch points where natural ground intersects the cut or fill slopes, all breakpoints, and the calculated roadway section. The engineer prior to construction may approve other terrain modeling methods that allow CDOT to create cross sections for verification from field data taken before and after embankments are built. The final cross sections shall be created at the same locations and intervals as the original plan data. Some situations involving bridge structures require interpolation of the original cross sections. This work is subsidiary to the item and will not be paid for separately.

All stakes shall be set for the project within the Right of Way or project easement unless the contractor provides a copy of the written permission from the property owner. The following may require staking of ROW and easements to eliminate encroachment on private land:

1. Referencing alignment control points outside the slope stakes.

2. Staking berms, slope refining, rounding, or slope sculpturing.

3. Areas where slope stakes fall near the Right of Way limits.

Refer to the Slope Stakes and Grade Stakes sections of this chapter for additional staking details and

information on marking slope stakes.

If the grade stakes are disturbed or destroyed they will require replacement before the engineer can accept the subgrade.

1. Tolerance and Interval

Slope stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical. The slope stakes shall be set at a maximum 50 ft spacing interval as shown by the plan sheet tic marks or at the designated intervals as shown on the survey tabulation sheet.

Grade stakes for the subgrade shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.098 ft horizontal and +/- 0.10 ft vertical. Grade stakes for the subgrade shall be set at a maximum 50 ft interval or at the interval shown on the survey tabulation sheet. The maximum transverse interval is 15 ft.

Borrow quantities may be calculated from cross sections or grids generated at a maximum interval of 50 ft if approved by the engineer.

2. Stakes and Documentation

All slope stakes shall be set at the true point of intersection of the plan cut or fill slope and the natural ground. Offset stakes shall be placed to reference slope stakes and facilitate construction.

The marking of stakes, the placing of offset stakes, and the method of documentation are described in the Slope Stakes section and Grade Stakes sections of this chapter.

6.7.5 Topsoil

(Reference Section 207 of the CDOT Standard Specifications)

The location of special berms and irregularities may require additional horizontal and vertical control. Location and volume of topsoil stockpiles shall be documented as specified on the plans.

1. Tolerance and Interval

Stakes shall be set at a 50 ft maximum interval and meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical.

2. Stakes and Documentation

The final staked topsoil area shall be documented by field-measured slope distances or field-measured project coordinates and elevations.

6.7.6 Reset Structures

(Reference Section 210 of the CDOT Standard Specifications)

All controls required to extend or reset a structure shall be in place prior to removal of the structure. Extending or resting of a structure shall be done in accordance with this manual as if it were a new installation of the structure. Refer to the Major and Minor Structures section of this chapter for additional information.

1. Tolerance and Interval

Extensions: Stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance for the item being staked. If the item being staked is does not have a tolerance stated in this chapter, then the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical shall apply.

Resets: Stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance for the item being staked. If the item being staked is does not have a tolerance stated in this chapter, then the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical shall apply.

2. Stakes and Documentation

The final staked locations shall be documented by field-measured stations and offsets or field-measured project coordinates and elevations.

6.7.7 Seeding, Fertilizer and Sodding

(Reference Section 212 of the CDOT Standard Specifications)

All seeding and rehabilitation areas shall be staked per plan and approved by the engineer including special seeding areas.

1. Tolerance and Interval

Stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical.

2. Stakes and Documentation

The final staked areas shall be documented by field-measured slope distances or field-measured project coordinates and elevations. Areas shall be calculated and converted to acres for seeding and square feet for sod.

6.7.8 Planting and Transplanting

(Reference Section 214 of the CDOT Standard Specifications)

Stakes shall show the location and type of plant. Locating plants properly may require judgment, as specifications exist for unsuitable planting locations for trees and shrubs. Plants that appear out of place in plan location shall be brought to the attention of the engineer.

1. Tolerance

Stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/ 0.98 ft horizontal and +/- 0.10 ft vertical. The vertical tolerance may be waived by the engineer.

2. Stakes and Documentation

The final staked locations shall be documented by field-measured stations and offsets or project

coordinates.

6.7.9 Herbicide Treatment

(Reference Section 217 of the CDOT Standard Specifications)

Areas are to be staked per plan and approved by the engineer.

1. Tolerance and Interval

Stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical. The vertical tolerance may be waived by the engineer.

2. Stakes and Documentation

The final staked areas shall be documented by field-measured slope distances or field-measured project coordinates and elevations.

6.7.10 Plant Mixed Bituminous Base

(Reference Section 301 of the CDOT Standard Specifications)

Grade stakes for plant mixed bituminous base may be waived by the engineer when a bituminous paver is used to distribute the mixture to the established grade and required thickness.

Set edge lines and grade lines as required by the plans or approved by the engineer. If the grade stakes are disturbed or destroyed they will require replacement before the base course can be accepted.

1. Tolerance and Interval

Grade stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical. Maximum grade stake spacing interval shall be 50 ft longitudinally and 15 ft transversely unless shown otherwise on the survey tabulation sheet.

2. Stakes and Documentation

Grade stake elevations shall be computed and recorded as described in the Grade Stakes section of this chapter.

6.7.11 Aggregate Base Course

(Reference Section 304 of the CDOT Standard Specifications)

If the grade stakes are disturbed or destroyed they will require replacement before the base course can be accepted.

1. Tolerance and Interval

Grade stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical. Maximum grade stake interval shall be 50 ft longitudinally and 15 ft transversely unless shown otherwise on the survey tabulation sheet.

2. Stakes and Documentation

Grade stake elevations shall be computed and recorded as described in the Grade Stakes section of this chapter. The surveyor shall verify the as-constructed surface of each individual layer of base course as called for by the specification. A written certification signed by the surveyor shall be provided to the engineer stating that the grade is within acceptable tolerances as called for by the specifications.

6.7.12 Reconditioning

(Reference Section 306 of the CDOT Standard Specifications)

Limits shall be established as required by plans or as approved by the engineer. Grade stakes shall be set after reconditioning. If the grade stakes are disturbed or destroyed they will require replacement before the reconditioned area can be accepted.

1. Tolerance and Interval

Grade stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical. The maximum grade stake interval shall be 50 ft longitudinally and 15 ft transversely unless shown otherwise on the survey tabulation sheet.

2. Stakes and Documentation

Grade stake elevations shall be computed and recorded as described in the Grade Stakes section of this chapter.

6.7.13 Lime Treated Subgrade

(Reference Section 307 of the CDOT Standard Specifications)

The limits of the areas to receive lime treatment are as shown on the plans and are defined by grade stakes. Grade stakes are used to establish the proper depth of lime treatment. The depth of treatment is specified in the contract. Grade stakes are required for subgrade and final grade. If the grade stakes are disturbed or destroyed they will require replacement before the subgrade can be accepted.

1. Tolerance and Interval

Grade stakes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical. The maximum grade stake interval shall be 50 ft longitudinally and 15 ft transversely unless shown otherwise on the survey tabulation sheet.

2. Stakes and Documentation

Grade stake elevations shall be computed and recorded as described in the Grade Stakes section of this chapter.

6.7.14 Reprocessed Asphalt Material for Base Course

This section reserved for future use.

6.7.15 Plant Mix Pavements

(Reference Section 401 of the CDOT Standard Specifications)

Subgrade or base course grade stakes shall be visible prior to paving unless an existing pavement is being

overlayed. Control alignment for each lift or lane of paving is required for adequate vertical and horizontal control. Staking of temporary pavement marking is required for the placement of striping to maintain traffic flow in conformance with the Traffic Control Plan.

6.7.16 Overlay Projects – Pavement Markings

(Reference Section 627 of the CDOT Standard Specifications (See Pavement Marking, for additional information).

Existing pavement marking requires referencing prior to placement of the overlay. New pavement marking requires staking after completing the overlay. Pavement marking locations may be adjusted by the engineer to fit field conditions. Reference stakes shall be replaced at the expense of the contractor.

1. Tolerance and Interval

Control alignments shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical.

Overlay stationing shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance +/- 0.98 ft horizontal and +/- 0.10 ft vertical. The vertical tolerance may be waived by the engineer.

Overlay projects require stationing at a 50 ft maximum interval or as specified on the survey tabulation sheet.

2. Stakes and Documentation

Stationing should be placed where it will not be disturbed by the normal operations of the contractor. The existing pavement marking locations and references shall be documented in the survey records.

6.7.17 Heating and Scarifying Treatment

(Reference Section 405 of the CDOT Standard Specifications)

This type of operation is used to rehabilitate roadway surfaces. The existing roadway surface acts as the grade and alignment control. Existing pavement marking requires referencing prior to performance of the treatment. New pavement marking requires staking after completing the treatment. Pavement marking locations may be adjusted by the engineer to fit field conditions. Reference stakes shall be replaced at the expense of the contractor.

1. Tolerance and Interval

Stationing shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical. Stationing shall be placed at a 50 ft maximum interval or as shown on the survey tabulation sheet.

2. Stakes and Documentation

Stationing should be placed where it will not be disturbed by the normal operations of the contractor.

6.7.18 Prime Coat, Tack Coat and Rejuvenating Agent

(Reference Section 407 of the CDOT Standard Specifications)

Prime coat (liquid asphaltic material) is applied the width of the grade stakes on the top of the base course. Stationing is usually the only survey work required for this item.

Tack coat (emulsified asphalt) is applied to an existing pavement surface at a width equal to or greater than the paver width. The paving operation may require vertical and horizontal control for the paver. The tack coat may be applied using the same alignment. Stationing is usually the only survey work required for this item.

Rejuvenating agent (ARA) is applied to asphaltic pavement surfaces. Stationing is usually the only survey work required for this item.

1. Tolerance and Interval

Stationing shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical. The vertical tolerance may be waived by the engineer. Stationing shall be placed at a 50 ft maximum interval or as specified on the survey tabulation sheet or as approved by the engineer.

2. Stakes and Documentation

Stationing should be placed where it will not be disturbed by the normal operations of the contractor.

6.7.19 Seal Coat or Chip Seal

(Reference Section 409 of the CDOT Standard Specifications)

Seal coat is placed over an existing pavement surface that controls material placement location.

Stationing is usually the only survey work required for this item.

Existing pavement marking requires referencing prior to placement of surface treatment. New pavement marking requires staking after completing the surface treatment. Pavement marking locations may be adjusted by the engineer to fit field conditions.

1. Tolerance and Interval

Stationing shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical. The vertical tolerance may be waived by the engineer. Stationing shall be placed at a 50 ft maximum interval or as shown on the survey tabulation sheet.

2. Stakes and Documentation

Stationing should be placed where it will not be disturbed by the normal operations of the contractor. The existing pavement marking locations and references shall be documented in the survey records.

6.7.20 Plant Mixed Seal Coat

(Reference Section 410 of the CDOT Standard Specifications)

Plant mixed seal coat is placed over an existing pavement surface that controls the material placement location.

Stationing is usually the only survey work required for this item.

Existing pavement marking requires referencing prior to placement of surface treatment. New pavement marking requires staking after completing the surface treatment.

1. Tolerance and Interval

Stationing shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical. The vertical tolerance may be waived by the engineer. Stationing shall be placed at a 50 ft maximum interval or as shown on the survey tabulation sheet.

2. Stakes and Documentation

Stationing should be placed where it will not be disturbed by the normal operations of the contractor. The existing pavement marking locations and references shall be documented in the survey records.

6.7.21 Portland Cement Concrete Pavement

(Reference Section 412 of the CDOT Standard Specifications)

Subgrade grade stakes shall be visible and in conformance with this chapter. If the contractor elects to use a fine grading machine or paver controlled by a string line, the grade stakes shall be set such that independent grade stakes controls each side of the machine. The string line for each side shall be set at the same fixed distance above the grade and parallel to the plane of the roadway cross section. This will enable quick checks of the setting of the string line. Dowel baskets or other load transfer devices shall be staked per plan location or as approved by the engineer. Transverse joint locations shall be staked for saw cut line according to the plans or the M & S Standards.

1. Tolerance and Interval

Horizontal control alignments and permanent stationing shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical.

At least one side of the string line which controls the fine grading machine or paver shall have stakes which determine horizontal position set to the Minimum Construction Horizontal and Vertical Accuracy Tolerance +/- 0.02 ft horizontal and +/- 0.02 ft vertical.

Grade stakes not used for horizontal control shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical.

Load transfer devices and transverse joint locations shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical.

When placed, the maximum longitudinal spacing for horizontal and vertical control lines shall be

50 ft.

2. Stakes and Documentation

Grade stakes may be used for more than one course if undisturbed between operations. If used for more than one course, the grade stakes shall be checked and may be used again if the grade stakes are found to be within acceptable tolerance. The checks shall be documented in the survey records.

6.7.22 Steel Sheet Piling

(Reference Section 501 of the CDOT Standard Specifications)

1. Tolerance and Interval

Stakes for sheet piling shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Stake alignment and cut off elevation according to the plans or as adjusted by the engineer and document in the survey records.

6.7.23 Piling

(Reference Section 502 of the CDOT Standard Specifications)

1. Tolerance and Interval

Stakes for piling shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Stake location and cut off elevation for each individual pile and document in the survey records. Document the field-measured cut off elevations in the survey records.

6.7.24 Drilled Caissons

(Reference Section 503 of the CDOT Standard Specifications)

Refer to M&S Standards – Monotube Overhead Sign, Standard Plan S-614-50 for substructure as-constructed survey requirements. (See Major Structures, for additional information.)

1. Tolerance and Interval

Stakes for drilled caissons shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Stake alignment and grade with references to allow inspection of the hole location and reinforcing steel placement and document in the survey records.

6.7.25 Cribbing

(Reference Section 504 of the CDOT Standard Specifications)

1. Tolerance and Interval

Stakes for cribbing shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

Stake vertical and horizontal alignment per plan or as approved by the engineer and document in the survey records.

6.7.26 Riprap

(Reference Section 506 of the CDOT Standard Specifications)

Riprap shall be slope staked per the Slope Stakes section of this chapter.

1. Tolerance and Interval

Stakes for riprap shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical.

2. Stakes and Documentation

Stake structure excavation limits and toe walls as shown on the plans and document in the survey records.

6.7.27 Slope and Ditch Paving

(Reference Section 507 of the CDOT Standard Specifications)

This may include slope staking for this item per the Slope Stakes section of this chapter. Staking for line and grade dirt work is required to establish ditch grades and slope neat lines prior to the ditch paving.

1. Tolerance and Interval

Stakes for slope and ditch paving shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.10 ft horizontal and +/- 0.03 ft vertical.

2. Stakes and Documentation

Stake structure excavation limits and grade to the plan limits or to meet sidewalk, curb and gutter, and slope and document in the survey records.

6.7.28 Timber Structures

(Reference Section 508 of the CDOT Standard Specifications)

See Major Structures, for additional information.

1. Tolerance

Stakes for timber structures shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Stake vertical and horizontal alignment to meet plan and project conditions as approved by the engineer and document in the survey records.

6.7.29 Steel Structures

(Reference Section 509 of the CDOT Standard Specifications)

Refer to section 601 for substructure as-constructed survey requirements. Refer to the Major Structures section of this chapter for additional information.

1. Tolerance

Stakes for steel structures shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.01 ft horizontal and +/- 0.01 ft vertical

2. Stakes and Documentation

Vertical and horizontal control shall be established for each longitudinal line (*ie.* edge of deck, centerline of girder or web, edge of girder, stage or phase construction joint, etc.) necessary to construct the structure or item. Girder 10th, "n"th, or fractional points for each longitudinal line shall be located and elevations set with the corresponding deflections provided on the plans or by the engineer. All points, marks, elevations, and computations shall be documented in the survey records by station and offset or project coordinates.

6.7.30 Structural Plate Structures

(Reference Section 510 of the CDOT Standard Specifications)

1. Tolerance

Stakes for structural plate structures shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

Stake horizontal alignment offset with vertical grades and document in the survey records.

6.7.31 Bearing Devices

(Reference Section 512 of the CDOT Standard Specifications)

Refer to section 601 for substructure as-constructed survey requirements after construction of the abutments and piers but prior to girder erection. Refer to the Major Structures section of this chapter for additional information.

1. Tolerance

Stakes for bearing devices shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.01 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Stake centerline of bearing and elevation of finished surface upon which bearings are to be placed and document in the survey records.

6.7.32 Bridge Expansion Devices

(Reference Revision of Section 518 of the Project Special Provisions)

Bridge expansion devices shall be set such that the alignment and grade (longitudinal and transverse) match the adjacent roadway to allow for a smooth, "bump-free" ride from one side of the device to the other. The plans and specifications contain information that instructs the contractor how to determine the appropriate temperature when setting the bridge expansion device opening. The plans show the bridge expansion device openings at various temperatures.

1. Tolerance

Stakes for bridge expansion devices shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.01 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

The elevations necessary to set the expansion device for the appropriate temperature opening to match the adjacent roadway shall be calculated by the surveyor and documented in the survey records.

6.7.33 Pipe Railing

(Reference Section 514 of the CDOT Standard Specifications)

1. Tolerance

Stakes for pipe railing shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.01 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Stake support posts for line and finished grade and document in the survey records.

6.7.34 Structural Concrete

(Reference Section 601 of the CDOT Standard Specifications)

Refer to section 601.12 for substructure as-constructed survey requirements. (See the Major Structures, for additional information.)

1. Tolerance

Stakes for structural concrete shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.01 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Vertical and horizontal control shall be established for each longitudinal line (ie. edge of deck, centerline of girder or web, edge of girder, stage or phase construction joint, etc.) necessary to construct the structure or item. Girder 10th, "n"th, or fractional points for each longitudinal line shall be located and elevations set with the corresponding deflections provided on the plans or by the engineer. All points, marks, elevations, and calculations shall be documented in the survey records by station and offset or project coordinates.

6.7.35 Pipe and Related Items

(Reference Section 603 of the CDOT Standard Specifications)

Offset stakes for alignment and grade are required. A check of existing field conditions for low point, other drainage structures, and controlling field conditions shall be made and compared to plan elevations and grades. Stake alignment and grade to assure proper drainage. If any discrepancy in vertical or horizontal alignment is discovered, the engineer shall immediately be informed in writing. Refer to the M & S Standards and the Minor Structures section of this chapter for additional details. Irrigation flows require special attention concerning the channel grade and may require field design work to adapt to field conditions as approved by the engineer. For long installations, stake the first 125 ft for line and grade at a 25 ft interval and thereafter at 50 ft intervals. If a laser device is used to grade pipes it shall be checked against the stakes at least every 125 ft and at the beginning of work each day.

6.7.36 Culverts

(Reference Section 603 of the CDOT Standard Specifications)

1. Tolerance

Stakes for culverts shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

Stake offset alignment and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.37 Manholes, Inlets, and Meter Vaults

(Reference Section 604 of the CDOT Standard Specifications)

1. Tolerance

Stakes for manholes, inlets, and meter vaults shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Stake offset location and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.38 Subsurface Drains

(Reference Section 605 of the CDOT Standard Specifications)

Place offsets for alignment and grade. Check vertical and horizontal placement to assure water is intercepted and can be disposed.

1. Tolerance

Stakes for underdrains shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

Stake offset alignment and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.39 Water Control Devices

(Reference Section 615 of the CDOT Standard Specifications)

Stake as needed with offsets. Follow the procedures in the Minor Structures section of this chapter.

1. Tolerance

Staking for water control devices shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Stake offset location and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.40 Siphons

(Reference Section 616 of the CDOT Standard Specifications)

Stake vertical and horizontal alignment with offsets. Check existing ditch flow lines if applicable and make necessary grade adjustments as approved by the engineer. Siphon drainpipes shall be located and graded. (See the Minor Structures, for additional information.)

1. Tolerance

Staking for siphons shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

Stake offset alignment and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.41 Culvert Pipe

(Reference Section 617 of the CDOT Standard Specifications)

Offset stakes for alignment and grade are required. Irrigation flows require special attention concerning the channel grade and may require field design work as approved by the engineer. Any discrepancies in vertical or horizontal alignment shall be brought to the attention of the engineer. Follow the procedures as described in the Minor Structures section of this chapter.

1. Tolerance

Stakes for culvert pipe and sewer pipe shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance +/- 0.03 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

Stake offset alignment and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.42 Water Lines

(Reference Section 619 of the CDOT Standard Specifications)

Set horizontal and vertical alignment at a maximum interval of 25 ft. Check proposed vertical and horizontal alignment to see if adjustments to the lines are necessary. Verify that minimum cover requirements are met.

1. Tolerance

Stakes for water lines shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

Stake offset alignment and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.43 Corrosion Resistant Culverts

(Reference Section 624 of the CDOT Standard Specifications)

Offset stakes for alignment and grade are required. Irrigation flows require special attention concerning the channel grade and may require field design work as approved by the engineer. Any discrepancies in vertical or horizontal alignment shall be brought to the attention of the engineer. Follow procedures as described in the Minor Structures section of this chapter.

1. Tolerance

Stakes for corrosion resistant culverts shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

Stake offset alignment and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.44 Guard Rail and Median Barrier

(Reference Section 606 of the CDOT Standard Specifications)

The surveyor usually locates the relative position of guardrail and median barrier along the roadway line and grade to fit the finished roadway. All earthwork, flares, and end treatments required to accommodate each run of guardrail shall be staked.

1. Tolerance and Interval

Stakes for guardrail shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical. Guardrail flares shall be staked at a maximum of 25 ft spacing and tangents at a maximum of 50 ft spacing.

Stakes for median barrier shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical.

Alignment and grade stake spacing for median barrier shall not exceed 25 ft or as shown on the survey tabulation sheet.

2. Stakes and Documentation

Stake offset alignment and document in the survey records.

6.7.45 Fences

(Reference Section 607 of the CDOT Standard Specifications)

All Right of Way fences shall be staked a minimum of 0.50 ft INSIDE the Right of Way. Fences shall be placed so as to not disturb or destroy any Right of Way monument and/or boundary monuments. Stakes for fences shall be set accordingly.

1. Tolerance and Interval

Stakes for fences shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical. The vertical tolerance may be waived by the engineer.

2. Stakes and Documentation

Stake grade control as required. Horizontal alignment for fencing may require Right of Way staking. Follow procedures as described in the Adequate Staking section of this chapter.

6.7.46 Sidewalks and Bikeways

(Reference Section 608 of the CDOT Standard Specifications)

Stake in conformance with the plans and specifications with adjustments as approved by the engineer to meet existing conditions. Follow procedures as described in the Curb & Gutter – Sidewalk - Median Barrier section of this chapter.

1. Tolerance and Interval

Stakes for sidewalks and bikeways shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical. Alignment and grade stake spacing shall not exceed 25 ft or as shown on the survey tabulation sheet. Stake offset alignment and grades to meet plan and project conditions as approved by the engineer.

2. Stakes and Documentation

Document in the survey records.

6.7.47 Curb and Gutter

(Reference Section 609 of the CDOT Standard Specifications)

Stake horizontal and vertical alignment including all radii and make grade adjustments as approved by the engineer to meet existing roadway conditions. Profile existing gutter or drainage to assure the grades match. The grade shall be field checked in flat areas to assure drainage. Refer to the Curb & Gutter / Sidewalk, Median Barrier section of this chapter for additional details.

1. Tolerance and Interval

Stakes for curb and gutter shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical.

Alignment and grade stake spacing shall not exceed 25 ft or as shown on the survey tabulation sheet.

Stake offset alignment and grades to meet plan and project conditions as approved by the engineer.

2. Stakes and Documentation

Stake offset alignment and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.48 Median Cover Material

(Reference Section 610 of the CDOT Standard Specifications)

The grade shall be checked for proper drainage. Refer to the Curb & Gutter / Sidewalk / Median Barrier section of this chapter for additional details.

1. Tolerance and Interval

Stakes for median cover shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical. Stake limits per plan or as approved by the engineer at a maximum interval of 25 ft.

2. Stakes and Documentation

Stake grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.49 Cattle Guards

(Reference Section 611 of the CDOT Standard Specifications)

Staking of horizontal alignment and grade is required using appropriate offsets. A profile survey of the existing roadway is required to assure a smooth transition through the structure. Attention to the grades at the ends of the cattle guard is also critical if the roadway is crowned or super elevated.

1. Tolerance

Stakes for cattle guards shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

The final staked locations and elevations shall be documented by field-measured stations and offsets or project coordinates.

6.7.50 Delineators and Reflectors

(Reference Section 612 of the CDOT Standard Specifications)

Delineators are placed from the edge of the pavement according to the plans, M & S Standards, and the Manual of Uniform Traffic Control Devices (MUTCD) (The plans may specify an offset distance!). The surveyor usually locates the relative position of the delineators along the roadway. Individual delineators shall be staked showing the type on the stake.

1. Tolerance and Interval

Delineators and reflectors shall meet the placement tolerance specified on the plans, M & S Standards, MUTCD, and as approved by the engineer.

2. Stakes and Documentation

The final staked locations shall be documented by field-measured stations and offsets or project coordinates.

6.7.51 Lighting and Conduit

(Reference Section 613 of the CDOT Standard Specifications)

Horizontal alignment and grade are required. Check for standard clearances, offsets, and depths. Refer to the plans and the M & S Standards.

1. Tolerance

Stakes for lighting and conduit shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.16 ft horizontal and +/- 0.04 ft vertical.

2. Stakes and Documentation

The final staked elevations shall be documented by field-measured elevations.

6.7.52 Traffic Control Devices

(Reference Sections 614 and 630 of the CDOT Standard Specifications)

Signpost lengths shall be field verified to assure proper height of signs. Any proposed variation from the Traffic Control Plan shall be approved by the engineer.

1. Tolerance and Interval

Traffic control devices shall meet the placement tolerance specified on the plans, M & S Standards, MUTCD, and as approved by the engineer.

2. Stakes and Documentation

Stake locations per the plans, Method of Handling Traffic (MHT), M & S Standards, MUTCD, and as approved by the engineer. Staking for concrete barrier, impact attenuators, delineation, and any other traffic control devices shall be as required for all phases and stages of construction. The final staked locations shall be documented by field-measured stations and offsets or project coordinates.

6.7.53 Signalization

(Reference Section 614 of the CDOT Standard Specifications)

Stake all elements as required by plans and approved by the engineer.

1. Tolerance

Stakes for signalization shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical.

2. Stakes and Documentation

The final staked locations and elevations shall be documented by field-measured stations and offsets and elevations or project coordinates and elevations.

6.7.54 Signing

(Reference Section 614 of the CDOT Standard Specifications)

Vertical and horizontal alignment are required. Slopes shall be calculated or field verified to determine sign post lengths and footing placement per plans and M & S Standards. Signing shall be field verified to assure proper sign height and roadway offset distance.

1. Tolerance

Stakes for signing shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical.

2. Stakes and Documentation

The final staked locations and elevations shall be documented by field-measured stations and offsets or project coordinates.

6.7.55 Prestressed Concrete Structures

(Reference Section 618 of the CDOT Standard Specifications)

Refer to section 601.12 for substructure as-constructed survey requirements. Refer to the Major Structures section of this chapter for additional information.

1. Tolerance

Stakes for prestressed concrete structures shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.01 ft horizontal and +/- 0.01 ft vertical.

2. Stakes and Documentation

Vertical and horizontal control shall be established for each longitudinal line (*i.e.* edge of deck, centerline of girder or web, edge of girder, stage or phase construction joint, etc.) necessary to construct the structure or item. Girder 10th, "n"th, or fractional points for each longitudinal line shall be located and the elevations set with the corresponding deflections provided on the plans or by the engineer. All points, marks, elevations, and calculations shall be documented in the survey records by station and offset or project coordinates.

6.7.56 Rest Areas and Buildings

(Reference Section 622 of the CDOT Standard Specifications)

Set vertical and horizontal control with appropriate references as required to control construction.

1. Tolerance and Interval

Stakes for rest areas and buildings shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical unless specifically addressed elsewhere. Staking interval shall not exceed 25 ft.

2. Stakes and Documentation

Stake offset location and grades to meet plan and project conditions as approved by the engineer. Document in the survey records.

6.7.57 Irrigation System

(Reference Section 623 of the CDOT Standard Specifications)

Field adjustment may be required as approved by the engineer.

1. Tolerance and Interval

Stakes for irrigation systems shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.07 ft horizontal and +/- 0.02 ft vertical. Staking interval shall not exceed 25 ft.

2. Stakes and Documentation

Set vertical and horizontal control with appropriate offsets. Check existing ditches and pipes to

assure drainage and match of the proposed irrigation system. The final staked locations and grades shall be documented by field-measured elevations.

6.7.58 Pavement Marking

(Reference Section 627 of the CDOT Standard Specifications)

Pavement marking locations may be adjusted, as approved by the engineer, to fit field conditions.

1. Tolerance and Interval

Stakes for pavement marking shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical. The interval for pavement marking is given on the plans and specifications.

2. Stakes and Documentation

Reference and record all existing pavement markings prior to construction. Stake pavement markings after construction from the references or plans and the MUTCD as appropriate and document in the survey records.

6.7.59 Construction Zone Traffic Control

(Reference Section 630 of the CDOT Standard Specifications)

Impact attenuators are placed relative to the hazard location. Signing shall be field verified to assure proper sign height and roadway offset distance. Any proposed variation from the Traffic Control Plan shall be approved by the engineer.

1. Tolerance and Interval

Construction zone traffic control shall meet the placement tolerance specified on the plans, Traffic Control Plan, M & S Standards, MUTCD, and as approved by the engineer.

2. Stakes and Documentation

Stake locations per the plans, M & S Standards, MUTCD, and as approved by the engineer. Staking for concrete barrier, impact attenuators, delineation, and any other traffic control devices shall be as required for all phases and stages of construction. The final staked locations shall be documented by the Method of Handling Traffic (MHT) approved by the engineer.

6.8 Slope Stakes

6.8.1 General

Slope stakes are set to mark the outside limits of the grading operation, except for rounding areas, and to inform the contractor of what earthwork is required to build the subgrade. Slope stakes are to be set at the point where the cut or fill intercepts the natural ground on both sides of the roadway at a maximum of 100 ft intervals on tangents and a maximum of 50 ft intervals on curves or as specified on the survey tabulation sheet. Offset stakes shall be placed to reference the slope stakes. Slope stakes shall be set for each phase of construction, typical section, channel change, ditch, berm, and selected borrow pits. The stakes give the contractor the cut or fill information needed to build the subgrade.

Cross sections will be taken while slope staking at 500 ft intervals or as specified on the survey tabulation sheet. This cross section data shall be compared to the original terrain data to determine the accuracy of the original data. If discrepancies, as determined by the engineer, are found during the comparison, new TMOSS data shall be taken to replace the original terrain data if the earthwork quantity is found to exceed the allowable limits. This will be paid for as extra work.

After slope staking, the "as staked" data shall be processed by the surveyor using a CDOT accepted roadway volumetric calculation method or computer program to determine the new earthwork quantities and then submitted to the engineer for verification before 20% of the earthwork in any given phase of construction is completed. This work is subsidiary to the item and will not be paid for separately.

6.8.2 Slope Staking Procedures

The slope staking interval shall be a maximum of 100 ft intervals on tangents and 50 ft intervals on curves or as specified on the survey tabulation sheet. Approved CDOT methods shall be discussed at the presurvey conference to assure all personnel know, understand, and comply with the approved methods. The slope staking procedure shall be discussed with the contractor and the earthwork superintendent prior to the beginning earthwork operations so all personnel are aware of how the slope stakes are marked and read.

Slope staking is an iterative process (trial and error) dependent on the accuracy of the original TMOSS data. The ground elevation is measured at the computer calculated coordinates and elevation of the slope intercept point to determine if the original terrain data is accurate and within the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical. If the tolerance is met, the slope stake can be placed at the calculated slope intercept point. If the tolerance is not met, the true position of the slope stake is to be field determined.

An accepted procedure for determining the true position of the slope stake in the field is as follows:

1. Measure the actual elevation at the plan Point of Slope Selection (PSS) distance perpendicular to the appropriate station to determine the approximate location of the slope stake

2. Measure an elevation and distance outside the PSS

3. The difference between the measured elevation and the calculated PSS elevation is computed and then multiplied by the plan slope to get the calculated horizontal distance

4. The calculated horizontal distance is then added to the plan PSS distance to determine the catch point distance from the centerline or survey line

5. The rodman then moves to the catch point distance where the process is repeated until the calculated horizontal distance is equal to the actual distance measured from the centerline or survey line

6. A grade stake is driven in the ground at this location and a slope stake written and placed with the appropriate information. (See Grade Stakes, for additional information.)

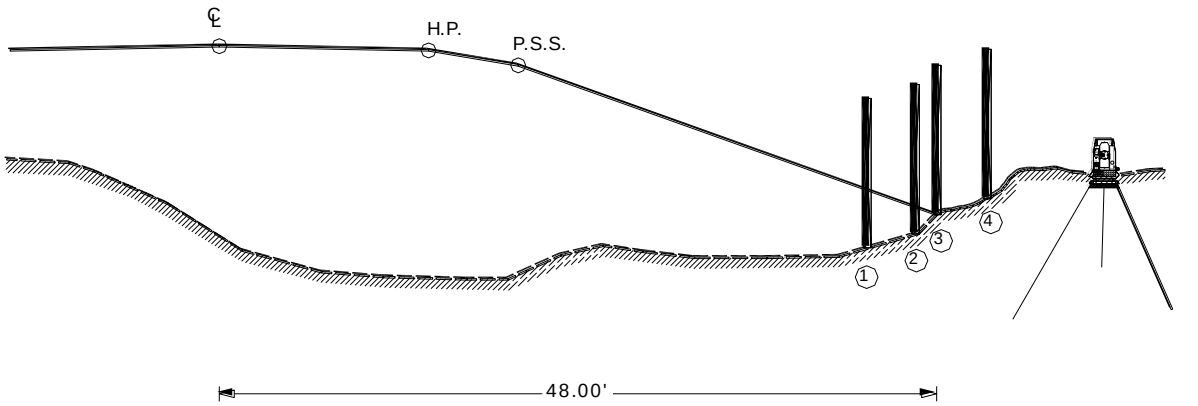
The slope stake shall in all cases represent the true point where the cut or fill slope from the plans intersects the natural ground. These locations shall have a grade stake driven in the ground and have an offset stake driven at a predetermined offset distance to preserve the slope intercept location during construction.

This new data generated by finding the true slope intercept point by the iterative process is to be included in the "as staked" data used in the re-calculation of earthwork quantities. If the original data is found to be in error as determined by the engineer, or if the quantities are out of tolerance as defined by the CDOT Standard Specifications, the whole area affected shall be re-surveyed using TMOSS and the earthwork quantities re-calculated and submitted to the engineer. This will be paid as extra surveying work.

Slope staking for each phase of construction shall be 100% complete and inspected before 20% of the earthwork for the particular phase is completed. If slope staking is not completed when 20% of the earthwork is complete, construction shall be stopped until the staking is complete and inspected. This will assure the "as staked" earthwork quantities will be calculated and any required earthwork changes are made in a timely manner.

Survey crews shall develop a system to check all computations being made. The computation check shall be documented in the survey records. Slope stakes shall be located within the Right of Way or easement boundaries. The engineer shall be informed of any discrepancies. A visual check of the slope stake line can be helpful in preventing errors. A quick look back over the already staked area may reveal stakes out of line which need to be checked and may require correction.

SLOPE STAKING EXAMPLE



Given P.S.S. = Elev. 20.0' @ 28.0' Rt.
Given Hinge Point = Elev. 20.6' @20.0' Rt.

Fill Slopes = 6:1 where H< 4'
4:1 where H> 4' < 10'
3:1 where H> 10'
H = Difference in elevation of existing ground and P.S.S.

Shot #1 1) Elevation = 14.6', Distance 40.0'
2) H = 20.0 - 14.6 = 5.4
3) Horizontal Distance = Fill x Slope = 5.4 x 4 = 21.6'
4) Distance from Centerline = Horizontal Distance + P.S.S. Distance
= 21.6 + 28.0 = 49.6'
5) Rodperson moves 49.6' from Centerline

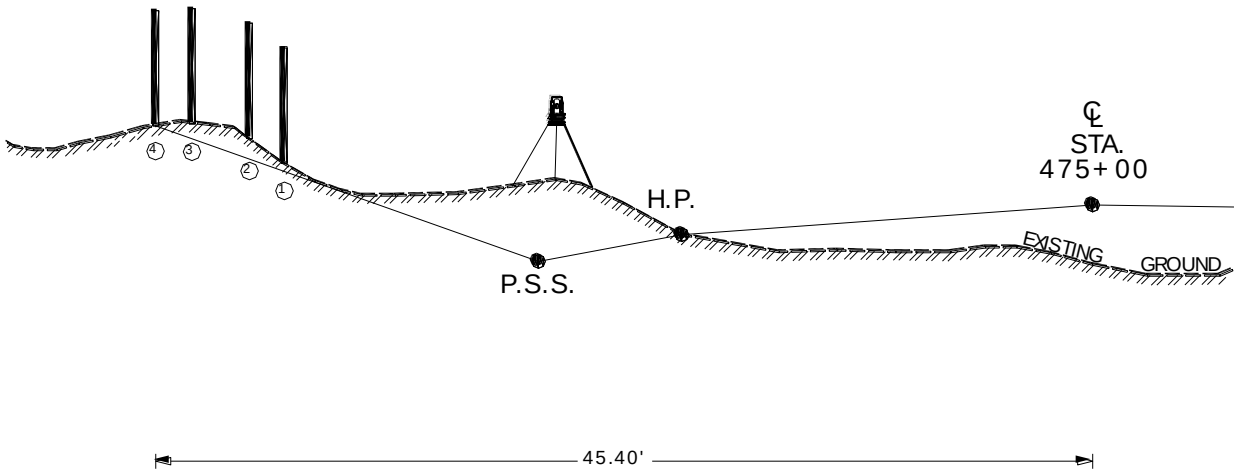
Shot #2 1) Elevation = 15.2', Distance = 49.6'
2) H = 20.0 - 15.2 = 4.8
3) Horizontal Distance = 4.8 x 4 = 19.2'
4) Distance from Centerline = 19.2 + 28.0 = 47.2'
5) Rodperson moves 47.2' from Centerline

Shot #3 1) Elevation = 15.0', Distance = 47.2'
2) H = 20.0 - 15.0 = 5.0'
3) Horizontal Distance = 5.0 x 4 = 20.0'
4) Distance from Centerline = 20.0 + 28.0 = 48.0'
5) Rodperson moves 48.0' from Centerline

Shot #4 1) Elevation = 15.0', Distance = 48.0'
2) H = 20.0 - 15.0 = 5.0'
3) Horizontal Distance = 5.0 x 4 = 20.0'
4) Distance from Centerline = 20.0' + 28.0' = 48.0' (Catch)

Figure 6 – 1

SLOPE STAKING EXAMPLE



Given P.S.S. = Elev. 20.0' @ 28.0' Lt.
Given Hinge Point = Elev. 20.6' @20.0' Lt.

Fill Slopes = 6:1 where H< 4'
4:1 where H> 4' < 10'
3:1 where H> 10' < 30'
2:1 where H> 30'

H = Difference in elevation of existing ground and P.S.S.

Shot #1 1) Elevation = 22.4', Distance 40.0'
2) H = 22.4 - 20.0 = 2.4
3) Horizontal Distance = 2.4 x 6 = 14.4'
4) Distance from Centerline = 14.4' + 28.0' = 42.4'
5) Rodperson moves 42.4' from Centerline

Shot #2 1) Elevation = 22.8', Distance = 42.4'
2) H = 22.8 - 20.0 = 2.8
3) Horizontal Distance = 2.8 x 6 = 16.8'
4) Distance from Centerline = 16.8 + 28.0 = 44.8'
5) Rodperson moves 44.8' from Centerline

Shot #3 1) Elevation = 22.9', Distance = 44.8'
2) H = 22.9 - 20.0 = 2.9'
3) Horizontal Distance = 2.9 x 6 = 17.4
4) Distance from Centerline = 17.4 + 28.0 = 45.4'
5) Rodperson moves 45.4' from Centerline

Shot #4 1) Elevation = 22.9', Distance = 45.4'
2) H = 22.9 - 20.0 = 2.9'
3) Horizontal Distance = 2.9 x 6 = 17.4'
4) Distance from Centerline = 17.4' + 28.0' = 45.4' (Catch)

Figure 6 – 2

BENCHING SLOPE STAKES

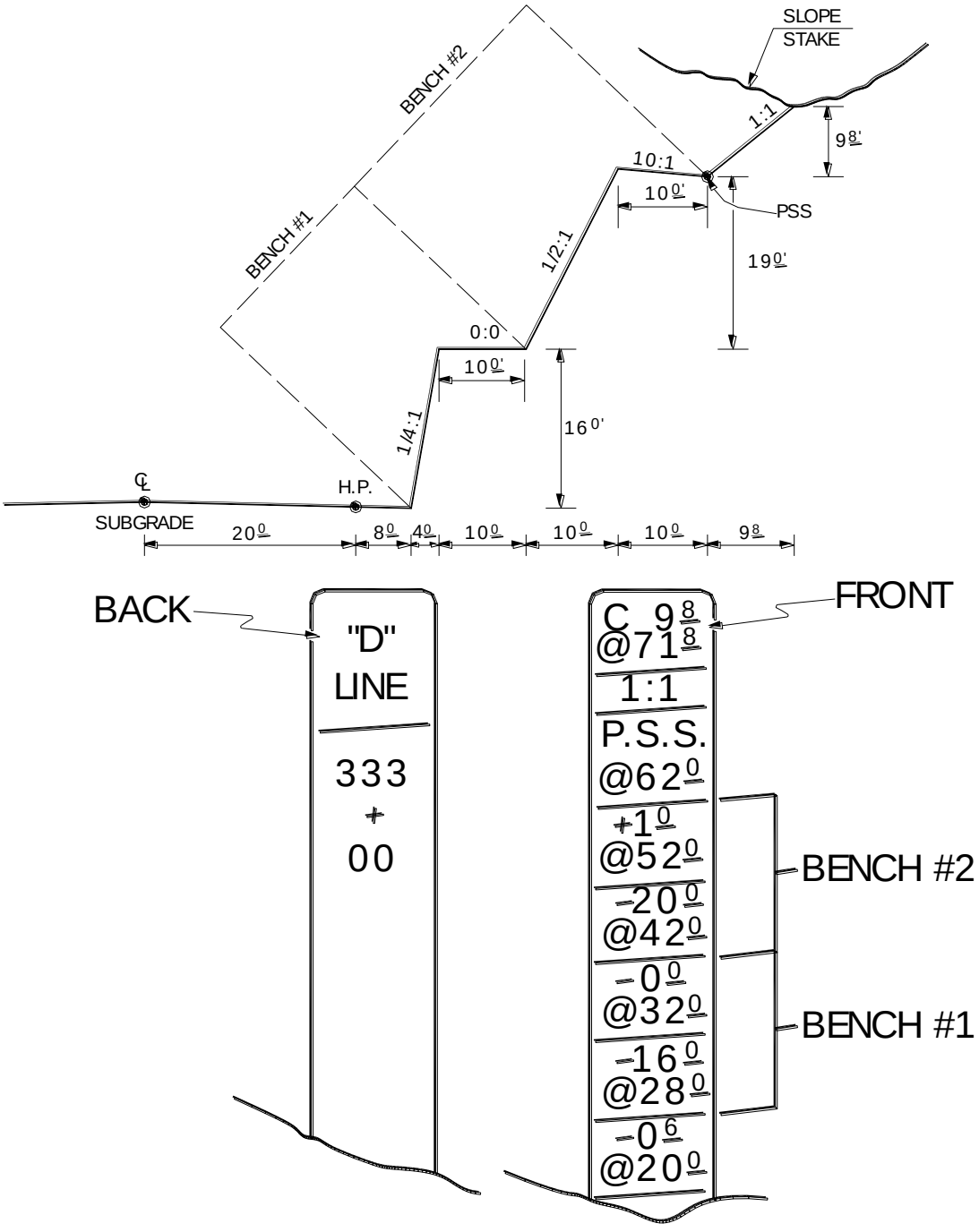
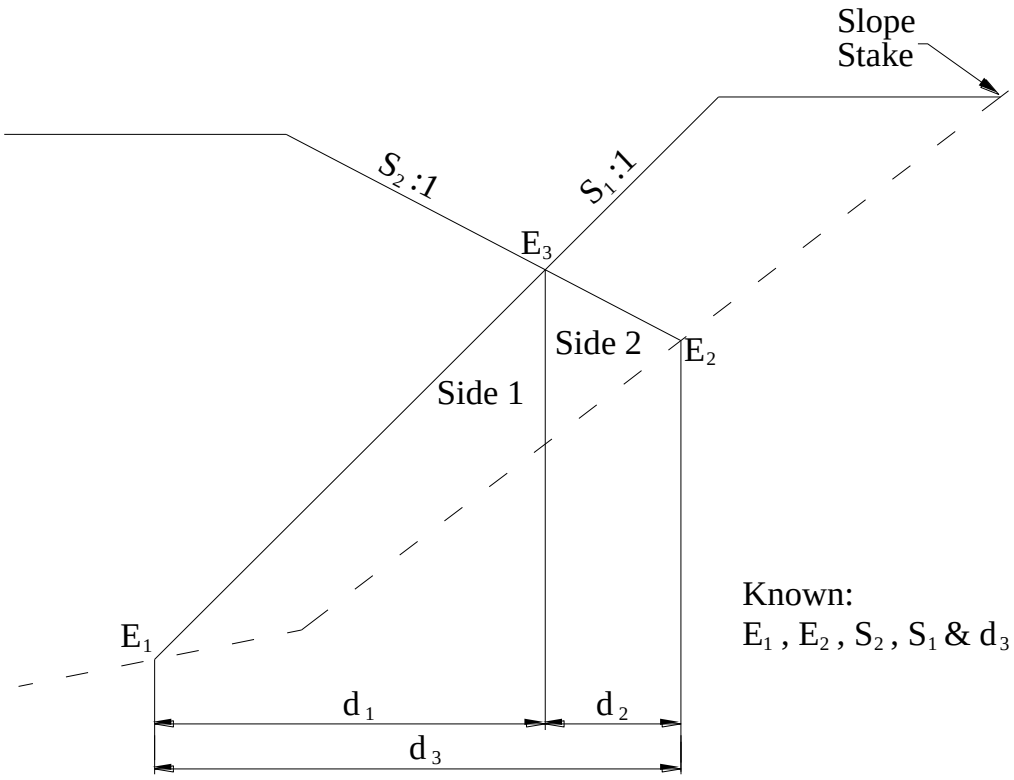


Figure 6 – 3

SETTING MEDIAN SLOPE STAKES



$$d_1 = \frac{S_1 [S_2 (E_2 - E_1) + d_3]}{S_1 + S_2}$$

$$E_2 = E_1 + \frac{d_1}{S_1}$$

Figure 6 – 4

CURB & GUTTER SLOPE STAKES

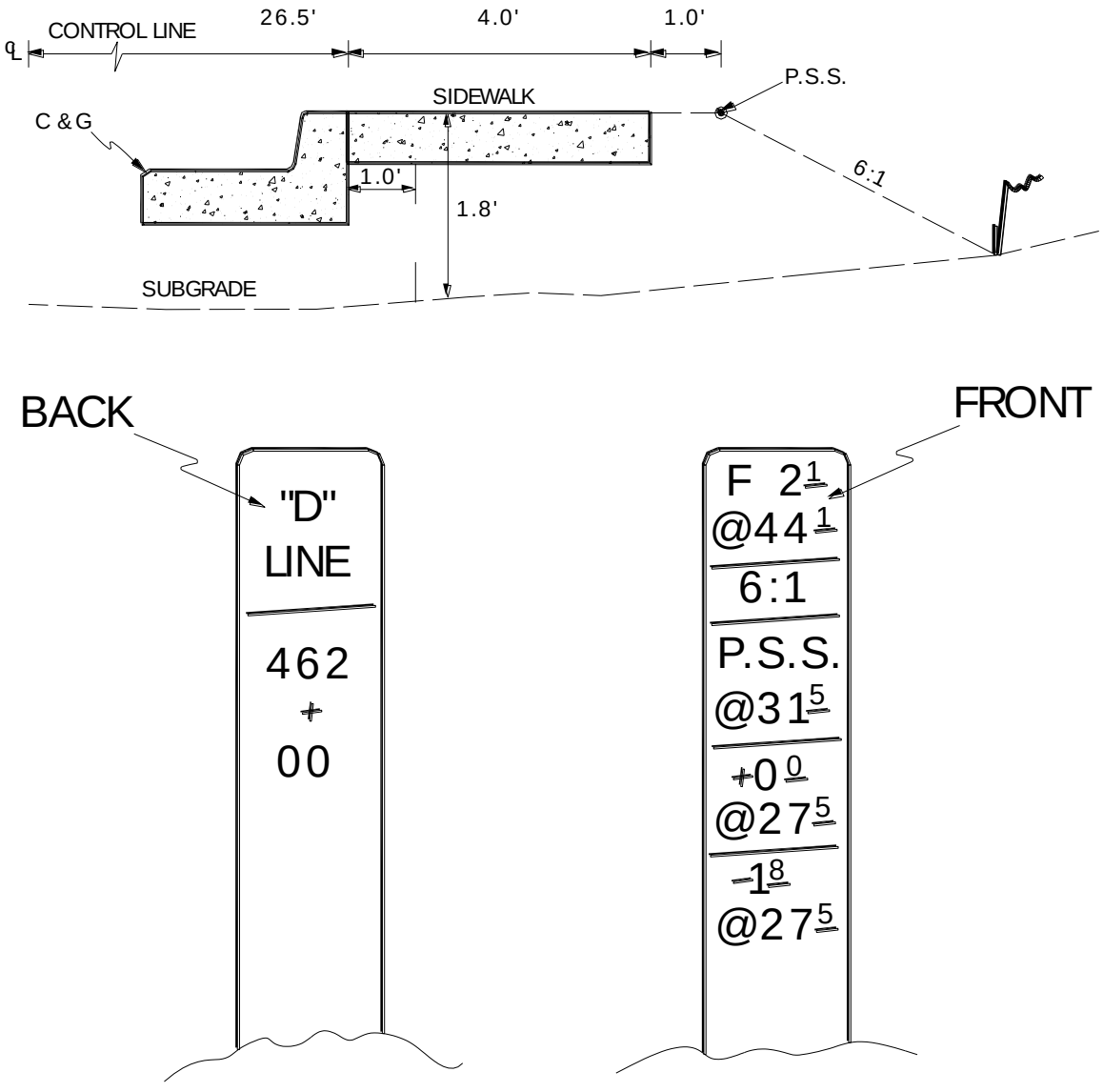


Figure 6 – 5

6.8.3 Stakes

The stake shall provide all the information the contractor needs to build the roadway prism from the slope stake on one side of the roadway to the roadway control line or survey line.

The stake shall provide the following information as a minimum:

1. Front side of stake:

    a. Cut or fill to the Point of Slope Selection (PSS).

    b. Distance from centerline or survey line to the slope stake.

    c. Slope ratio.

    d. Plan distance from centerline or survey line to PSS.

    e. Other information required to build the roadway template that may vary from station to station on the project such as, offset distance, benching of slopes, etc. (Items that may cause a variation from the typical roadway section are acceleration or deceleration lanes and cover thickness changes).

2. Back side of stake:

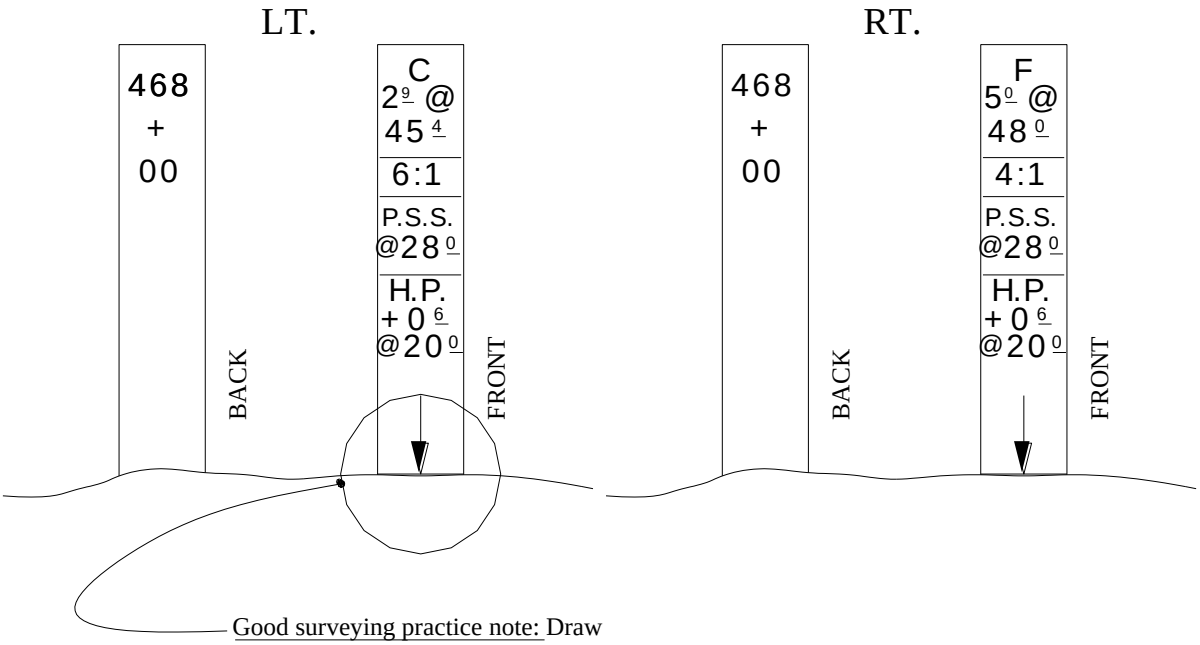
    a. Station number.

    b. Alignment description or line number, if there is more than one line. (Centerline, survey line, ramp, detour, etc.

If slope stakes must be used over a prolonged period of time, they should be marked using permanent non-fading ink with a heavy or wide point that will leave an impression in the wood stake. Slope stakes should be written with lettering large enough and clear enough so an equipment operator is able to read the stake while operating the machine. Slope stakes shall be marked with a lath with white flagging or white paint.

An offset slope stake shall contain the same information as the slope stake and include the offset distance and elevation difference from the catch point. For example, if the offset stake is 1.96 ft above the slope stake and 9.8 ft farther out, it would have –1.96 and 9.8 in a circle. In other words, it is –1.96 ft vertically and 9.8 ft horizontally back to the slope catch point from the offset stake.

Slope Stakes



Good surveying practice note: Draw a line with an arrow pointing to it at the point where the stake is driven into the original ground.

Offset Stakes

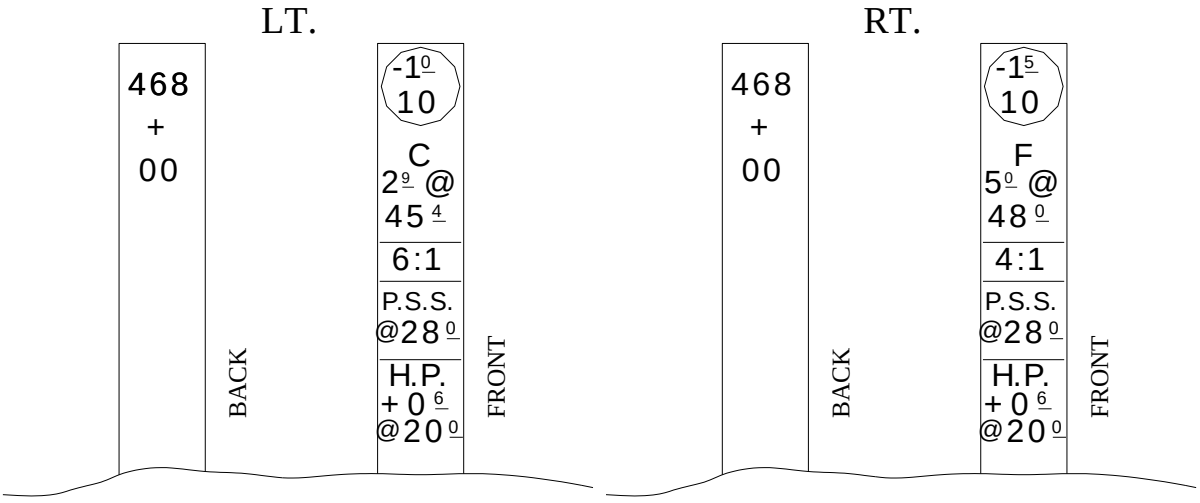


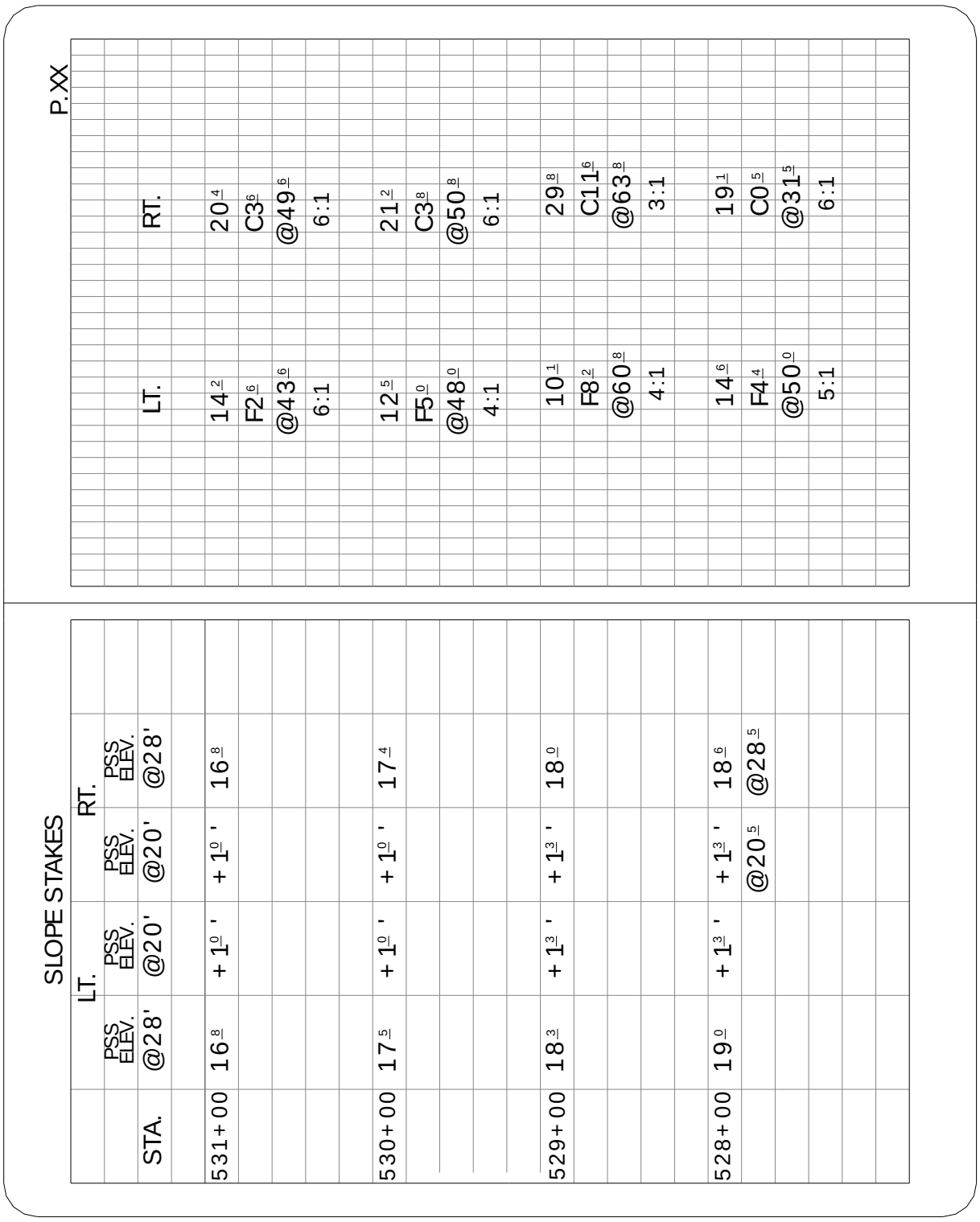
Figure 6 – 6

6.8.4 Slope Stake Notes

An acceptable alternative to the method shown below is to record the distance from the slope stake to the next terrain break perpendicular to the centerline alignment and then the cut or fill and the distance to the next terrain break and continuing on to the centerline alignment. This method ends at the centerline alignment and is repeated on the other side of the roadway section.

Slope staking notebooks shall be prepared prior to setting the slope stakes. Field data is filled in as it is generated. The minimum information required is as follows:

1. Right hand page:
    a. Elevation of ground at catch point
    b. Cut or fill
    c. Distance from centerline or survey line
    d. Slope ratio
2. Left hand page:
    a. Station
    b. Calculated PSS grade
    c. Any additional information such as benches, other constant features of the roadway section, level work, etc.



Note: A printout of an electronic field book is an acceptable alternative if the printout contains all of the information stated above. (See Survey Records, for additional information.)

Figure 6 – 7

6.8.5 Tolerance

Slope staking shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.98 ft horizontal and +/- 0.10 ft vertical.

6.9 Minor Structures

6.9.1 General

Minor structures should be staked early in the project in order to check plan quantities. Cross culvert stakes should be checked against slope stakes to determine actual required pipe length. If differences are found between the plan and "as staked" pipe lengths, a list of field-measured pipe lengths shall be given to the engineer so the contractor may be informed of the actual lengths required.

Before staking a minor structure, the following items shall be verified in the field from the plans. Should any of the following items differ from the plans, it shall be called to the attention of the engineer immediately, since it may affect the hydraulic design:

1. Location:

   Is the location proper for efficient operation of the structure? Careful examination of the site may indicate that another line and grade would provide better performance.

2. Alignment:

   Skew and length shall be checked against the plan, and the best fit that can be developed without being economically unsound is to be used. Check for fit to roadway section. For the greatest hydraulic efficiency, culverts should be placed so the stream or ditch will have as straight an entrance and outlet as possible.

3. Elevation:

   Do the plan elevations fit existing features?

4. Grade:

   Do the grades for the inlet and outlet provide the proper gradient? The plan flow line should be checked against the existing flow line. If the culvert is installed on a steep slope, there is danger of water undercutting the outlet. Headwalls, end sections, or some type of energy dissipation device may be required.

5. Cover:

   Have cover requirements been met for the type and class of culvert?

6.9.2 Methods

Short sections of cross culverts should be staked at each end of the pipe and with at least two offsets in a line to each end staked. On long pipes, sewer pipes and underdrains, grade stakes should be set at the offset specified by the contractor.

If a significant change is made in the pipe alignment and grade, a new profile of the pipe shall be taken for computation of structure excavation and backfill quantities.

6.9.3 Stakes

The information required on the stake is as follows:

1. Front side of stake:
    a. Cut or fill to flowline
    b. Rise or fall of pipe in feet
    c. Offset to pipe on reference stakes
2. Back side of stake:
    a. Station
    b. Size, length, and type of pipe

Stakes shall be identified with yellow flagging for structure stakes and yellow and white flagging for structure reference stakes.

6.9.4 Tolerance

Stakes for culvert pipe, pipe, and sewer pipe shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.03 ft horizontal and +/- 0.02 ft vertical.

Stakes for inlets and manholes shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical.

Stakes for concrete box culverts shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.01 ft horizontal and +/- 0.01 ft vertical.

CROSS CULVERT STAKES

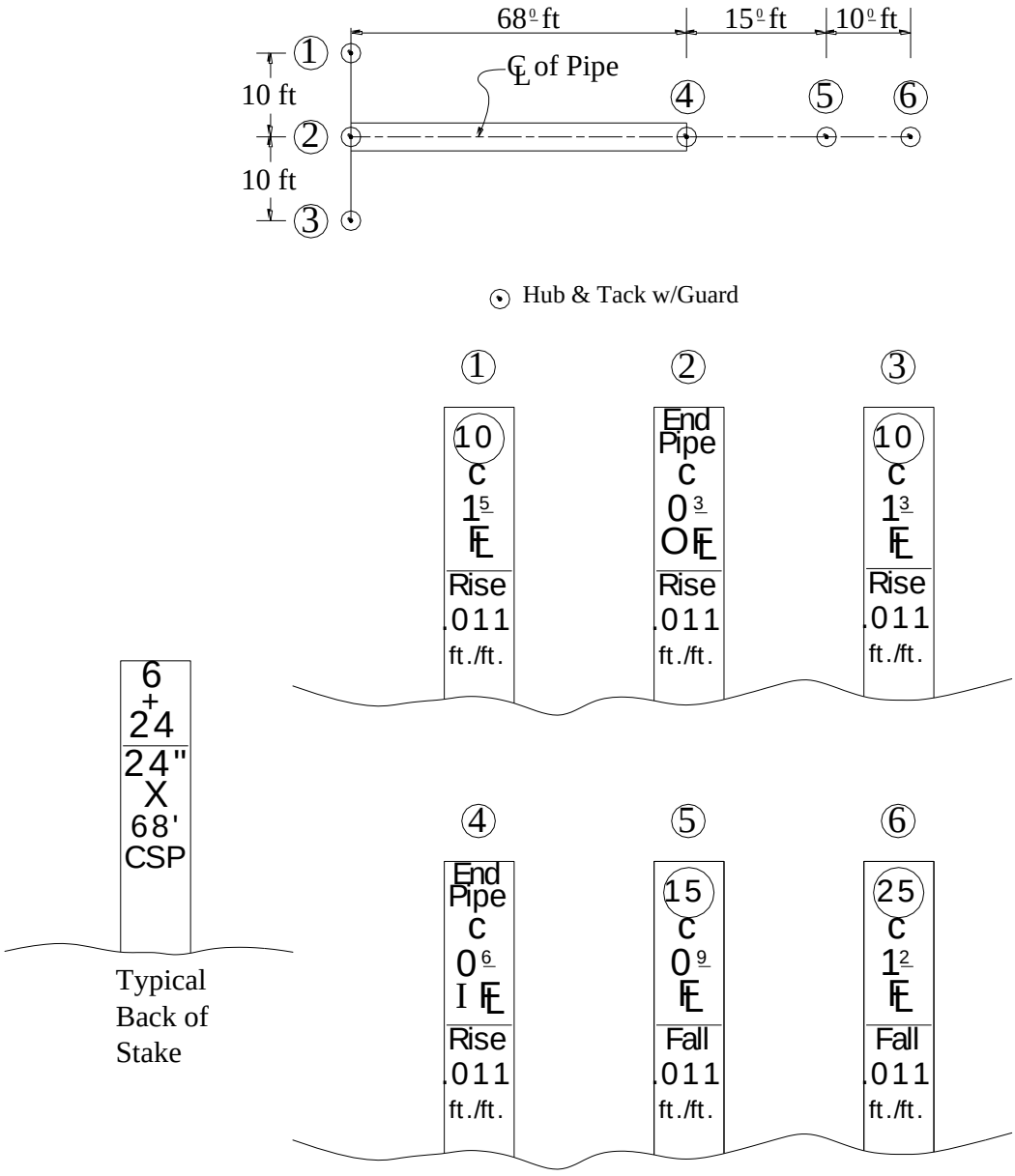


Figure 6 – 8

STORM SEWER STAKES

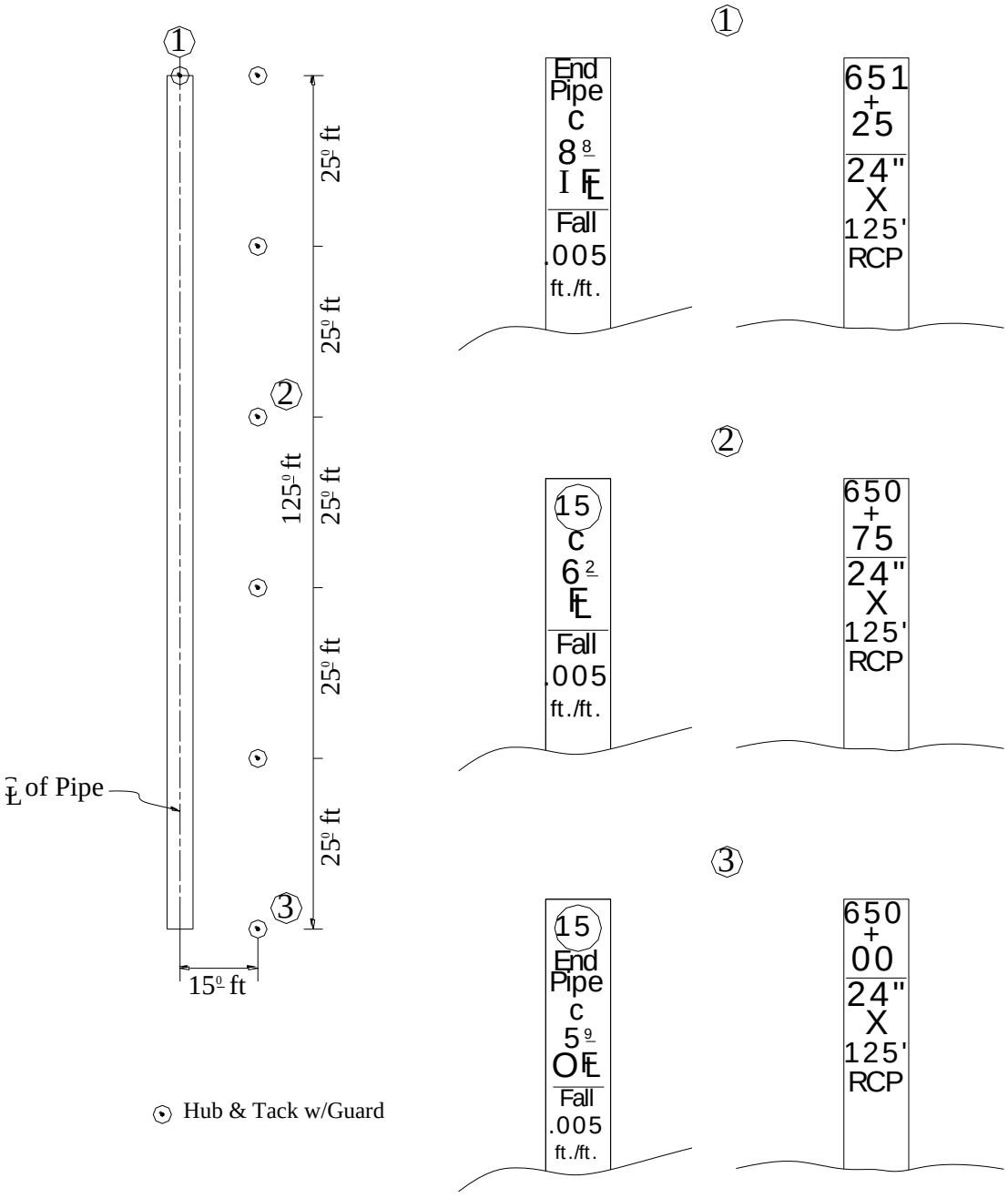


Figure 6 – 9

6.10 Major Structures

6.10.1 General

The alignment, riding surface, and appearance of a bridge are the result of care taken in preparing the plans and specifications, constructing the bridge according to plan and specification, and accurate staking which provides good geometric control. The surveyor is responsible for the staking and geometric control used, and shall have full knowledge of the plans and methods used in staking structures. Systematic checks shall be developed on each structure to assure the local accuracy of all points and stakes set. The staking of a structure shall be completed and an independent check of the same shall be made before construction begins. Stakes that are out of tolerance shall be reset within the specified local accuracy tolerance.

Errors in staking or in replacing points for major structures can be very costly. Extra time and care is warranted in staking and checking to prevent errors.

Horizontal and vertical dimensions, and elevations shall be checked by the surveyor prior to staking. Structure grades shall be checked for coincidence with the roadway grades.

Alignment and stationing of abutments, piers, wing walls, and other bridge components shall be checked in the field to assure the structure fulfills the purpose for which it was designed. Adjustments in alignment and or grade may be required at stream crossings, canals, irrigation ditches, etc., to provide maximum efficiency. The appropriate ditch company, water board, or other authority shall be consulted to assure the alignment and grade of the structure crossing meets with their approval. All adjustments in line and grade shall be thoroughly documented and approved by the Project Manager, Region Construction Engineer, and the Staff Bridge Engineer prior to implementing.

6.10.2 Notes

Prior to any field survey work, appropriate sketches and computations necessary to stake the structure shall be made in the appropriate survey fieldbook. A computer graphics program may be used to provide drawings and data to completely stake and reference the structure. Several sketches may be required for clarity and neatness. Remember, you may not be there when the structure is built, so the notes must be self-explanatory. This information shall include the following:

1. Stationing of abutments and piers
2. Span distances
3. Skew angles
4. Wing wall angles and lengths
5. Work line locations, and offset distances
6. Point numbers shall be clearly shown on computer generated drawings
7. Dimensions between points shall be shown to provide quick checks
8. Text or dimensioning shall not overlap
9. Arrows to points should be utilized for clarity when necessary

10. All reference points shall be shown and clearly described in the notes to allow rapid recovery in the field

6.10.3 Horizontal Control

The first step in staking a major structure is to establish and reference the project line or layout line (work line) of the structure, as shown on the plans. All substructure control points are established in reference to this line. From the substructure control points, points and bent lines can be set. A bent line is a term used generically to mean any transverse line that intersects the project line, layout line, or any longitudinal line used to construct the structure. When coordinates are used for staking, all points set shall be checked from another instrument setup or chain measurement and the difference recorded and reported to the engineer. Use of complete three-dimensional coordinates is required.

After control points have been established, they shall be referenced. Reference stakes are of vital importance for the construction of a structure. The reference stake's accuracy, accessibility, and permanence are essential for good geometric control. All bent lines shall have at least two (2) intervisible reference points at all times to facilitate setting and checking of points for the structure. Points shall not be used unless a check has been performed to assure the point is within tolerance.

There are two methods of referencing structure stakes as follows:

1. Centerline and offset distance
2. Intersecting lines

A good practice is to use a combination of both methods. The intersection method is often the easiest and most accurate because distance and measurement errors are eliminated. Enough stakes should be set to assure adequate geometric control. When setting references, always keep in mind the various construction stages for which the control points must be re-established.

After setting the references, the final and most important step in geometric control is checking the staking. The independent check shall consist of measuring to the installed structure stakes from a separate and different control point or measuring the set structure stakes using control survey procedures to verify positions. There are two general methods of checking the staking. The first is triangulation and the second is traversing. The results of the field check should be compared with calculated values to assure the stakes are within tolerance.

6.10.4 Vertical Control

Vertical control shall be maintained by a minimum of three independent benchmarks at each site. When setting grades, a check shall be made into one other benchmark.

6.10.5 Stakes

Reference hubs should be heavy-duty stakes or steel pins having a defined point and driven flush with the ground. Guard stakes shall be placed with enough information on them to completely describe the referenced hub and be readable. Structure control and reference points shall be lathed and identified with yellow flagging.

6.10.6 Tolerance

Stakes for all major structures shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.01 ft horizontal and +/- 0.01 ft vertical.

6.10.7 Bridge Substructure As-constructed Survey

(Reference Section 601.12 of the CDOT Standard Specifications)

The contractor shall provide an as constructed survey of the bridge abutments and piers prior to girder erection. The contactor shall submit to the engineer a copy of the survey notes detailing the girder seat elevations, anchor bolt locations and projections and span distances from centerline of bearing to centerline of bearing. The survey notes shall indicate all adjustments necessary for bearing device dimensions other than those shown on the plans. The contractor shall submit details for all adjustments to the engineer for approval.

See As-constructed Survey, for additional information.

6.10.8 Overhead Sign Bridge Substructure As-constructed Survey

(Reference Standard Plan S-614-50 of the M & S Standards)

The contractor shall provide a survey of each overhead sign foundation to verify placement soon after work on the foundation has been completed. The survey shall conform to the requirements of Section 625 – Construction Surveying. The contractor shall submit to the engineer a copy of the survey notes detailing the foundation location and elevation and the anchor bolt locations, projections, and orientations and in the case of sign bridge type of overhead signs, the distance measured between the centerline of the anchor bolt groups. The elevation of the ground surrounding each foundation shall also be provided. The contractor shall compare the survey information to the reviewed shop drawing and reconcile any differences between them. The contractor shall submit all proposed adjustments or modifications to the engineer for approval.

See As-constructed Survey, for additional information.

TYPICAL CBC STAKING LAYOUT

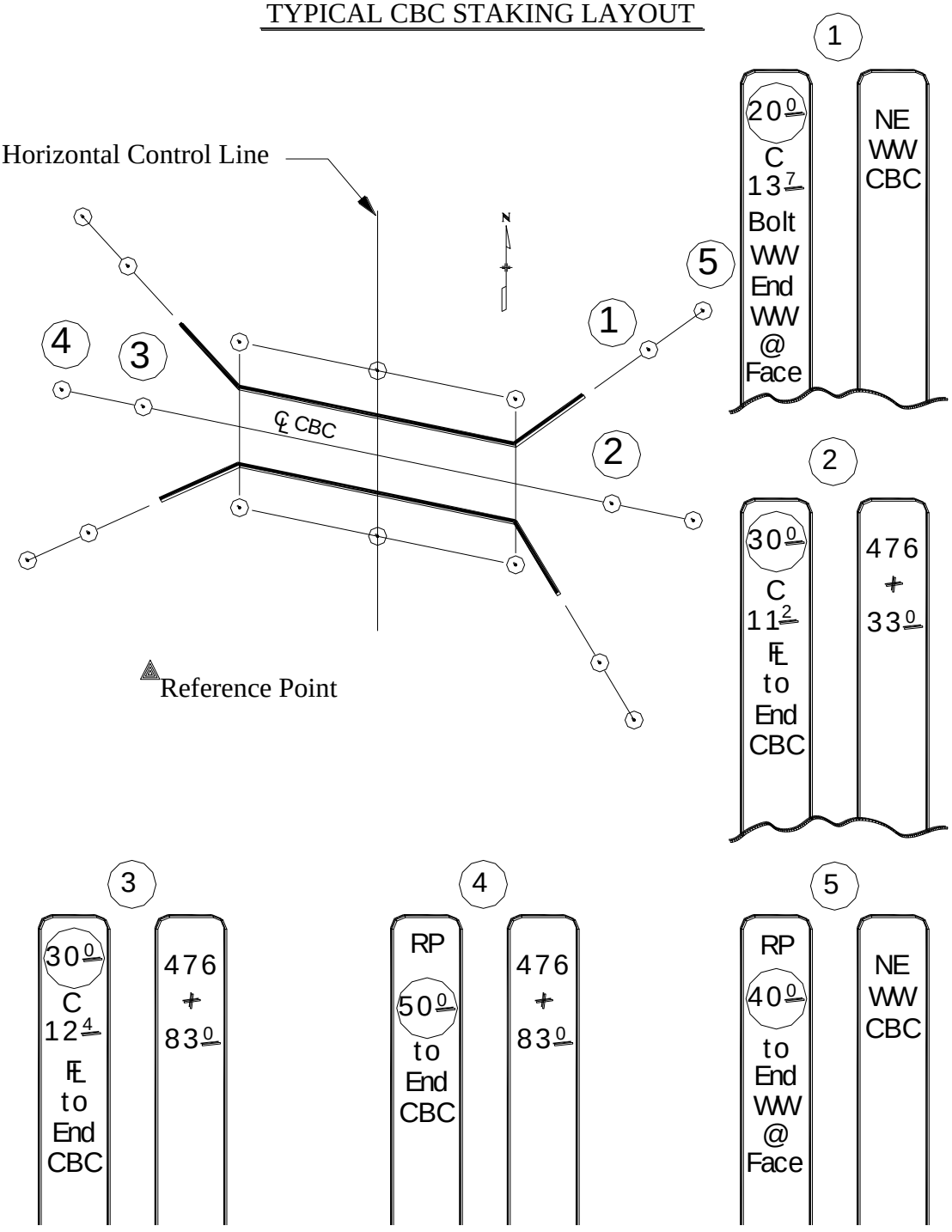
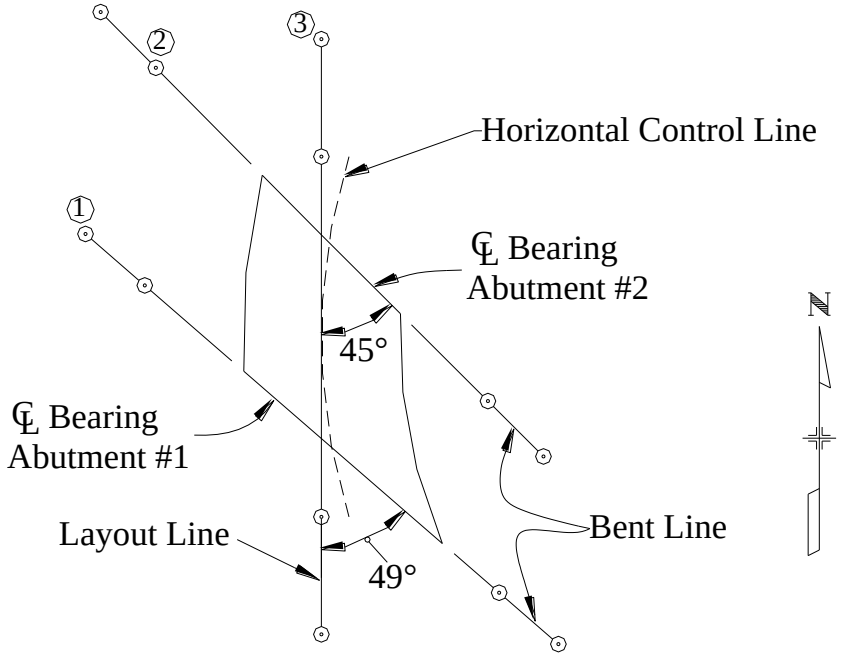


Figure 6 – 10

TYPICAL STAKING LAYOUT FOR A CURVED BRIDGE



◎ Reference Point
(Hub & Tack w/Guard)

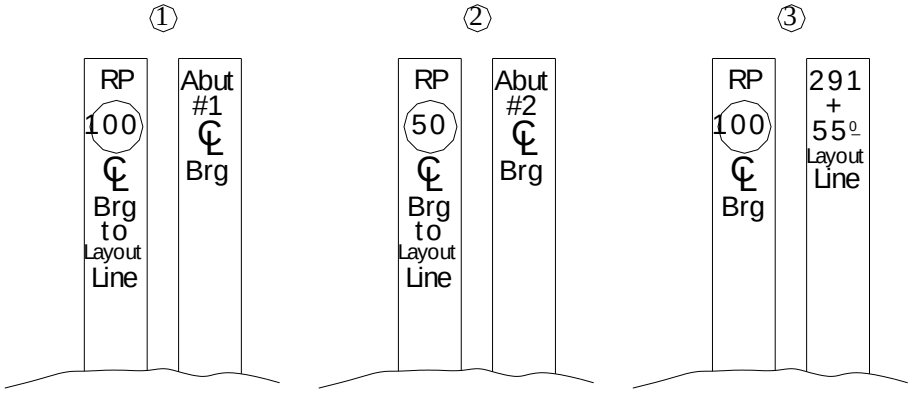


Figure 6 – 11

6.11 Grade Stakes

6.11.1 General

Grade stakes, also known as blue tops, are stakes that are driven down until the top of the stake is at the design grade. Historically, the top of the stake was painted blue, hence the name blue top. Within this chapter, for reason of consistency, the term grade stakes shall be used for either grade stakes or blue tops.

Only after the sub-grade and each succeeding course has been brought within the following "rough grade" tolerances shall grade stakes be set:

1. Embankments (sub-grade):

   Minimum Construction Vertical Accuracy Tolerance +/- 0.30 ft vertical

2. Bases and Pavements:

   Minimum Construction Vertical Accuracy Tolerance +/- 0.20 ft vertical

3. Grades to be graded using a fine grader:

   Minimum Construction Vertical Accuracy Tolerance +/- 0.10 ft vertical

After the rough grading is complete, grade stakes shall be set for trimming and finishing the subgrade and each required course of material. Grade stakes shall have sufficient stiffness, section modulus, and length to remain stable during the normal grading operations. The minimum length of a grade stake shall be 0.50 ft unless otherwise approved by the engineer.

Prior to beginning work on any subsequent operation, such as placing base course or paving, the contractor shall certify in writing to the engineer that the final grade is within the specified tolerance.

6.11.2 Methods

Grade stakes shall be set at 50 ft intervals along the centerline and at 15 ft maximum spacing perpendicular to centerline, survey line, or control line. Roadway approaches to bridges shall have grade stakes set at 25 ft intervals for the first 150 ft each side of the structure. It is important that grade stakes be kept perpendicular to centerline, survey line, or control line to avoid grade discontinuities which may result in a poor riding roadway and bridge. Roadway approach data is usually given on the bridge plans, 150 ft on each end of a bridge at 10 ft intervals.

As additional lifts of subbase and base course are placed, grade stakes shall be set for each course at the same spacing as for the subgrade. If the contractor elects to use a fine grading machine or a paver controlled by a string line, the grade stakes shall be set such that independent grade stakes controls each side of the machine or as approved by the engineer. The string line for each side shall be set at the same fixed distance above the finished grade and parallel to the plane of the roadway cross section. This will enable quick checks of the roadway grade. At least one side shall have stakes set to the Minimum Construction Horizontal and Vertical Accuracy Tolerance of +/- 0.02 ft horizontal and +/- 0.02 ft vertical.

Grade stakes may be used for more than one course if undisturbed between operations. If used for more than one course, the grade stakes shall be checked and may be used again if the grade stakes are found to be within acceptable tolerance. The checks shall be documented in the survey records.

6.11.3 Notes

The grade book shall be set up prior to placing grade stakes. A good surveying practice is to check off each grade stake set in the grade book, as they are set. If computer generated grade books are used, they shall contain the same data that shows the minimum requirement of a grade book page. All staking information and computations shall be placed in the survey records.

STA.	GRADE DATA	TAN. GRADE	V.C. OFFSET	PROFILE GRADE	SUPER		20 ft. Lt.	℄ SUBGRADE	20 ft. Rt.
									P.XX
21+50		$16^{\underline{10}}$		$16^{\underline{10}}$			$15^{\underline{12}}$	$16^{\underline{38}}$	$17^{\underline{64}}$
21+00		$16^{\underline{20}}$		$16^{\underline{20}}$			$15^{\underline{22}}$	$16^{\underline{48}}$	$17^{\underline{74}}$
20+50		$16^{\underline{30}}$		$16^{\underline{30}}$			$15^{\underline{32}}$	$16^{\underline{58}}$	$17^{\underline{84}}$
20+00	-0.20%	$16^{\underline{40}}$	+.00	$16^{\underline{40}}$			$15^{\underline{42}}$	$16^{\underline{68}}$	$17^{\underline{94}}$
19+50		$16^{\underline{50}}$	+.17	$16^{\underline{67}}$			$15^{\underline{69}}$	$16^{\underline{95}}$	$18^{\underline{21}}$
19+00		$16^{\underline{60}}$	+.68	$17^{\underline{28}}$			$16^{\underline{30}}$	$17^{\underline{56}}$	$18^{\underline{82}}$
18+50	400 ft. V.C.	$16^{\underline{70}}$	+1.52	$18^{\underline{22}}$			$17^{\underline{24}}$	$18^{\underline{50}}$	$19^{\underline{76}}$
18+00		$16^{\underline{80}}$	+2.70	$19^{\underline{50}}$			$18^{\underline{52}}$	$19^{\underline{78}}$	$21^{\underline{04}}$
17+50		$19^{\underline{60}}$	+1.52	$21^{\underline{12}}$			$20^{\underline{14}}$	$21^{\underline{40}}$	$22^{\underline{66}}$
17+00	-5.60%	$22^{\underline{40}}$	+.68	$23^{\underline{08}}$	+0.063		$22^{\underline{10}}$	$23^{\underline{36}}$	$24^{\underline{62}}$
16+50		$25^{\underline{20}}$	+.17	$25^{\underline{37}}$	+0.0492		$24^{\underline{39}}$	$25^{\underline{37}}$	$26^{\underline{35}}$
16+00		$28^{\underline{00}}$		$28^{\underline{00}}$	+0.0353		$27^{\underline{02}}$	$27^{\underline{73}}$	$28^{\underline{45}}$

Figure 6 – 12

6.11.4 Tolerance

Grade stakes used for horizontal control alignments shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance +/- 0.02 ft horizontal and +/- 0.02 ft vertical.

Grade stakes not used for horizontal control shall meet the Minimum Construction Horizontal and Vertical Accuracy Tolerance +/- 0.07 ft horizontal and +/- 0.02 ft vertical.

6.12 Curb & Gutter / Sidewalk / Median Barrier

6.12.1 General

Stakes for concrete curb, gutter, and median barrier shall give the contractor both line and grade.

6.12.2 Methods

Generally, a line of stakes is run on a constant offset distance behind the back of the curb or centerline of the barrier. On tangents, line and grade are given every 25 ft. On curves, line and grade are given at a maximum interval of 15 ft. On sharp curves, the spacing interval shall be reduced to provide a good alignment. If slip form machines are used, line and grade spacing may be doubled on tangents provided the string line is adequately supported, (*i.e.* no visible sag).

If sidewalks are placed adjacent to curb, the existing curb may be used for line and grade control. If sidewalks are located away from the curb, they can be staked in the same manner as curb and gutter.

There are many ways in which barrier can be staked. The contractor shall be consulted to determine the staking method and offset prior to staking. The most common method for staking barrier is to locate the bottom edge of the barrier. Median barrier for offset roadways is staked in the same manner. All staking information and computations shall be placed in the survey records.

CURB & GUTTER, SIDEWALK AND MEDIAN BARRIER STAKES

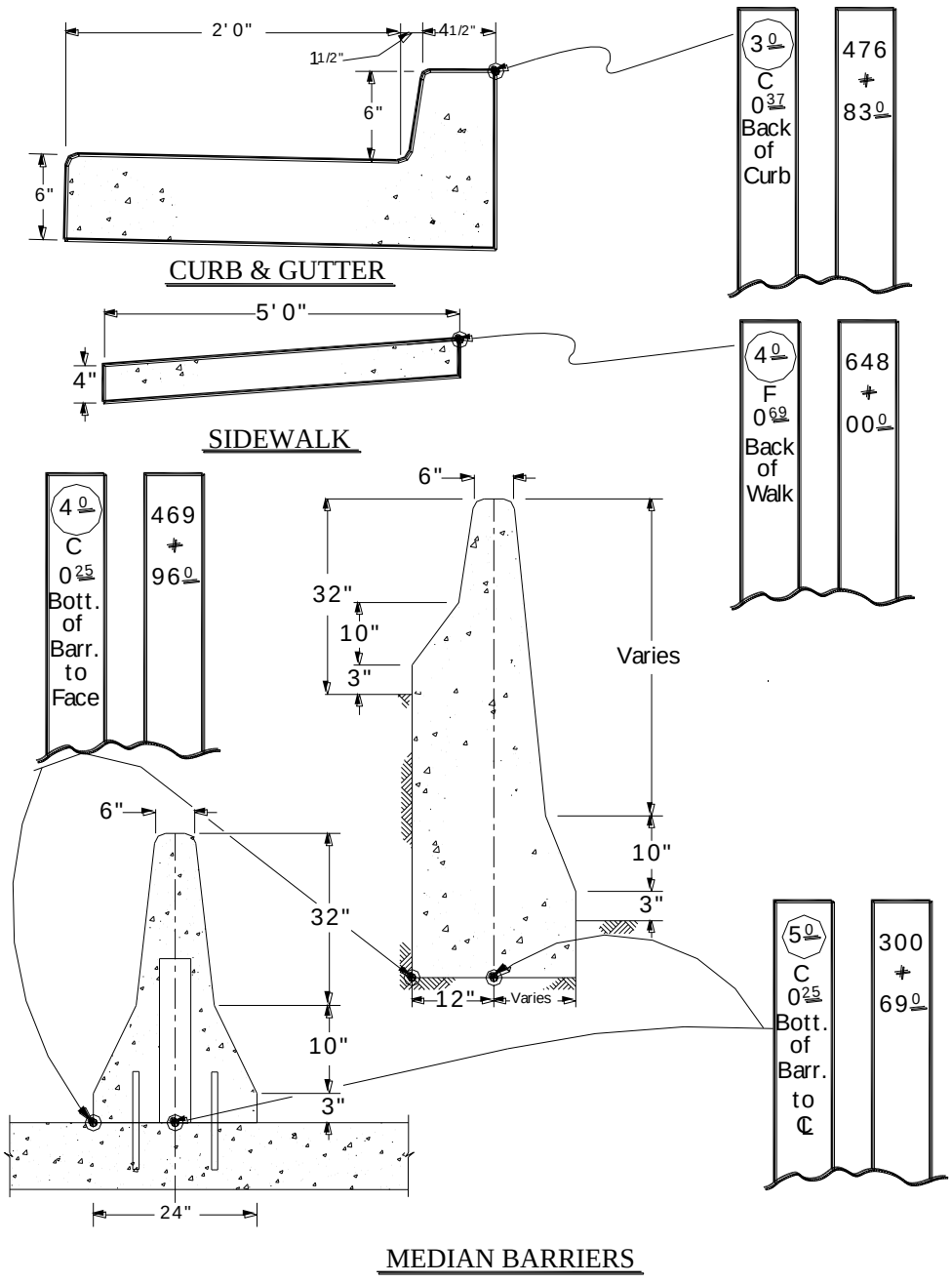


Figure 6 – 13

CURB & GUTTER
ALL GRADES TO TOP BACK OF CURB

P.XX

STA.	@24^{5} ft Lt.	@24^{5} ft Rt.	Lt. ELEV.	Lt. C or F	Rt. ELEV.	Rt. C or F
70+75	26^{04}	26^{08}	25^{62}	F 0^{42}	28^{62}	C 2^{54}
70+50	25^{81}	25^{86}	25^{68}	F 0^{13}	27^{16}	C 1^{30}
70+25	25^{58}	25^{64}	26^{32}	C 0^{74}	25^{43}	F 0^{21}
70+00	25^{35}	25^{42}	25^{92}	C 0^{57}	24^{28}	F 1^{14}
69+75	25^{12}	25^{20}	26^{08}	C 0^{96}	23^{18}	F 2^{02}
69+50	24^{89}	24^{98}	26^{43}	C 1^{54}	23^{96}	F 1^{02}
69+25	24^{66}	24^{74}	25^{92}	C 1^{26}	24^{05}	F 0^{69}
69+00	24^{43}	24^{50}	25^{30}	C 0^{87}	23^{86}	F 0^{64}
68+75	24^{20}	24^{26}	25^{16}	C 0^{96}	22^{98}	F 1^{28}
68+50	23^{97}	24^{02}	25^{01}	C 1^{04}	23^{10}	F 0^{92}
68+25	23^{74}	23^{78}	24^{52}	C 0^{78}	23^{56}	C 0^{22}
68+00	23^{51}	23^{54}	23^{00}	F 0^{51}	23^{18}	C 0^{36}

Figure 6 – 14

6.13 Miscellaneous Staking

6.13.1 General

There are many other items that must be staked on a project. These items shall be staked according to plan. The engineer, contractor, and surveyor should confer to determine what stakes are needed and how the particular item is to be staked. Such items are to be addressed in the surveying work schedule. Staking of items shall be discussed and resolved at the presurvey conference. All staking information and computations shall be placed in the survey records.

6.13.2 Final Quantities

The engineer will perform all interim and final measurements deemed necessary by CDOT to determine contract pay quantities unless otherwise specified on the plans or specifications. The contractor shall establish and maintain control points and stationing as required in this manual for these measurements.

Measurements shall be taken with an accuracy commensurate with the rounding of final quantities as specified in the CDOT Construction Manual. The CDOT Standard Specifications and Special Provisions should be reviewed prior to measuring to determine the appropriate method of measurement.

6.14 As-constructed Survey (*a.k.a.* As-Built)

6.14.1 General

As-constructed surveys (*a.k.a.* as-built surveys) tie in features that have just been built. These measurements provide a record of construction and a check that the construction has proceeded according to plan. The as-constructed survey allows for design changes to be identified during the construction process when problems are encountered that are only apparent after construction has commenced.

As-constructed surveys shall be performed as required for the following items:

1. Bridge substructures
2. Overhead sign bridge substructures
3. Any structure's substructure identified in the plans with a structure number
4. Permanent Water Quality Best Management Practices (BMP's)
5. Any other items required by the engineer

6.14.2 Methods

In order to achieve an accurate and reliable relationship between the construction staking and the as-constructed survey, all as-constructed surveys shall:

1. Be tied to the same primary and secondary control monuments as that of the construction staking.
2. Meet the same Minimum Construction Horizontal and Vertical Accuracy Tolerance as that of the construction staking.
3. Be performed with the same survey instruments types, methods and procedures as that of the construction staking.
4. Collected in standard InRoads TMOSS Codes using CDOT MicroStation and InRoads CAD standards

6.14.3 Permanent Water Quality Best Management Practices (BMP's) As-constructed Survey

(Reference Section 208 of the CDOT Standard Specifications)

The permanent BMPs as-constructed survey will be discussed at the Environmental Preconstruction Conference.

All Water Quality BMP's as-constructed surveys shall be tied to the CDOT approved primary control network and shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class D – TMOSS survey as required in this manual.

The results of the as-constructed survey shall be provided on an electronic drawing of each BMP in MicroStation/InRoads format with the requested information including but not limited to the applicable items listed below:

1. Permanent BMP location at the point of discharge for the BMP
    a. Geodetic Coordinates – Latitude, Longitude, Height and associated meta-data
    b. Project Coordinates – Northing, Easting, Elevation and associated meta-data

2. Type of Permanent BMP Structure

3. Locations and dimensions of maintenance access points

4. Type, location, material, and dimensions of each basin or pond inflow or inlet, *e.g:*
    a. open ditch
    b. closed pipe, including type of pipe material
    c. overland flow
    d. other

5. Type, location, material, and dimensions of each basin or pond outflow or outlet, *e.g.:*
    a. riser
    b. box with baffle plate
    c. closed pipe, including type of pipe material
    d. other

6. Include details of the outflow or outlet discharge area, *e.g.*:
    a. rip rap, including rip rap size and area dimensions
    b. splash pan, including dimensions
    c. or other material to inhibit erosion

7. Type, location, material, and dimensions of applicable items
    a. basin or pond
    b. forebay
    c. micropool
    d. underdrain
    e. spillway or overflow
    f. constructed wetlands
    g. sand filters
    h. of swales
    i. proprietary or manufactured systems

The Contractor shall provide three electronic files on a compact disk (CD):

1. MicroStation format drawing of the as-constructed surveyed BMPs
2. MicroStation format drawing of the as-constructed surveyed BMPs converted to .PDF format
3. Electronic copy of the surveyor's field notes from the field book in .PDF format.

6.15 Supplemental Construction Topographic Surveys

6.15.1 General

Supplemental construction topographic surveys are areas that have been identified by the CDOT engineer where additional topographic survey data is needed to be collected by the contractor's surveyor in order to supplement or add to the preliminary topographic survey of the existing conditions. These additional areas may be needed for additional design and construction, or to check or verify different 3D surface models.

6.15.2 Methods

In order to achieve an accurate and reliable relationship between the preliminary topographic survey and the construction staking, all supplemental construction topographic surveys shall:

5. Be tied to the same primary and secondary control monuments as that of the preliminary topographic survey.
6. Meet the same Minimum Construction Horizontal and Vertical Accuracy Tolerance as that of the preliminary topographic survey.
7. Be performed with the same survey instruments types, methods and procedures as that of the preliminary topographic survey.
8. Collected in standard InRoads TMOSS Codes using CDOT MicroStation and InRoads CAD standards.
9. The area shall not overlap or create areas of conflict with the preliminary topographic survey.
10. The data shall be collected in a manner the best supports the creation of digital elevation models and the construction of the project.

References

CDOT Survey Manual – CDOT, 1992

CDOT Right of Way Manual – CDOT, July, 2002

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

CDOT Procedural Directive 1305.1, Land Surveys – CDOT Effective 1/23/1998
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Memorandum of Understanding between the State Board of Registration for Professional Engineers and Land Surveyors and the Colorado Department of Transportation – July 1, 1985, Revised January 13, 1995.

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