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PART III

3.00 SURVEYING EQUIPMENT

3.01 EQUIPMENT RECORDS

3.01.01 RECEIPT OF EQUIPMENT

The Area Construction Engineer may acquire surveying equipment from the District Office or Stockroom. The Area Construction Engineer will issue KDOT Form No. 452, transferring equipment to the District Storeroom or to another Area Construction Engineer. Responsibility for equipment will be determined solely by the receipts on file with the District Office.

The Area Construction Engineer will be responsible for all missing equipment and for all unreasonable damage to the equipment, which is turned into the District or transferred.

All surveying equipment, hand levels, range poles, field notebooks, etc., will be purchased by the District Office or Stockroom.

3.01.02 ANNUAL INVENTORY

Each year, before the close of the fiscal year, a complete inventory of all audited equipment will be conducted. The District Office will assist the Construction offices with this inventory. The District Office will return one copy of the inventory to the Construction Office.

3.01.03 SERIAL NUMBERS

Special numbers will be placed on all new surveying office equipment with a purchase price over $500.00 at the District Office.

3.02 CARE AND USE OF SURVEYING EQUIPMENT

Each employee shall handle and use all equipment with the same care as if it was owned personally. Any damage to surveying equipment as a result of negligence may cause punitive measures or disciplinary action to be assessed against any employee responsible for the care of the instruments at the time the damage occurs.

Never leave the instrument unattended.

The District Land Surveyor shall establish guidelines for equipment handling and transporting, and inspect all surveying equipment at least once each year or when damaged. If necessary, the equipment will be sent to an approved instrument repair shop, where they will be repaired, cleaned and completely adjusted.

Field employees shall not take any instrument apart. Field employees will be expected to keep the external parts of the instruments clean. They will also find it necessary to make the simpler adjustments of the instruments from time to time in order to obtain proper results in their fieldwork.

All surveying instruments when not in use shall be kept in their respective boxes to preserve the condition of the instruments.

Instruments shall not be exposed to rain, snow or rapid changes in temperature. A hood shall be used in emergencies to protect them from weather until they can be put in their cases. Care shall be exercised to see that the instrument is kept as nearly at a uniform temperature as possible. An instrument shall not be taken suddenly from outside freezing weather into a heated room.

3.03 MAINTENANCE AND LUBRICATION OF SURVEYING INSTRUMENTS

The District Land Surveyor shall provide procedures or training for equipment maintenance. All other maintenance work to instruments is to be performed by approved personnel or repair shops as designated by the District Engineer. These operations are to be done according to recommendations of the manufacturer.

3.04 SURVEYS FOR EARTHWORK

3.04.01 GENERAL

To facilitate project scheduling and accurate project staking the Engineer will provide a staking package of electronic files upon request by the Contractor or Area Construction Engineer. A construction staking package can be obtained from the Bureau of Design, State Road Office and may contain all or part of the following: project control, cross section data and GeoPak chain and/or coordinate data. R/W point files and a hard copy of R/W plans may be requested from the Engineering Section of the Bureau of R/W. Preliminary survey information can be obtained through the Coordination Section of the Bureau of Design.

The Area Construction Engineer shall inspect the plans and project with the Contractor before beginning construction to obtain a plan for staking on the project, in accordance with Standard Specifications and Special Provisions for Contractor Construction Staking.

The staking as outlined in this manual is based on a typical project and may be adjusted for types of work, equipment used and terrain over which it was constructed.

The Area Construction Engineer and Contractor should review the project with plans in hand immediately after centerline and R/W are staked for location and alignment of structures and culverts, guard fence and other miscellaneous features. At this time, discrepancies and adjustments may be addressed to minimize project delays.

3.04.02 CHECKING GRADE

All grade elevations on the plan-profile sheets should be checked before any grade stakes or slope stakes are set. A neat set of grade computations should be made when checking plan grade elevations and a set kept on file for future reference. All pluses for which elevations will be required shall be computed in addition to those points at which elevations are shown on the plans.

In checking grade elevations in vertical curve area the following formula may be used to compute the mid ordinate for vertical curves:

$$E = \frac{DN}{8}$$

Where E is the mid ordinate, D is the algebraic difference in grades (percent), and N is the length of the vertical curve in stations.

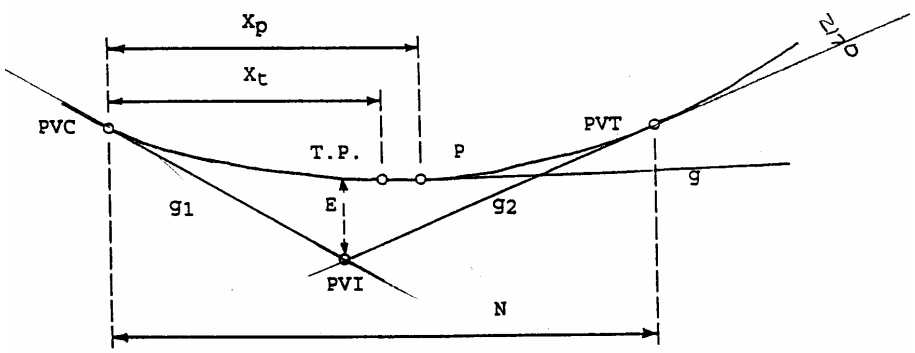
The value of any intermediate vertical ordinate may be determined from the theory of a parabola, namely, that the vertical ordinates will vary as the squares of the distances. For instance, an ordinate 49 feet from the P.V.C. of a 600 foot vertical curve would equal

$$\frac{(49)^2}{(300)^2} \times E$$

To compute plan grade at any point in the vertical curve area the tangent grade at the intermediate point must be computed. The value obtained for the ordinate of the intermediate

point, as computed above, is then added (for sag vertical curves) or subtracted (for crest vertical curves) to the tangent grade to obtain the plan grade of the intermediate point.

FIGURE No. III-1
VERTICAL CURVES



TERMS:

D	=	Algebraic Difference in grades (g2 – g1)
E	=	Midordinate of V.C. in feet
N	=	Length of V.C. in Stations
g_1	=	Percent of Tangent grade from PVC to PVI
g_2	=	Percent of Tangent grade from PVI to PVT
g	=	Percent of Tangent of any point on V.C.
P	=	Any point on V.C.
T.P.	=	Turning Point (Lowest Point on a sag; highest point on a crest)
Xp	=	Distance in Sta. from PVC to P.
Xt	=	Distance in Sta. from PVC to T.P.
r	=	Rate of Change of Grade (% per Sta.) $= (G_2 - G_1)/ N$
L	=	N/2

FORMULAS:

Elev. "P" = PVC Elev. + $G_1(Xp) + (r / 2)x^2$

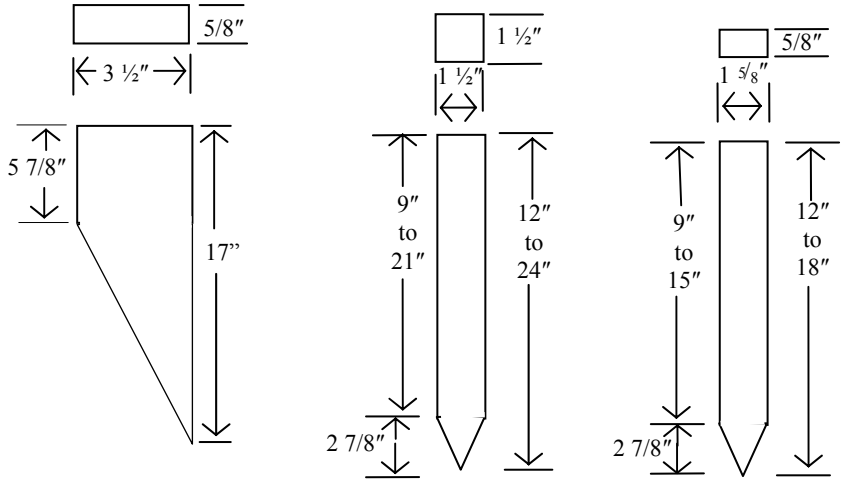
Midordinate E = DN / 8 ; or $E = ½ G_1L + ½ (G_1L + G_2L)$

Any Ordinate = $\frac{(\text{Dist. from PVC})^2}{(N/2)^2} \times E$

Dist. to T.P. = $(G_1N) / (G_1 - G_2)$

Dist. to point where tan. grade is "G"; $Xp = (G - G_1) / r$

FIGURE No. III-2
CONSTRUCTION STAKES



TYPE “A”	TYPE “B”	TYPE “C”
To be used for slope stake, guide stake, R/W stake or center line stake.	To be used for grade stake, hub stake, reference stake or blue top stake.	To be used for blue top stake when conditions will permit. When this type is not suitable, Type B shall be used for blue top stkes.

3.04.03 STAKES

Stakes used on construction shall be of three standard types: Type “A”, Type “B”, and Type “C”. The design for each of these three types of stakes is shown on FIGURE No. III-2.

To facilitate identification of construction stakes on a project, a system of color-coding may be used with Type ″A″ stakes. An example might be to paint right-of-way stakes red, slope stakes white, and structure stakes yellow.

Special stakes may be obtained at times for specific jobs such as the hickory “spoke” stakes. This stake is sometimes used as a finishing stake when the subgrade is very hard. The stake is similar to Type “C” stake except that the bottom half has been turned down to a rounded section.

Devices which are generally used to “mark” or “guard” stakes are lath, wire flags and flag devices that are attached to the top of the stake. The wooden lath in general use is approximately 1½"x ¼"x 48". Laths may also be color coded for easier identification by the use of solid or striped painting, colored cloth, or colored plastic flagging. Colored flags fastened on a wire stem or attached to the top of the stake are also convenient for use as markers or guards.

3.04.04 FIELD NOTES

Field notes shall be kept in standard commercial bound field books, except in cases where loose-leaf notes are approved by the Area Construction Engineer. Notes for more than one project should not be kept in the same book. On large projects, certain notes, such as surveys for documentation of pay quantities, may necessitate separate books for each part of the project.

In general, notes should be kept in separate books as follows:

(a) Alignment
(b) Topography
(c) Bench Mark and Adjustments
(d) Original cross sections and stream bed profiles
(e) Slope stakes and grade stakes
(f) Culvert staking
(g) Bridge staking (each bridge separate book.)
(h) Finishing stakes
(i) Guard Fence, guard rail and guide posts
(j) Surfacing staking
(k) Signing and delineation

It is not always necessary to break down the books as listed above on smaller projects, since some items may be combined. The Area Construction Engineer may choose to combine such items as deemed proper.

At the beginning of each day's work, the date, weather condition, and the name and duties of the various members of the survey party should be shown at the top of the page. Each page shall be numbered in the upper right-hand corner of the right half of the page. The back side of one sheet and the front side of the adjacent sheet will be considered as one page. Field notes shall be recorded with a well-sharpened, hard-lead pencil. Notes shall be kept as clean and neat as possible. Erasing will not be permitted. Usually, it is possible to draw a line through an erroneous notation and write the correction above or to one side. The correction should be initialed by the party making the correction. Field notes should be recorded in the notebook as the work progresses. Field entries of notes on loose paper or in memorandum books will not be tolerated.

It has been noticed that the general tendency of a good many Surveyors is to make their field notes too brief for clarity. Quite often the field notes are kept in such a poorly arranged manner that it is difficult to interpret the full and correct meaning though all the necessary information may be shown. Good field notes should be so complete, logically arranged, and neatly recorded that the correct and complete meaning is readily grasped by any qualified Surveyor.

The following abbreviations and symbols have been adopted as standards for the Department and shall be used in construction field notes:

Point of Curve (horizontal) = P.C.
Point of Tangent (horizontal) = P.T. or P.O.T.
Point of Intersection (alignment tangents) = P.I.
Change from Tangent to Spiral = T.S.
Change from Spiral to Curve = S.C.
Change from Curve to Spiral = C.S.
Change from Spiral to Tangent = S.T.
Horizontal Control Point = H.C.P. (GPS geodetic)
Point on Curve = P.O.C.
Midpoint on Curve = M.O.C.
Point on Curve (vertical) = P.V.C.
Point of Tangent (Vertical) = P.V.T.
Point of Intersection (grade tangents) = P.V.I.
Beginning of Superelevation = B.S.

End of Superelevation = E.S.
Beginning of Maximum Superelevation = B.M.S.
End of Maximum Superelevation = E.M.S.
Guide Stakes = G.S.
Grade Stakes = Gr. S.
Slope Stakes = S.S.
Grade Point or Zero Point = 0.0 Pt.
Cut = C.
Fill = F.
Top of Rock = T.R.
Bottom of Rock = B.R.
Backsight or Plus sight = +S.
Foresight or Minus Sight = -S.
Bench Mark = B.M.
Traverse Point = T.P.
Center Line =U
Reference Point = R.P.
Fence = Fc.

Each notebook shall be thoroughly indexed. A few sheets in the front of the book should be reserved for this purpose. The section and number of the project to which the notes pertain as well as the Area Construction Engineer's name and address shall be shown in ink, on the fly-leaf in the front of each book.

A numbering system should be established so that all books for a particular project may have a specific number and/or letter designation. It is convenient to establish a referencing system which is flexible enough to fit all projects so that specific books on all projects carry similar numbers. The front of the field book should show project number, book title or contents, and the reference designation. With a well planned reference system of field books, a master list may be kept. This simplifies cross-referencing source documents and helps to keep account of all field books.

The Documentation Manual should be studied and used as a guide for proper documentation. For additional information on field notes and documentation, see Standard Specifications and Special Provisions for Contractor Construction Staking.

3.04.05 ELECTRONIC FIELD NOTES

Electronic field notes gathered using data collectors or handheld computers should have the same credibility as field notes taken in a book. Electronic field notes may be substituted for field notes called for elsewhere in this manual if the electronic notes contain all the information specified. The same care and procedures used with field books should be observed with data collectors. The major advantages of data collection systems are that mistakes in reading and recording measurements in the field are eliminated and the time to process, display, and archive the notes is reduced.

The information gathered in the collector is the original field notes and shall not be changed at anytime. Copies of all original notes shall be forwarded to the district's survey coordinator for review and approval. Most collectors will not allow editing of the data, but care should be taken not to tamper with the original files. If necessary, sketches should be included in field books if it will help to clarify the notes in the collector. These sketches should be

referenced in the collector and in the book.

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

At the end of the day, the raw data from the collector should be downloaded in binary format into a computer for editing and processing. At this time a hard copy of the nonedited file should be acquired and signed by the survey crew chief. This will help with the legality of the survey should a problem arise. A copy of the nonedited file should be made to a disk, and then both disk and hard copy should be archived for future use. The original file should never be edited; it should be kept just like an original field book. If problems or questions arise over the use of the collector, contact the district's survey coordinator for clarification.

3.04.06 SIGNALS

Except for short distances, a good system of hand signals between different members of the party makes a more efficient means of communication than is possible by word of mouth. The number of signals necessary will depend upon the character of the work and the nature of the terrain. A few of the more common signals are given below.

Right or Left: The arm is extended in the direction of the desired movement, the right arm being extended for a movement to the right and the left arm for a movement to the left. A long, slow sweeping motion of the hand indicates a long movement; a short, quick motion indicates a short movement. This signal may be given by the instrument person in directing the chainperson on line, by the chief of the party to any member, or by one chainperson to another chainperson.

Up or Down: The arm is extended upward or downward with wrist straight. When desired movement is nearly completed, the arm is moved towards the horizontal. The signal is given by the leveler.

All Right: Both arms are extended horizontally and the forearms waved vertically. The signal may be given by any member of any party.

Plumb the Range Pole or Plumb the Rod: The arm is held vertically and moved in the direction that the range pole or rod is to be plumbed. It is given by the instrument person or leveler.

Give a Foresight: The instrument person holds one arm vertically above their head.

Establishing a Turning Point or Set a Hub: The instrument person holds one arm vertically above their head, and waves it in a circle.

Give line: The flagger holds the range pole horizontally in both hands above their head, brings it down and turns it to a vertical position. If desired to set a hub, wave the range pole from side to side with one end in the ground.

Turning Point or Bench Mark: In profile leveling the rod person holds the rod horizontally above their head and then brings it down on the point.

Wave the Rod: The leveler holds one arm above their head and moves it from side to side.

Invert Telescope: The flagger holds the range pole in a vertical position and moves the top of the range pole in a circle.

Pick Up the Instrument: Both arms are extended outward and downward, then inward and up, as one would do in grasping the legs of the tripod and shouldering the instrument. It is given by the chief of the party or by the head chainperson, when the instrument is to be moved to another point.

Number signals are as follows:

One: Right arm extended 45° above horizontal Two: Right arm extended horizontally
Three: Right arm extended 45° below horizontal
Four: Left arm extended 45° above horizontal
Five: Left arm extended horizontally
Six: Left arm extended 45° below horizontal
Seven: Both arms extended 45° above horizontal
Eight: Both arms extended horizontally
Nine: Both arms extended 45° below horizontal
Zero: Both arms forming a 0 over head

Care should be taken to make the signals so clear that they can be readily understood. Where long sights are taken or where the peculiar color of the background renders hand signals indistinct, colored flags may be used to good advantage. The color should be in contrast with that of the background. Red can be seen very well against snow or white clouds, while white can be distinguished clearly against the dark green of the forest or dark clouds.

3.04.07 CHECKING ALIGNMENT

The essential purpose of checking the alignment of the project is to check the angles and the distances as shown on the plans and to orientate the project to the correct land ties.

The first field work should be that of checking the alignment with the plans, establishing any new control points which may be required, referencing existing points and checking topography. The baseline or centerline will be established as the alignment is checked.

FIGURE No. III-3 is illustrated to present a type of field book that would be prepared in the office and completed in the field. Two essential items should be checked in the field and verified in the field books. These are the measured lengths between various control points of the alignment and the interior angle of the intercepting tangents.

The purpose of keeping field notes is to record the action taken as the survey progresses, document the basic location of the project and show the action taken in correcting minor discrepancies of the plan alignment.

The document length of the project is often used as one dimension for the final pay quantity of earthwork or concrete pavement. The allowable tolerances are defined in the project special provisions.

3.04.08 RECOVERING CENTER LINE

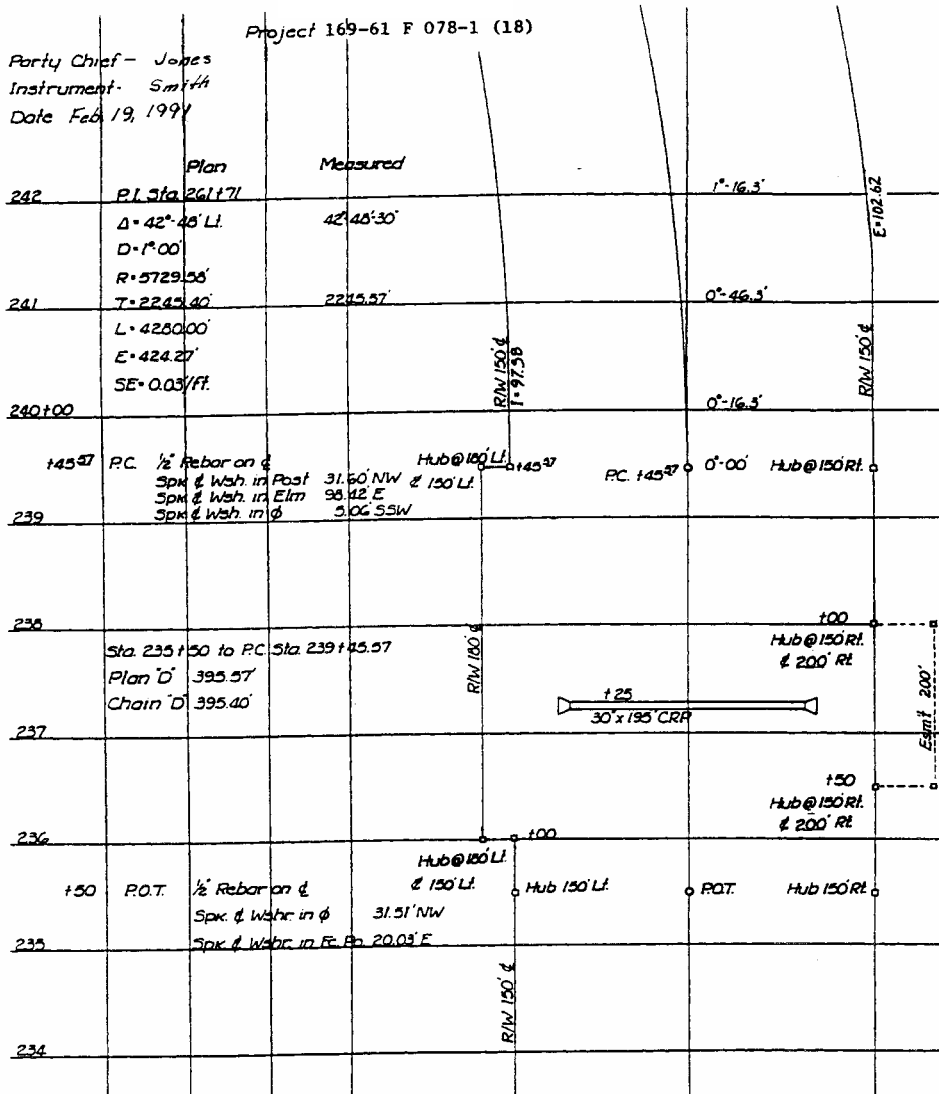
The first survey work in construction surveying will be to reestablish the centerline of the project. The plan control points shown as P.O.T.'s and P.I.s can be located from the reference data given on the plans. These control points must be established one half to one mile in advance of the centerline survey to provide the instrument person with the necessary control points. It is the intent to follow the points established on the preliminary survey, and adjustment in stationing and alignment will be made between the nearest P.I.s and P.O.T.'S. From some selected plan control point which is designated as the starting point, the centerline of the project may be reestablished.

As the centerline is reestablished, the distances to the nearest section corner or other public land monument should be checked at every opportunity. This can be most readily accomplished by setting a centerline point on the observed section line as the two lines intersect, then measure the distance to the nearest observed section or fractional section corner or radially checking the plan location. The plans should show some reference to local land monuments.

As copies of right of way descriptions are received by the construction offices, they can be checked against the measurement shown on the plans, which in turn, have been checked against field observations. If right of way descriptions are available at an earlier date, the plan data may be checked against the legal description prior to beginning construction surveys. If any discrepancies are found they should be reported to the District Surveyor.

Prior to entering on any property for the purpose of surveying or locating control points, it is the policy of the Department of Transportation that permission should be obtained to enter onto the premises. Under no conditions should a vehicle be driven on a tract of land without prior consent from the owner or manager.

FIGURE No. III-3
ALIGNMENT NOTES



3.04.09 STAKING CENTER LINE

Forty penny nails with red plastic tied at the top should be used for the centerline markers whether the alignment follows an old roadway or is relocation. The nail affords a definite point from which to make linear measurements.

The centerline or baseline should be marked at 100 foot intervals on tangents, flat vertical curves, and horizontal curves with a radius longer than 750 feet. On sharp vertical curves and horizontal curves with a radius of 750 feet or less, nails should be set on the centerline at 50 foot intervals.

A nail should be set on centerline or baseline at all plus stations at which it will be necessary to set grade stakes, so that the grade stakes may be offset with greater facility. Centerline nails should be set accurately in their true positions at all stations or plus stations where the width of right of way changes. Right of way stakes at such points may be accurately set by the use of a theodolite or a total station.

3.04.10 CHECKING ANGLES

If an angle does not check with the value shown on the plans, it shall be measured by repetition; measuring the angle with the telescope in direct position a number of times and an equal number of times with the telescope in the inverted position.

If the mean value of the angle varies from the Delta angle shown on the plans by > 20 inches, it may be necessary to redesign the curve. It must be kept in mind that a major change in the design of the curve will also cause the length of the project to be changed. As a further consideration, remember the right of way descriptions were written from the same information as that provided on the plans.

Any proposed change in the plan alignment shall be discussed with the Area Construction Engineer, who can analyze the various factors that might become involved.

3.04.11 CHECKING THE DISTANCES

With the increased use of electronic equipment, the discrepancies between the measured distances and the plan distances should not be more than 1:10,000.

When a second check by the survey party indicates that an error exists of more than 1:10,000, it will be necessary to write an equation in the stationing at the nearest control point. All equations should be recorded in the alignment book. Variation in plan stationing will possibly cause the construction quantities to be changed.

Any apparent errors in stationing of control points should be analyzed for an overall adjustment. A control point might be simply incorrectly stationed on the plans, whereas two equations to correct this error in nomenclature would be superficial and confusing.

All transverse and longitudinal measurements shall be measured horizontally. In fact, the only cases in which distance should not be measured horizontally, are those in which final measurements are being made to determine the actual length of edge curb, curb and gutter, etc.

3.04.12 REESTABLISHING THE CENTER LINE REFERENCE AND CONTROL POINTS

(a) References and Control Points.

The centerline should, at all times, be staked in advance of the construction work so that errors discovered in the Plans may be adjusted without causing delay to the Contractor. In general, it will be necessary to establish the centerline and set the right-of-way stakes for the

entire length of the job as early as possible. This will insure that the property owners have ample time to remove obstructions such as fence, power and telephone poles, pipe lines, etc., before construction commences on the project.

Centerline control points shall not be placed more than one half mile apart. If alignment points are not within 1500 feet, the Survey Coordinator, Bureau of Design, shall be notified. In case the plan survey party has established them at greater intervals, the construction survey party shall establish new ones, so that the interval between any two adjacent points will be one half mile, or less, depending upon the topography of the area and the location of structures which are to be built. Control points shall be placed so that it will be possible for the instrument man to occupying any one point to see at least 3 feet of a range pole held on either of the adjacent points or on any points along the center line between the points. It will sometimes be necessary to establish new control points for future use, when the ruling distance or the topography of the ground might not necessitate it. It is also advantageous to establish additional center line P.O.T.'s near the 0.0 points of deep cuts. Plan P.O.T.'s will be, as a rule, located near the maximum depth of cut. To reestablish P.O.T.'s at the latter mentioned locations often requires considerable work. The new points set near the 0.0 points allows for easy chaining and lining of the reference to the original control points.

Points should be established on centerline at each culvert location as the centerline is established in order to save duplicate set-ups of the instrument.

Reference hubs should be established at the P.C., P.T., T.S., S.C., C.S. and S.T. of all curves. If a curve is so situated or so long that it is impossible to stake the entire curve from the P.C. and P.T., a reference hub shall be established at each P.O.C. at which it is necessary to set up the instrument in staking the next portion of the curve. These hubs shall be tacked and referenced.

On curves as well as tangents, at least two centerline references hubs should be set on each side of each watercourse where a bridge is required. These points should be back 100 or 200 feet from the proposed abutments, so that they will not be disturbed by bridge construction operations. On horizontal curves, reference hubs can be established at full or half station intervals in the ordinary process of running in the curves.

All hubs set to reference the centerline shall be driven flush with the ground surface and tacked.

(b) Control Points.

All control points should be carefully referenced, if possible, to four suitable points. Reference points shown on the Plans should be checked, and new reference ties should be taken when necessary. Reference points should be so chosen that the angle determined by any two reference points and the hub shall not be less than 45°. This is necessary to get a definite point of intersection of arcs struck from the reference points. Reference points should be so situated that horizontal straight-line measurements from such points to the control point can be easily made.

When a steel bar or tacked stake is used for a reference point, it shall be driven flush with the ground surface and the locations indicated by a guide stake marked "R.P." Other points, such as a cross in concrete or a drill-hole in a boulder should be circled with keel marks to aid in locating them. The reference points shall be located outside or on the right-of-way lines, except in cases where a permanent structure within the right-of-way is available for such use. If possible, the reference points shall be located on permanent objects. Reference ties shall be measured to the nearest 0.01 foot with a steel tape.

3.04.13 STAKING HORIZONTAL CURVES

(a) When a surveying instrument is set on the P.C.

An expedient method of laying out a simple horizontal curve, after the P. C. and P.T. have been located and set from the computed tangent distant "T", is to set the instrument on the P.C. Place a zero reading on the vernier and lock the line of sight on the P.I., turn the telescope in the direction of the curve until the vernier reads the first angle, then set the first point. If the arc length to the first point is 100 feet, the angle of deflection will be D/2, but if arc length of the first point is less than 100 feet, then the angle of D/2 will be reduced in direct proportion of the length of that arc to the arc of 100 feet. All subsequent stations will be set by accumulating the value of D/2 for each arc length of 100 feet. For curves with a "R" of 1900 feet or longer ("D" of 3° or less), the chord length is comparable to the arc length. For sharper curves of a shorter "R" (larger "D"), refer to curve table for a chord correction factor.

(b) With the instrument set up at the P.T.

When the entire curve is visible from the P.T. and the basic curve layout is known to be accurate, it is possible to eliminate one setup by running the curve in with the instrument located at the P.T.

When the instrument is set at the P.T., with the telescope in its normal position, the instrument can be orientated by sighting the P.I., vernier reading Δ 1/2 (Delta), or by sighting on the P.C., vernier reading 00°00'.

With the instrument orientated as noted in the preceding method, the curve notes are the same as when computed for a instrument setup on the P.C.

(c) When instrument is set up on intermediate Point of Curve.

After locating some part of the curve from the P.C., and it is not possible to view the remainder of the curve, it is necessary to move the instrument up to some located point on the curve. There are two methods to orientate the instrument to continue locating the curve.

Method A: Backsight on the P.C. with the scope inverted and the vernier reading 0; invert the scope, release the upper motion and turn until the original computed deflection for the sighted point reads on the vernier. The curve is simply continued using the original computed deflections as determined for the setup at the P.C.

Method B: Backsight on the P.C. with the scope inverted and the vernier reading the total deflection from the P.C. to the occupied point, reset the angle on the opposite side of 0. The scope is then plunged, release the upper motion and turn the vernier to 0, thus locating the local tangent to the occupied point. The deflection to the remaining points must be recomputed. This procedure is convenient in locating and laying out a structure that is normal, skewed or rotated to the centerline of the curve.

On highway designs of four lanes or more, the curve data given on the plans will pertain to the centerline of the total roadway and not that of the lanes of travel. Since construction control will require some type of centerline control for each set of traffic lanes or even the right of way limits, it is suggested that the intrados and extrados of the curve be staked.

An approximate method for staking the two curves is by the two tapes method. After the centerline curve has been run and the points on the offset lines opposite the P.C. and P.T. have been set. The stakes at the points on the offset curve measuring the transverse distance to the offset curve with one tape and measuring the longitudinal distance between the points of the offset curve with the second tape. The chord distance on the offset curves will be greater or less than the distance between the points on the centerline curve in direct proportion to the radii of the two curves.

The following formula is a formula submitted for convenience in calculating the longitudinal distances on the offset curves:

E or I = LR_1 / R

E = Extrados

I = Intrados

L = Chord Length

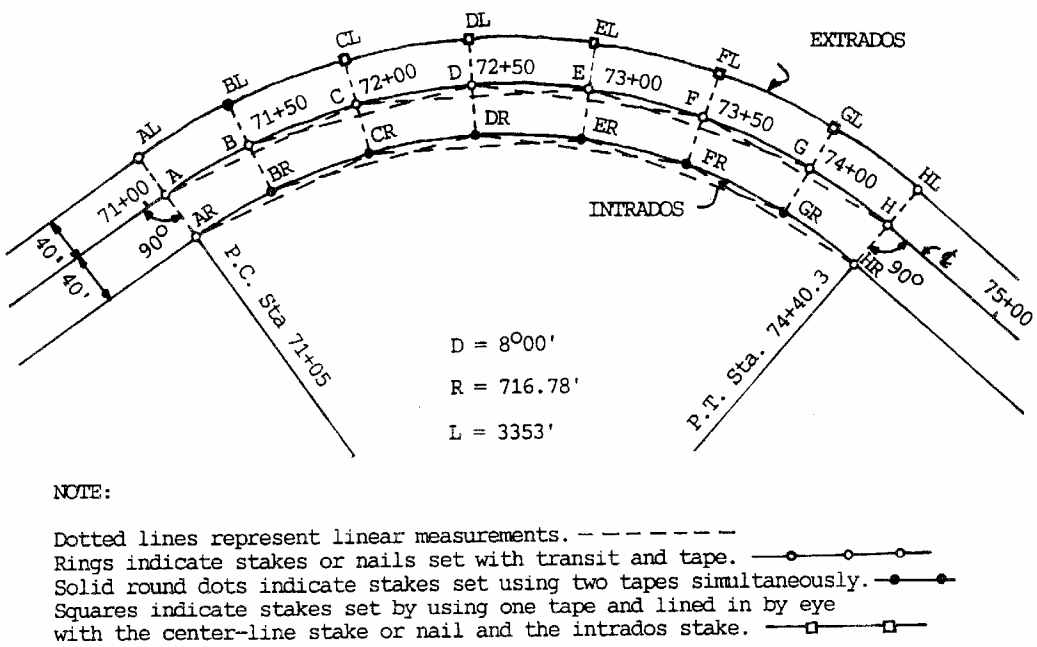
R = Radius of centerline curve

R_1 = R + or - the distance from the centerline curve to the curve being considered.

When setting either the intrados or extrados stakes by the two-tape method, the longitudinal, or circumferential measurements should be made to and from some definite point on each stake. It is recommended that a pencil mark or fine keel mark be drawn transversely, or radially, across the top of each stake at the forward end of the longitudinal tape after the stake has been driven in place. The longitudinal measurements shall be made from these radial lines.

For more exact staking, a theodolite or total station can be used. The original computations, as made up for the centerline curve deflections, will be true for the revised arc length of the offset curves.

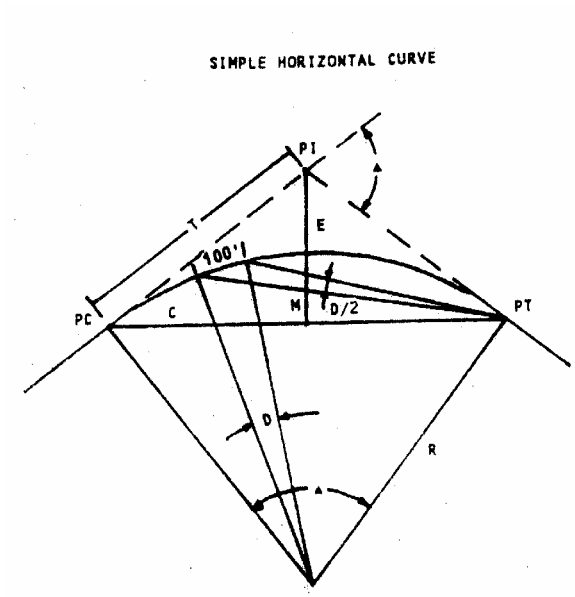
FIGURE No. III-4
INTRADOS-EXTRADOS



NOTE:

Dotted lines represent linear measurements. — — — — — — —
Rings indicate stakes or nails set with transit and tape. —o—o—o—
Solid round dots indicate stakes set using two tapes simultaneously. —●—●—
Squares indicate stakes set by using one tape and lined in by eye
with the center-line stake or nail and the intrados stake. —□—□—

FIGURE No. III-5
HORIZONTAL CURVE



D = Angle subtended at center of circle by an arc length of 100'= Degree of Curve
Δ = Central Angle (angle subtended at center of circle by total arc length of curve)
R = Radius of circle
L = Total arc length of curve
T = Tangent length (dist. from Point of Curvature to Point of Intersection)
C = Long Chord length
E = External distance of curve
M = Middle ordinate of curve

CIRCULAR CURVE FORMULAS

$R = \underline{L\,(180)} / \Delta\pi$ or $R = T/\tan(\Delta/2)$ or $R = C/2\,[\sin(\Delta/2)]$
$L = R\,\pi\,\Delta/180$ or if "D" is known $L = 100\Delta/D$(in stations)
$T = R\,[\tan(\Delta/2)]$
$C = 2\,R\,[\sin(\Delta/2)]$
$E = T\,[\tan(\Delta/4)]$
$M = R\,[1-\cos(\Delta/2)]$

3.04.14 CURVE WITH SPIRAL TRANSITIONS

Curves with spiral transitions are somewhat more complex than simple horizontal curves. With highway curves of one degree or less there is little need of a transition to start or terminate a horizontal curve. Curves designed with a higher degree of curvature may need a short transition to ease the abruptness of changing from a tangent alignment to a curved configuration and vise versa at the end of a curved section. For this reason, the curve may be designed with a spiral transition to allow the driver time to find the change in steering required to adjust to the circular alignment.

Since a straight line and a circle each have constant curvature and the transition spiral is a curve of uniformly changing curvature, the spiral diverges in angle and offset from the circular curve, for a given distance, at the same rate as from the initial tangent.

The degree of curvature of a spiral (arc definition) varies directly as the distance L from the T.S., being zero at the beginning of the transition and equal to Dc and the S.C. This is a parabolic curvature and follows the equation of $y = ax^2$.

$$D = (L/ Ls)\ Dc$$

The spiral angle, θs, at the S.C. equals the central angle of the circular curve for a length just half the length of the spiral.

$$\theta_S = Ls \times Dc/200$$

The spiral angle varies as the square of the length of the spiral from the T.S. so that any other point the spiral angle,

$$\theta = (L^2/Ls)\ \theta_S$$

This type of curve may be set out in the field in several ways. One commonly used method of staking a spiral curve requires that the T.S. and S.T. be located at the Ts distance from the P.I. Then using the (Xs) and (Ys) distances, the S.C. and C.S. are located. Another method of locating the S.C. or C.S. is to establish the intersection of the L.T. and S.T. on the tangent line by measuring the L.T. distance from the T.S. or S.T. With the instrument set on this point and the vernier reading zero, the P.I. is sighted and the angle θs is turned and S.T. distance is measured along this line. Using the Xs and Ys distances to locate the C.S. and S.C. is normally preferred over using the L.T. and S.T.

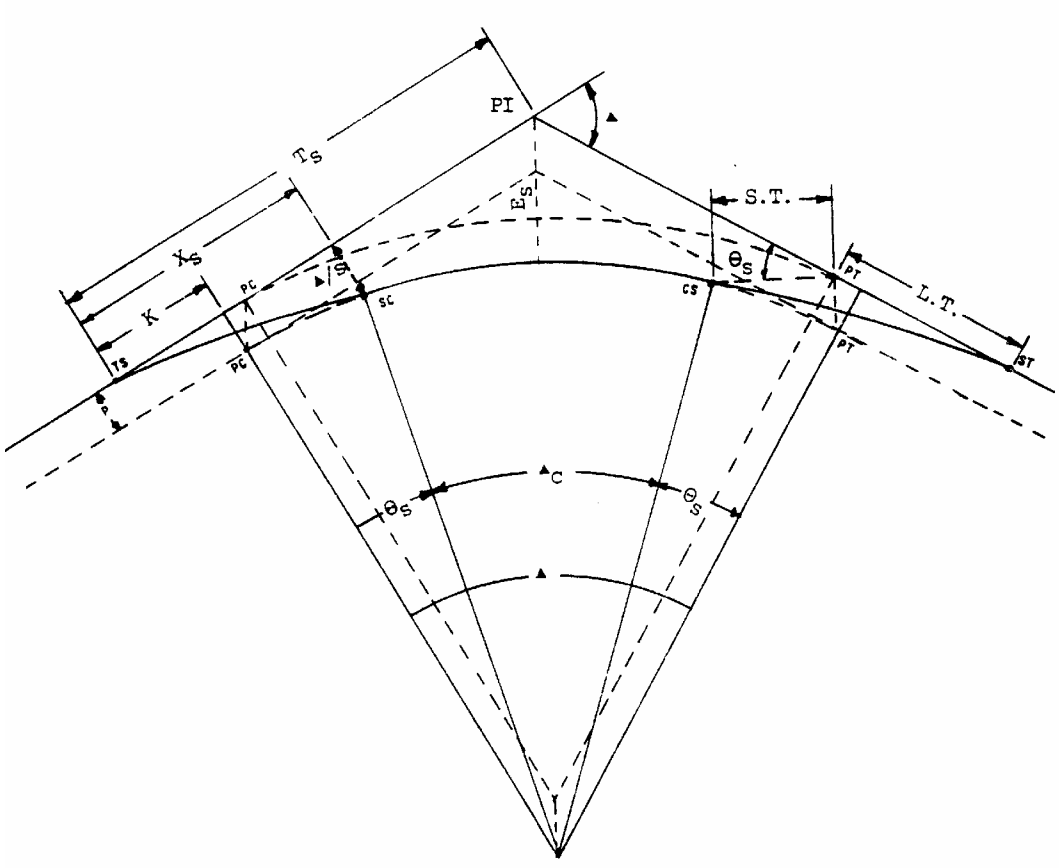
With the T.S. and the S.C. located, the instrument is then located on the T.S. Set the vernier at zero and sight the P.I. or a point on tangent. The deflection angle, Ø, at a set-up on the T.S. from the tangent to any point on the spiral is the angle whose tangent is x/y. It is unnecessary to compute x and y since the deflection angle is very nearly equal to one-third of the spiral angle, the correction being very small for spiral angle values less than 15 degrees. The deflections from the T.S. to intermediate points on the spiral can be computed by the formula:

$$Ø = (\theta s/3) \times (L^2/ Ls)$$

The total deflection to the S.C. is $\theta s/3$. For values of θ greater than 15 degrees a correction must be applied.

When the points on the spiral curve have been located, the instrument is moved to the S.C. The deflection from the T.S. to any point on the spiral equals 1/2 of the deflection from said point back to T.S. In order to orient the instrument to proceed with the simple curve which lies between the two spirals, preset 2/3 θs on the reverse side of the zero. Invert the telescope and sight the T.S. Lock the lower motion on the back sight, invert the scope and turn the upper motion to zero. An alternate method of orienting the instrument at the S.C. is to set the vernier on zero, invert the scope and sight the intersection of the L.T. and S.T. Return the scope to the normal position and proceed with the simple curve. When the C.S. has been reached, the instrument is moved to the S.T. for staking of the second spiral. This curve is backed in with the same procedures as described in staking the first spiral transition.

FIGURE No.III-6
SPIRAL CURVE



SPIRAL CURVE FORMULA

$\theta = (L/Ls)^2 \times \theta s$
$\theta s = \blacktriangle - \blacktriangle c/2$ or $Ls \times Dc/200$
$Ø = \theta s/3$ = Total spiral deflection from TS or ST

In the event it is necessary to move up on a point "t" on the spiral to complete the staking of the spiral, new deflections must be calculated. The new deflections may be calculated for a point ahead (or forward) on the spiral (towards the S.C. or C.S.) by the formula:

$$Ø\ A = D/2 \times L_2/100 + (L_2)^2/Ls \times \theta s/3$$

Or (for points ahead)

$$Ø\ A = \theta s\ (3L_1 + L_2)\ L_2$$

The formula can also be used to calculate the deflections from the TS. In this case L1 and D = 0. To orientate the instruments from point "t" on the spiral, the deflection from point "t" to a previously established point behind (or back) on the spiral must be calculated. This deflection may be calculated by the formula:

$$Ø\ B = D/2 \times L_2/100 - (L_2)^2/L \times \theta s/3$$

or (For points back)

$$Ø\ B = \theta s/(3Ls)\ 2 \times (3L_1 - L_2)\ L_2$$

If the theodolite is located at the SC or CS, then $L_1 = L_2$. With the deflection from the move up point to a previously set point on the spiral set on the reverse side of zero, sight the point with an inverted scope. Invert the scope and turn the vernier to zero. The instrument is now oriented at the move up point.

Various other methods may be used to stake a spiral curve. These methods and additional information on spiral curves are available in publications listed at the end of this section.

(References are listed in FIGURE No. III-23)

Total spiral deflection from S.C. or C.S. = 2/3 θs

$Ø = (\theta s/3) \times (L^2/Ls)^2$

$Xs = Ls - [(Ls)^3/40Rc^2]$

$Ys = (Ls)^2/6Rc$

$Ø_A = [\theta s/(3Ls)^2]\ [(3L_1 + L_2)L_2]$ or $[(D/2)(L_2/100)] + [(L_2^2/Ls)(\theta s/3)]$

$Ø_B = [\theta s/(3Ls)^2]\ [(3L_1 - L_2)L_2]$ or $[(D/2)(L_2/100)] - [(L_2^2/Ls)(\theta s/3)]$

SPIRAL CURVE NOMENCLATURE

P.I. Point of intersection of the main tangents.
T.S. Tangent to spiral, common point of tangent and spiral of near transition.
S.C. Spiral to curve, common point of spiral and circular curve of near transition.
C.S. Curve to spiral, common point of circular curve and spiral of far transition.
S.T. Spiral to tangent, common point of spiral and tangent of far transition.
Rc Radius of circular curve.
Ls Length of spiral between T.S. and S.C.
L Length between T.S. and any other point on the spiral.
L_1 Distance from T.S. to move up point on the spiral.
L_2 Distance from a move up point on the spiral to any other point on the spiral
Ts Tangent distance between P.I. and T.S. or S.T., tangent distance of the complete curve.
Es External distance from P.I. to center of circular curve portion.
L.T. Long tangent distance of spiral only.
S.T. Short tangent distance of spiral only.
L.C. Straight line chord distance from T.S. to S.C.
P Offset distance from the tangent of P.C. of circular curve produced.
k Distance from T.S. to a point of the tangent opposite the P.C. of the circular curve produced.
▲ Intersection angle between the tangents of the entire curve.
▲c Intersection angle (interior angle) between the tangents at the S.C. and at the C.S. The central angle of the circular curve portion of the curve.

Dc Degree of curvature of the circular curve. The same as the degree of curvature of the spiral at the S.C. (arc definition).

D Degree of curvature of the spiral at any other point on the spiral (arc definition).

θ_s Spiral angle. The intersection angle between the tangent of the complete curve and the tangent at the S.C.

θ Intersection angle between the tangent of the complete curve and the tangent at any other point on the spiral. The angle at any other point.

$\varnothing_c$ Deflection angle from the tangent at the T.S. to the S.C.

$\varnothing$ Deflection angle from tangent at any point on the spiral to any other point on the spiral.

$\varnothing_A$ The spiral deflection angle ahead from an intermediate point on the spiral to any other point on the spiral.

$\varnothing_B$ The spiral deflection angle back from an intermediate point on the spiral to any other point on the spiral.

X_s Tangent distance for the S.C. or C.S.

Y_s Tangent offset of the S.C. or C.S.

X Tangent distance for any other point on the spiral.

Y Tangent offset for any other point on the spiral.

3.04.15 PRELIMINARY STAKING OF RIGHT-OF-WAY

In the early stages of right-of-way acquisition, the Right-of-Way Department will make a property appraisal sometimes called a pre-appraisal. The Right-of-way Department will need a very general type of survey consisting of marking and flagging the outline of the project.

Also, the adjustment of utilities cannot be started until the right-of-way has been acquired and staked. If the adjustment of utilities is a major item on a particular project, the right-of-way in the immediate areas of the utility adjustment should be singled out for early staking.

Staking right-of-way by coordinate pairs is the preferred method. The stakes should be placed and driven to an accuracy comparable to the dimension of the end area of the hub stake.

Generally all stakes should pertain to public right-of-way and property fence lines. These stakes and flags may be strips of cloth or plastic markers attached to a 48" building lath which is driven at the approximate limits of the proposed right-of-way.

It is not the intent to reestablish alignment controls with this type of survey, but many existing structures or topographic features can be used to orientate the plan design with the local terrain. Right-of-way breaks and easement limits can be set out with a non-metallic tape. It is not essential to reestablish the centerline point by point, but rather to find and identify points that can be determined from apparent topographic features.

Color-coding can be of great assistance to the appraiser. Since the extent of staking is very limited, it is convenient to differentiate between the centerline, right-of-way and easement limits. Various colors may be assigned to each type of delineation, and the brighter the color the more effective the flagging.

3.04.16 LAND MONUMENTS

Many of the roads in Kansas are located on the section lines of the government land surveys. It is evident, therefore, that many of these stones or monuments marking the section or fractional-section corners will fall within the lines of the highway right-of-way. These monuments are usually disturbed or covered over during construction operations.

The Coordinating Section, Bureau of Design, is making an effort to locate all existing land monuments and reference the line of survey to them. Therefore, the location of many of them is known before construction begins. In other cases the actual monuments are not found but new monuments are established by a resurvey, from physical evidence, from oral or written testimony of local residents, or by a combination of the above methods. It sometimes happens that after diligent search for a monument at a section corner, the section line survey party was unable to find it and reestablishes the section corner, when the monument was actually in place. In such cases, the construction operation will often reveal the original or accepted monument, so the construction forces must be on the lookout for them. When a section corner monument is uncovered, a Licensed Land Surveyor will be notified immediately, and who will take proper references. Land Survey Reference Report forms are available for this purpose. The Bureau of Right of Way and the Survey Section of the Bureau of Design should also be notified if any such evidence is uncovered.

In case the reference points for an endangered section corner monument fall within the ROW and an easement, the monuments shall be re-referenced by a Licensed Land Surveyor. A Section Corner Endangerment Report shall be filed at the Kansas State Historical Society and copies will be forwarded to the Area Engineer. Should reference ties for an endangered corner become destroyed or disturbed during construction, new ties shall be made and the endangered corner shall be re-referenced and refiled. At the completion of the project the Construction Staker shall submit a completion of Endangerment Activities Report for each Endangered Corner with permanent ties. FIGURE No. III-7A and III-7B show each side of a blank "Land Survey Reference Report". Of special note are the check boxes in the upper third of FIGURE III-7A that are used to designate what type of reference report applies.

FIGURE No. III-7A

LAND SURVEY REFERENCE REPORT
Department of Archives
Kansas State Historical Society
6425 SW Sixth Avenue, Topeka, KS 66615-1099
(785) 272-8681 Ext. 322 FAX (785) 272-8682

FOR OFFICIAL USE ONLY

Surveyor _____ **L.S. Reg. No.** _____
Company _____ **Job No.** _____
Address _____ **Telephone** _____
_____ **Date of Survey** _____

This report is for _____ **County, Kansas.**

This report is filed as a (check only one):

☐ SURVEY REFERENCE REPORT (K.S.A. 58-2011a). ☐ NOTICE OF ENDANGERMENT ACTIVITY (K.S.A. 58-2011b).

There is a $5.00 fee for the first five reports filed per township per submission and a $1.00 fee for each additional report filed.

☐ NOTICE OF COMPLETION OF ENDANGERMENT ACTIVITY AND REPORT OF RESTORATION (K.S.A. 58-2011c).
This may only be filed after filing a NOTICE OF ENDANGERMENT ACTIVITY. **There is no filing fee.**
Endangerment report filed _____.

LOCATION CODE OF MARKER IN TOWNSHIP (see illustration on back): ☐☐☐

Legal Description: _____ Sec. _____ - Twp. _____ Rng. _____
Survey Datum (if known): _____ North _____ East _____
Corner status prior to survey: _____ Existent _____ Obliterated _____ Lost _____ Endangered
Monument Condition: _____ Found _____ Set _____ Reset _____ Found Record
Monument Description: _____

REFERENCE MARKS AND MEASUREMENTS: **(Please, no symbols or abbreviations.)**

R1 _____

R2 _____

R3 _____

R4 _____

R5 _____

R6 _____

METHOD OF RECOVERY OR ESTABLISHMENT: _____
_____
_____

SURVEYOR'S CERTIFICATE

This is to certify that I, _____, have found evidence of the corner hereon described and that the statements contained hereon correctly represent the evidence, corner, monuments and accessories for the corner.

Signed _____ Date: _____

(SEAL)

THIS BLANK FORM MAY BE PHOTOCOPIED

FIGURE No. III- 7B

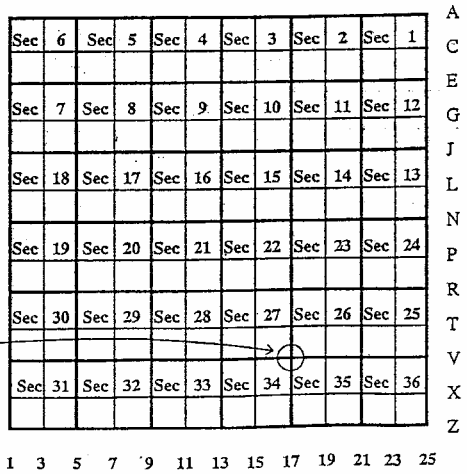
This space for sketch or additional information.

IDENTIFYING A MARKER

To identify the location of a marker in a township, use the following standard alpha-numerical grid to designate an identifier for a given section, corner or intersection.

For example: The southwest corner of Section 26 would be designated by the identifier 17V (this is the **LOCATION CODE OF MARKER IN TOWNSHIP** to be entered in the three boxes on the front side of this sheet).

1	7	V



3.05 BENCH MARKS

3.05.01 SETTING NEW BENCH MARKS

All bench mark elevations must be thoroughly checked before any other level work is started. The level shall be pegged and documented prior to running bench marks.

The location of the bench marks set by the plan-survey party should be checked before any check level work is started. In case the plan-survey party has not established bench marks at the proper intervals or has established them in places where they will be disturbed by construction operations or in cases where they have been destroyed prior to any construction activity, it will be necessary to set additional or new bench marks. The construction survey party shall establish and check new bench marks near all structures and between bench marks which are more than 1500 feet. There shall be at least two bench marks near each structure. At important bridge sites across streams of considerable width or which might be difficult to cross, at least two bench marks shall be established on each side of the stream near each end of the proposed structure. In cases with centerline hubs, bench marks established near centerline 0.0 points will be found to be of convenience. The new bench marks, established by the construction-survey party, shall carry the same numerical designation as the supplemental original bench marks with the suffix A, B, C, etc., dependent on the number of new bench marks established. For example, three new bench marks established between B.M. 7 and B.M. 8 on a project will bear the designation 7A, 7B, 7C, etc.

3.05.02 BENCH MARKS AS TURNING POINTS

In running bench-mark levels or checking bench-mark elevations, each bench mark shall be used as a turning point. This shall be done though it will necessitate taking a short backsight and a short foresight at the set-up between the bench mark and turning point preceding it.

3.05.03 EQUALIZING SIGHTS

In all level work, the leveler shall exercise reasonable care to equalize backsight and foresight shots, being consistent with good practice in leveling, in order that instrumental errors will be eliminated by compensation.

3.05.04 DIFFERENCE BETWEEN BENCH MARK ELEVATIONS TO BE COMPARED IN CHECKING

In checking bench mark elevations, it is important to compare the various values of the difference in elevation between any two adjacent bench marks rather than various elevations obtained for a particular bench mark. The computed difference in elevation between any two adjacent bench marks will be obtained by running two sets of check levels for comparison. If these two differences do not check within the prescribed limits, as hereinafter stated, the level party shall run one or more additional lines of levels between the two bench marks until there are two computed differences which check within specified limits. When two such differences are obtained, the average (computed to the nearest hundredth of a foot) of these two differences shall be taken as the correct difference in elevation between the two bench marks. If one bench mark has a greater elevation than the following bench mark, the difference between them shall be considered negative, and vice versa. In this manner, the correct difference between each two adjacent bench marks shall be determined.

3.05.05 ALLOWABLE VARIATION

When checking bench-mark elevations in the manner described above, the allowable variation between differences in elevation of any two adjacent bench marks shall be a function of the number of instrument setups required in turning from one bench mark to the other. The following formula shall be used in determining the allowable variation in differences of elevation for any two adjacent bench marks:

Formula (5): $V = 0.01 \sqrt{2N}$

Where V is the allowable variation in feet and N is the number of setups required.

In computing the allowable variation by the above formula, V should be calculated only to the nearest hundredth of a foot.

3.05.06 NOTES

Bench-mark notes shall be kept as illustrated in FIGURE No. III-8. The condensed form of notes rather than the staggered or loose form is recommended for several reasons. This form is the one most universally used and therefore most generally understood. It requires less space and for this reason is the preferable form for recording peg-leveling notes for slope-stake and grade-stake notes, finishing stake notes, pavement form stake notes, and cross section notes. In order to be consistent with the above mentioned notes, the bench-mark notes shall be in the condensed form.

In keeping bench mark notes no erasing will be allowed. Recorded rod readings shall never be erased. If a mistake is made in recording or in calculations, a line shall be drawn through the erroneous figure and the correct figure written above. The horizontal spaces are deep enough to permit this if all notes are made in small letters or figures, as they should be. The difference in elevations between adjacent bench marks should be computed by determining the difference between the total + S (plus sights) and the total - S (minus sights) taken between the two bench marks. Computing the H.I. (height of instrument) or the elevations of turning points or bench marks of the bench-mark level rerun is not necessary. This procedure eliminates most field computations, thereby speeding up the work and also eliminates duplicate computations of values which are of no use after the final adjustment of the bench mark elevations.

FIGURE No. III-8
BENCH MARK LEVELS

July 6, 1991 — Inst. - Jones
Clear, Hot — Rod - Smith
Calm

B.M. Check Levels

Point	+ S		- S		Diff.	
		1st Check				
B.M. #1	3.17					X-Cut in Conc. Step 64' Lt. Sta 0+49
T.P.	9.67	+12.84	2.06			
B.M. #2	6.81		2.88	-4.94	+7.90	Spk. & Wshr. in root 16" Elm 72' Rt. Sta. 10+63
T.P.	11.76		1.10			
@ 50' Rt.	6.93	+25.50	1.16			
B.M. #3	4.11		3.06	-5.32	+20.18	Spk. & Wshr. in Pow. Pole 110' Lt. Sta. 21+17
T.P.	1.86	+5.97	8.13			
B.M. #4	8.41		11.39	-19.52	-13.55	Drill Hole top Limestone Rock 67' Rt. Sta. 31+67
T.P.	10.36	+18.77	4.72			
B.M. #4A			1.86	-6.58	+12.19	X-Cut in Conc. Pump Base 93' Rt. Sta. 39+21
		2nd Check				
B.M. #4A	0.84					
T.P.	3.17	4.01	11.43			
B.M. #4	11.88		4.78	16.21	12.20	
T.P.	7.98	19.86	2.06			
B.M. #3			4.31	6.37	13.49	
		3rd Check				
B.M. #3	4.56					Checked back from B.M. #3 to B.M. #4
T.P.	1.26	+5.82	7.75			
B.M. #4			11.63	-19.38	-13.56	
		2nd Check				
B.M. #3	1.37					
T.P.	1.64		8.56			

(Continue 2nd check back to B.M. #1)

3.05.07 ADJUSTMENT OF BENCH MARK ELEVATIONS

A table for the adjustment of bench-mark elevations similar to the one illustrated in FIGURE No. III-9 shall be prepared before going into the field to run the bench-mark check levels. In the first column to the left, the bench-mark numbers shall be recorded in alternate horizontal lines. To the right of the bench-mark number are three columns which are reserved for recording the differences in elevation between the adjacent bench marks. The differences recorded in the second column are obtained by carrying the levels from the beginning of the project and proceeding forward with the stationing of the project. The plus and minus signs are indicative of the proper sign to use in computing the difference in elevation. For convenience, the second check run is made in reverse order and the plus and minus signs recorded in the third column will be reversed. The fourth column is reserved for use if the differences recorded in the preceding two columns indicates that the allowable variation as computed by formula (5) is exceeded and an additional check is necessary.

The fifth column is used for recording the average difference, prefixed with the proper plus or minus sign, between any two adjacent bench marks which meet the allowable variation required. The sixth column is used for computing the adjusted elevation for each bench mark by adding or subtracting the adjusted differences in order. Beginning with the elevation of the first bench mark, which will usually be an assumed elevation or one whose correct elevation is known, the difference between it and the next bench mark will be added or subtracted, as the

case may be, and the correct elevation of the second bench mark thus obtained. In like manner, the elevation of the third bench mark will be obtained by adding to or subtracting from the correct elevation of B.M. 2 the correct difference in elevation between B.M. 2 and B.M. 3. Proceeding in this manner, the correct elevations of all the bench marks along the project shall be determined.

FIGURE No. III-9
ADJUSTMENT OF BENCH MARK ELEVATIONS

Adjustment of B.M. Elevations

B.M. No.	1st Diff.	2nd Diff.	3rd Diff.	Avg. Diff.	Adjusted Elev.	Plan Elev.	Description
1					1500.000	1500.00	X-Cut in Conc. Step 64' Lt. Sta. 0+49
	+7.90	7.92		+7.910			
2					1507.910	1507.92	Spk. & Wshr. in root 15" Elm 72' Rt. Sta. 10+63
	+20.18	20.19		+20.185			
3					1528.095	1528.11	Spk. & Wshr. in Pow. Pole 110' Lt. Sta. 21+17
	-13.55	13.49	-13.56	-13.555			
4					1514.540	1514.58	Drill Hole top Limestone Rock 67' Rt. Sta. 31+67
	+12.19	12.20		+12.195			
4A					1526.735		X-Cut in Conc. Pump Base 93' Rt. Sta. 39+21
	-13.64	13.64		-13.64			
5					1513.095	1513.12	3/4" Ø Re-bar in Fc. Line 61' Lt. Sta. 49+53
	-2.60	2.59		-2.595			
6					1510.500	1510.53	3/4" Ø Re-bar in Fc. Line 104' Rt. Sta. 57+97
	-12.23	12.25		-12.24			
7					1498.260	1498.30	X-Cut S.E. Cor. Conc. Hdwl. 157' Lt. Sta. 68+93
	+0.46	0.40	+0.48	+0.470			
8					1498.73	1498.72	USC & GS B.M. # L-92 (1935) 78' Rt. Sta. 79+53
		Total Plus =		40.760			
		Total Minus =		42.030			
		Net Diff. =		-1.270			
		1500.000-1.270 =			1498.730		

On the right-hand page, a column is designated to record the plan elevations for the original bench marks noted in the plans. The purpose for this information is to provide a means for comparison between the planned and adjusted datum. If there is a consistent variation between the two, indicating an error in the elevation of the initial bench mark from which the adjusted elevations were computed, the datum may be corrected by making an inspection of all the original bench marks to determine which ones are undisturbed and check within the proper tolerance when compared with the adjusted difference as determined by the construction survey party. This inspection and check will insure that the bench-mark datum is adjusted to the datum in the plans and will prevent any sizable variations in earthwork quantities. In other cases this inspection may reveal a need for incorporating an equation in the bench-mark datum to correct an error in the information given in the plans. Construction bench-level datum should not vary over one hundredth of a foot from the planned datum for any considerable distance. Equations in levels should be introduced as needed so the datum used on construction follows very closely to that shown on the plans. Care must be exercised in this procedure to base the equations on undisturbed plan bench marks.

3.05.08 GOVERNMENT BENCH MARKS

Government bench marks have been established over a large portion of the State of Kansas by the National Geodetic Survey, and it is very important that these bench marks be preserved without exception. If preservation is impossible:

The Area Construction Engineer shall handle the changing of these bench marks through the District Office. The District Office shall contact, or designate the Area Construction Engineer to contact the National Geodetic Survey which will send personnel to relocate the bench mark or issue instructions concerning its relocation.

The following information and instructions have been issued by the National Geodetic Survey concerning government bench marks:

The National Geodetic Survey has been responsible for establishing and maintaining the nation's horizontal and vertical control networks for more than 160 years. These networks now consist of more than half a million marked control points in the U.S.

Anyone having information regarding markers that are in need of repair, in danger of being destroyed, or destroyed is requested to notify the KDOT Bureau of Design, Attn: Geodetic Advisor.

When a project has been designed using an assumed elevation, this said elevation should be tied into a government bench mark, if practicable, and so noted on the Completed-Construction Plans.

3.06 CROSS SECTIONS

3.06.01 ORIGINAL CROSS SECTIONS

The present Standard Specifications provide for Plan Quantity Payment. In this case the quantities of excavation and embankment shall be the quantities shown on the plans for the various balances, provided the project is constructed essentially to the lines and grades shown on the plans. No allowance will be made for any quantities included as contingencies on the plans.

When the Plans have been altered or when disagreement exists between the Contractor and the Engineer as to the accuracy of the plan quantities in any balance or the entire project, either party shall have the right to request and cause the quantities involved to be measured for payment, the original plan cross sections plotted on the plans shall be used as original field cross sections. Additional original cross sections may be interpolated or determined by other approved methods at points where it is necessary to determine more accurately the quantities.

If there is doubt as to the accuracy of the original plan cross sections or, after study of the original plan cross sections, if there is a need for additional original cross sections they should be taken as described in this section.

Generally, the plans will not include original cross sections for channel changes and excavation pits; therefore, original cross sections from which to measure quantities, in case measured quantities are required, should be taken in the field prior to the start of work. Methods of taking these cross sections are described in this section.

3.06.02 ROADWAY CROSS SECTIONS

Field procedure: Cross sections should be taken every 100 feet and at intermediate points where necessary to insure an accurate determination of quantities. It shall be kept in mind that a cross section may be required at certain plus stations though there is no break in the centerline profile. It is just as important to take additional cross sections at points where the shape of the cross section changes abruptly as it is to take them at breaks in the centerline profile. In addition to the cross sections, which will be necessary because of the contour of the original ground surface, original cross sections shall be taken at all points at which it will be necessary to take final cross sections after the construction work has been completed.

Before going into the field to take original cross sections, the Area Engineer and Construction Staker shall check over the plans thoroughly and make a record of all the plus

stations at which it will be necessary to take original cross sections due to the design of the improvement. A study of the plans will reveal a number of points at which it will be necessary to take final cross sections; it will, therefore, be necessary to take original cross sections at the same points. The list of plus stations should be recorded in a small memorandum book which the rod person shall carry during the cross section work. In this book shall be tabulated the plus stations to the following points:

(a) The P.C. and P.T. of all horizontal curves.

(b) The P.C. and P.T. of sharp vertical curves, and points of vertical intersection where no vertical curve is to be constructed.

(c) Points were superelevation begin and end.

(d) Points where maximum superelevation begin and end.

(e) Points where spiral transitions begin and end.

(f) Points where the shoulder slope changes.

(g) Points where the distance from centerline to either shoulder changes.

(h) Points where the width of side ditches change.

(i) Points where there is a break in ditch grade line.

(j) Points where the back slope, or the road side slope (in case there is a berm) of the ditch changes.

(k) Points where a berm begins or ends.

(1) Points where berm obtains its full width.

(m) Points where the berm ceases to be of full width and starts tapering to a point.

(n) The ends of wing walls of bridges and large culverts.

(o) The back side of bridge abutments.

(p) The back side of the end walls of multiple-box bridges or large culverts.

(q) At all 0.0 points, and any other points where a cross section is necessary for accurate determination of quantities.

Where rock excavation is anticipated, both original and final cross sections shall be taken at intervals of 50 feet or less, in order to insure a more reliable determination of the quantities.

Rod and tape readings shall be taken at all breaks in the ground along the normal line out to the right-of-way line on each side. Since the grade stakes will be driven flush with the ground surface, the last rod bearing shall be taken on the grade stake. The rod when held on the grade stake shall be read to the nearest 0.01 foot. Grade stakes should also be used for turning points. If this system is followed, the point at which any error is introduced can readily be determined. The grade stake will not be graded at the time the cross sections are taken. This will be done at the time the slope stakes are set. The elevations of the grade stakes as determined at the time the original cross sections are taken, will therefore, serve as a check on the elevations obtained when grading the grade stakes.

In cross section work, the tape should be read to the nearest 0.5 foot. Rod readings for ground elevations should be taken to the nearest 0.1 foot.

When taking original cross sections, a rod reading should be taken at both the upstream and downstream flow line of all culverts, and multiple-box bridges which are to remain in place. The elevations of the tops of the hub guards and the top of the slab shall be determined for each side of the roadbed. The distance between the hub guards should also be measured and recorded. This data should then be checked against corresponding data shown on the plans.

Special care shall be taken, at all bridges and miscellaneous structures for which the plans show a pay item of some class of excavation, to get sufficient cross sections to insure an adequate determination of the excavation quantities.

Public road intersections which connect with the improvement should be cross sectioned

with the same degree of accuracy as the main part of the improvement. The cross sections should be taken at right angles to the centerline of the intersected road and shall cover the area between property lines. They should be extended for a sufficient distance from the centerline of the main road to cover all the proposed work.

3.06.03 NOTES

Cross section notes can be kept in electronic format or in the standard commercial field notebooks. See Section 3.04.05 for Electronic Field Notes. On the left hand sheet shall be recorded the station number and plus at which each section is taken, and the peg leveling notes by which the height of instrument and the elevations of bench marks and turning points are kept. In the first column to the left should be recorded the station number or the bench mark number. In the second, third and fourth columns from the left should be recorded the +S, H.I., -S, respectively. In the fifth column should be recorded the elevations of the turning points and bench marks as determined by the cross section peg leveling notes. In the sixth column should be recorded the correct bench mark elevations. The notebook containing the adjustments of the bench mark elevations should be carried by the instrument person during the cross section work. When the elevation of the bench mark has been determined in the cross section notes the correct or adjusted elevation should be recorded to the right of it in the sixth column from the left. If two elevations differ by 0.1 foot the survey party should run the line of levels back, checking on each grade stake until the error is found or until the proceeding bench mark is reached. The cross sections need not be taken again, as the error can be rectified by correcting the H. I. where the error was first introduced, and carrying the correction forward to the bench mark where the error was detected. At each bench mark, the peg leveling notes should be corrected to the correct bench mark elevation; In other words, the plus sight taken on each bench mark should be added to the correct elevation to determine the height of instrument rather than to the elevation obtained in the cross section notes.

The rod readings and tape readings at cross section points should be recorded on the right hand sheet. The rod readings shall be shown above the corresponding tape readings. The centerline rod reading should be recorded at the vertical center of the sheet, the other readings being recorded in the order from the center toward the edges of the sheet. If all the readings for a particular section cannot be recorded in one horizontal tier, one tier should be left blank, the remaining readings being recorded in the third tier below and listed from the outside edges of the sheets towards the center in the order taken.

If it is impossible to take cross sections for the entire width of the right of way from one set up of the instrument, the instrument should be set in such a position that the rod can be read when held on one right of way line. Cross sections should then be taken from the right of way line as far as possible toward the centerline. When all the locations within the range of the instrument have been partially cross sectioned in this manner, the instrument should be set up in such a position that part or all of the remaining portions of the cross sections can be taken. When this procedure is necessary, each location should be listed in the cross section notes as many times as it is necessary to set up the instrument to complete the cross section at the location. In other words, no attempt should be made to block off the cross section notes and indicate that certain rod readings were taken from one H.I. and others were taken from another H.I. The various portions of the cross sections shall be shown in different places in the notes.

The hand level may be used in completing cross sections in case there are only a few rod readings which cannot be taken with the engineer's level. Extreme care must be exercised in reducing rod readings which are taken with a hand level, to the H.I. of the engineer's level.

Rod readings taken on outcropping ledges of rock at points where cross sections were taken shall be recorded in the same manner as the rod readings taken on earth, an appropriate notation being made to indicate that the rod reading was taken on the top of rock (T.R.), bottom of rock (B.R.), or some other unusual point. Rod readings taken on outcrops at points where no cross sections are taken may be recorded on the left hand sheet between the peg leveling notes.

Cross section notes shall not be crowded; two lines shall be omitted between each two successive tiers or rod and tape readings. The notes shall be kept from the top of the page down.

3.06.04 BORROW AREAS

All Borrow Pits are to be cross sectioned before and after the excavation is made. Cross sections should be taken at least every 50 feet to insure greater accuracy in determining excavation quantities. The Contractor shall be required to leave all pits in a neat, well trimmed, and well cleaned condition so as to facilitate the accurate measurement of the material used. When possible, all pits should be constructed so that they will drain to some natural drainage course. Final cross sections for borrow pits should be taken as soon as possible after the excavation work has been completed and before the pit is filled with sediment or scoured out by high water or heavy rains. Side excavation pits, or those which are merely an extension of the roadway ditch may be cross sectioned from the centerline of the project at the same time the roadway cross sections are taken.

In case an excavation pit is to be cross sectioned from any base line other than the centerline of the project, the base line shall be carefully staked and referenced. Complete field notes should be kept regarding the staking operations. A sketch shall be drawn in the field notes showing the layout of the pit and base line, and the reference ties to the terminals of the base line. These notes should be kept in electronic format or a notebook set aside for and labeled, "Miscellaneous Field Notes". In case a side pit is located to one side of an alignment, curve, it is suggested that a straight base line be established either across the pit longitudinally or on the outside of the pit and the cross sections for that part of the pit which is not included within the roadway cross sections be taken from the base line. This will eliminate the necessity of correcting the computed earthwork quantities for curvature.

There may be cases, however, in which it will be more convenient to cross section a curved pit from the centerline of the project rather than from a straight base line. If this is done the proper correction shall be made for curvature. The method of making this correction is explained in most engineer's handbooks or textbooks on highway or railway curves and earthwork. Occasionally, it will be necessary to apply the correction for curvature to regular roadway cross sections which have not been extended to include an adjoining excavation pit. Where the centers of gravity of the cross sections taken from a short-radius centerline fall appreciably and uniformly to one side of the centerline, as will usually be the case where a curve is located on a hillside, it is imperative that this correction be made.

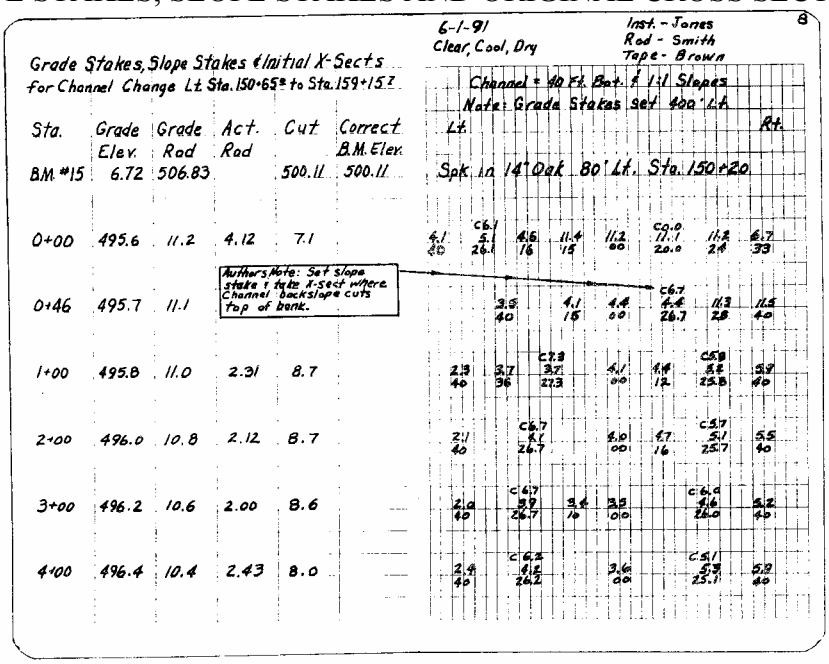
Before any excavation or clearing has been started, the construction survey party should check the topography within the limits of the excavation pit. Large trees, hedge fences, stone fences and all other pay items shall be carefully checked to determine the quantity of each which must be removed.

3.06.05 CHANNEL CHANGES

The earthwork involved in channel changes is frequently quite large and shall receive the same careful attention as the improvement proper. Original and final cross sections shall be taken, and slope stakes and grade stakes should be set.

The first operation will be that of staking the centerline of the channel change. This shall be done according to the design shown on the plans or in such a manner that sufficient data will be obtained to enable the Engineer to show on the Completed Construction Plans the exact manner in which the channel change was laid out and constructed. The hubs along the centerline of the channel change shall be carefully referenced to four points by one of the methods described in Subsection 3.04.11. The centerline of the channel should be tied to the centerline of the project by at least one angular and one linear measurement. Deflection angles in the centerline of the channel change shall be measured. After the centerline has been staked and referenced, grade stakes shall be offset at such a distance from the centerline that there will be little danger of their being disturbed by construction operations. The grade stakes may be graded at the same time the slope stakes are set and the original cross sections are taken. Field notes for this three-fold operation may be kept in the manner illustrated in FIGURE No. III-10 or in electronic format.

FIGURE No. III-10
GRADE STAKES, SLOPE STAKES AND ORIGINAL CROSS SECTIONS



Before any work on the channel change has been initiated, the construction survey party shall check the topography within the limits of the construction operations. Large trees, hedge fences, stone fences, and all other pay items should be carefully checked to determine the quantity of each which must be removed.

When large trees are a pay item and are to be removed, they shall be blazed or tagged, as they are counted, on the side facing the centerline of the channel change.

All trees which are to be saved should be marked with the standard tag provided for that purpose.

If the grade stakes are still in place at the time the final cross sections are taken, it will not be necessary to restake the centerline except in cases in which the channel change is cut to a depth of more than 6 or 7 feet below the original ground surface. In such case, the centerline shall be reestablished, in order that the measurements to points within the excavation may be accurately determined with greater facility. All the field notes pertaining to any one channel change should be kept on successive sheets in the same notebook. The field notes pertaining to channel changes should be kept in electronic format or a notebook or notebooks which are set aside for, and labeled, "Miscellaneous Field Notes".

KDOT Field Book No. I may be used for setting slope stakes on large channel changes.

Slope stakes and grade stakes should be set every 100 feet and at all breaks in the grade and points of deflection of the alignment. Slope stakes should also be set at all points where the back slope of the channel change intersects the tops of the banks of the original channel.

Channel changes shall be excavated in a neat and suitable manner to facilitate the accurate measurement of the excavated material. Final cross sections should be taken immediately after the channel changes are completed and before silting or scouring in the channel has started.

3.06.06 PLOTTING CROSS SECTIONS

One of the following methods should be employed in plotting cross sections.

(a) **Plotting by Elevations method**. In this method it will be necessary to compute the elevation of each point at which a reading is taken. These elevations shall be computed and checked before any plotting is done.

(b) **Modified H.I. and Rod Reading Method.** The procedure when using this method is as follows:

A fraction of a foot shall be added to or subtracted from the H. I. to convert it to an elevation of an integral number of feet. The same fraction shall then be added to or subtracted from all rod readings which were taken from the H.I. All of this addition or subtraction, as the case may be, should be performed mentally with no record being made of it in the notes or on the cross section sheets. The modified H.I. shall then be plotted at such a point that the elevations of the heavy horizontal lines will be expressed in integral numbers which are divisible by the number of feet to the inch on the scale to which the sections are being plotted. Having assumed a line which represents the modified H.I. the plotter shall then plot in the cross section points, using the scale on the paper, as the reader calls out the modified rod readings. For example: Assume that the H.I. 127.62, the rod readings at a point 16.5 feet right is 8.9 feet, and the cross sections are being plotted to a scale of 5 feet to the inch, the same scale being used both horizontally and vertically. The reader should call out the H.I. as being 128.0 feet, mentally adding 0.4 feet to the actual H.I. The plotter should then choose a lightweight horizontal line which is three-fifths inch above one of the heavy horizontal lines and assume its elevation to be 128.0 feet. The heavy horizontal line directly below will then assume an elevation of 125.0 feet. After the plotter has located his H.I. on the paper, the rod reading shall be called out as 9.3feet, which is really 0.4 feet greater than the actual rod reading. The plotter shall then plot the point 9.3 feet below the modified H.I. and 16.5 feet to the right of the centerline. After the H.I. bar has been set and the center elevation plotted, the actual road reading between the H.I. and the elevation of the point involved should be read by the plotter. This procedure will insure against

the introduction of an error in setting the H.I. bar, the plotting of the elevation of the point or the mental calculation in modifying the rod readings.

After the cross section points have been plotted and the cross sections have been drawn by connecting adjoining points with straight lines, the plotting of each section should be checked in a manner which shall be just as thorough as the method employed in plotting. It is important that the cross section be completed by drawing the lines between the plotted points before checking in order to insure that all points have been used.

When plotting original cross sections, it should be remembered that the cross section notes at the 0.0 point are not contained in the regular cross section notebooks. The notes for the sections at the 0.0 points are recorded in the back of the slope stake and grade stake notebooks. Care should be taken to plot the sections for the 0.0 points in their proper position, in the order of their station numbers.

When plotting original cross sections for a portion of the project on which slope stakes have not been set, the exact location of the 0.0 points will not be known. By inspecting the plans, the approximate location of the 0.0 points can be determined. A space, in order, should be reserved for the plotting of each anticipated zero-point section.

Cross sections shall be plotted to the nearest 0.5 foot on the, horizontal and the nearest 0.1 foot on the vertical scale.

Shallow Sections In case a large percentage of the cross sections of a project or a portion of a project has little depth as compared to the length, as is often the case on a paving or light grading project, the cross section shall be plotted to a larger or a dissimilar scale. When plotting to a larger scale use two or two and one half feet to the inch both horizontally and vertically. When using a dissimilar scale, the vertical scale should be larger than the horizontal scale. A convenient dissimilar scale is one in which the vertical scale is two feet to the inch and the horizontal scale is five feet to the inch, one square inch on the cross section sheet will then represent ten square feet.

(c) Computer generated cross section method. Microstation/Geopak preferred.

3.07 SLOPE STAKES AND GRADE STAKES

3.07.01 GENERAL

The plan grade of the roadbed and the ditches are taken to the field and made workable with grade stakes and slope stakes. These stakes are set to establish cut and fill grades for the contractor and to limit the scope of the contractor's operations. These are the working stakes, and they are set after the right of way is staked, the heavy vegetation, trees and hedges, are cleared prior to moving any earthwork.

These stakes may be "flats" or Type "A" Stakes for writing the necessary information on a slope stake, and a Type "A" and "B" for the grade control hub and guard stake.

Color coding can be effective in making these stakes more prominent and in providing a more illustrious background for written information. The grade stakes should be graded and the slope stakes should be set after the original cross sections have been taken. The setting of the grade stakes and slope stakes should be performed simultaneously.

Since the grade stakes are to be graded at the same time the slope stakes are set, KDOT Field Book No. 1 has been designed for use in performing these two operations simultaneously. FIGURE No. III-11 is a reproduction of a typical set of grade stake and slope stake notes as they shall be kept in the field book provided for this purpose.

3.07.02 SLOPE STAKES

The following method should be used for setting slope stakes:

Slope Stakes for Embankments - Slope stakes for embankment sections shall be set at the toe of the slope and shall be marked to show the vertical distance or fill from the ground at the point where the stake is driven to the finishing grade elevation for the shoulder of the embankment. The procedure in setting slope stakes for embankment sections should be as follows:

The slope stake should be set by taking trial readings at right angles to the centerline until a point is found at a distance from the centerline equal to the shoulder slope ratio times the fill from the ground at the point to the plan grade elevation of the shoulder, plus the distance from the centerline to edge of the shoulder.

The fill which is marked on the slope stake shall be the fill from the ground at the point where the stake is set out to the shoulder finishing grade elevation.

Embankment Slope stakes shall be set at a distance from the centerline which is determined by the shoulder grade elevation, the width of roadway, and the shoulder slope ratio as indicated on the plans, but the fill which is marked on the stakes shall be a function of the shoulder finishing grade elevation.

Slope Stakes for Cuts - Slope stakes for cuts are the stakes set at the point of intersection of the back slope with the natural ground. They shall be marked to show the vertical distance or cut from the ground at the point where the stake is driven to the grade elevation for the bottom of the ditch.

In determining the point at which to set the slope stake, it will first be necessary to determine the point at which the horizontal distance from the centerline to the toe of the back slope, plus the quantity obtained by multiplying the cut by the back-slope ratio is equal to the measured distance from that point to the centerline. The slope stake should be set at this point and the cut from this point to the bottom of the ditch shall be marked on the stake.

The above described method of marking shall apply to all slope stakes except berm-slope stakes. Where a berm is cut to grade, the cut will begin at the toe of the embankment slope and the slope ratio of the berm cut will be the same as the embankment slope ratio. Two slope stakes should be set at the toe of the embankment slope where there is a berm to be cut to grade. One stake shall be the embankment slope stake which shall be marked as described above; the other shall be the berm slope stake on which shall be indicated the cut from the ground at the stake to the berm-grade elevation. The cut should be marked in a horizontal position across the back side of and near the top of the stake. Directly beneath the cut should be written the word “Berm” in a vertical position. The station number should be marked in a horizontal position across the front side and near the top of the berm-slope stake. Directly below the station number, the distance from the centerline of the project to the berm-slope stake shall be marked in a horizontal position.

Marking and Driving Slope Stakes - The cut or fill shall be marked in a horizontal position across the front side (side facing the centerline) and near the top of the slope stake. The distance from the centerline to slope stake shall be marked in a horizontal position directly below the cut or fill. The back-slope ratio shall be marked in a horizontal position immediately below the centerline distance.

The station number should be marked in a horizontal position across the back side and near the top of the slope stake.

3.07.03 OFFICE PREPARATION OF NOTES

The data which is to be shown in the first, second, third, eighth, tenth, eleventh, twelfth,

fifteenth, nineteenth, twentieth, and twenty-first columns should be recorded before going into the field. The plans should be studied carefully to determine at which plus station it will be necessary to set slope stakes. The points at which slope stakes shall be set are enumerated herein before. The location of all of these points can be determined in the office.

If the plans are provided with plotted cross-sections, the tentative location of the slope stake may be determined. The cross sections will show the approximate cut or fill and the distance from centerline to the slope stake. If desired, it is helpful to make a very light entry in the slope stake book of the cut or fill and distance from the centerline as shown on the section. These figures will probably prove not to be correct, but they will provide a fast reference for the first trial shot, and often the identical values are determined to fit the field conditions. These trial values provide a check of the field work, because more often a wide variation in the trial shot and actual shot is caused by an error in computations or reading the rod.

3.07.04 NOTES FOR STEEP SIDEHILL SECTIONS

If in hilly country, it is impossible to set slope stakes on both sides of the road and grade the grade stakes from one setup of the instrument, the instrument should be set in such a position that the slope stakes from the downhill side of the road can be set. When the slope stakes have been set on the downhill side at all points within range of the instrument, the instrument should be set up on higher ground in such a position that the slope stakes for the uphill side can be set. The grade stakes will usually be near one row of slope stakes and may, in most cases, be graded from the same H.I. used in setting the row of slope stakes near the grade stakes. When the above described procedure is necessary, each station shall be listed in the slope-stake and grade-stake notes as many times as it is necessary to set up the instrument in setting the slope stakes and grading the grade stakes at the station. When preparing the notes in the office before going to the field, it will be an easy matter to determine from an inspection of the plan cross sections at which stations or plus stations it will be necessary to set up the instrument more than once in setting the stakes. A sufficient number of station tiers should be reserved to provide space for a separate entry of each station for each H.I. used in staking the station. If there are only a few stakes which cannot be set from the setup of the engineer's level, the hand level may be used.

3.08 GRADE STAKES

3.08.01 GENERAL

1½"x1½" stakes (Type "B", See FIGURE No. III-2) varying in length, from 12 to 24 inches, to suit local conditions, should be used for grade stakes. Grade stakes should be set on both right-of-way lines, on horizontal curves, extremely rough terrain, and at other locations where deemed advisable. Where grade stakes are set only on one right-of-way line, they should, if practicable, be set on the same side of centerline throughout the project. Grade stakes should be located so that the danger of disturbance during construction will be as small as possible, without placing them too far away from the centerline of the project.

Grade stakes should be driven flush with the ground surface. A Type "A" guard stake (See FIGURE No. III-2) shall be placed along side the grade stake. The right-of-way (or R/W) stake will very often meet the required condition of the grade stake. Since this R/W hub is driven flush with the ground, and it is located in an area accessible to the project but clear of construction, it is expedient to designate them as the grade control stakes.

At locations of interchanges, where the R/W widens to a substantial distance from the project centerline or in city sections where the R/W is often existing property lines of irregular distances, grade stakes should be set at the most reasonable position convenient to the needs.

Grade stakes shall be set at every 100 feet on tangents, flat vertical curves, and on horizontal curves with a radius longer than 750 feet. They shall be set at every 50 feet on horizontal curves with a radius of 750 feet or less. Grade stakes should also be set opposite the P.C. and P.T. of horizontal curves, at points where superelevation begins and ends, at points where maximum superelevation begins and ends (usually the P.C. and P.T., respectively), and at the beginning and end of all spiral transitions.

The distance from the centerline to the grade stake shall be marked in a horizontal position on the back of the guard stake. Later the cut or fill from the grade hub to the centerline finish grade will be marked on the front side of the guard stake directly below the station number.

The rod readings on the grade stakes shall be taken and recorded to the nearest 0.01 foot, but the fill or cut shall be shown on the guard stakes only to the nearest 0.1 foot. With elevations determined to the 0.01 foot, each stake becomes somewhat of an intermediate bench mark which can be used for checking purposes. The elevations obtained when grading the stakes should be compared with those obtained at the time the original cross sections were taken.

In rough country, it is important that grade stakes be offset in their true position at right angles to the centerline. To do this, it is necessary to employ some method more exact than estimating by eye the angle of offset.

Grade stakes may be offset on curves by the method explained in Subsection 3.04.13 and illustrated on FIGURE No. III-4. The method of accurately offsetting grade stakes from a tangent is very similar to that of offsetting from a curve.

The surveying instrument should be used to offset the grade stake on a normal line opposite each P.O.T. This should be done at the time the centerline is being staked. In case the surveying instrument is not set up at both the P.C. and P.T. of the horizontal curve during the operation of running the curve, it will be necessary to set up these points for the purpose of offsetting the grade stakes. Right-of-way stakes should also be offset in this manner on the side opposite the grade stakes at each P.C. and P.T.

With these correct offset grade or R/W stakes as beginning points and control points, the intermediate stakes may be offset as follows:

Using two tapes, one stretched along the right-of-way line on the offset line, to measure the longitudinal distance between stakes, and the other, stretched from the centerline point transversely to the forward end of the longitudinal tape, a stake shall be set at, or vertically below, the point where the outside end of the transverse tape and the forward end of the longitudinal tape meet. Both tapes need to be drawn tight and held in a horizontal position.

Longitudinal measurements between grade and R/W stakes should be made from definite points on the stakes. It is recommended that a pencil mark or fine keel mark be drawn transversely across the top of each stake at the forward end of the longitudinal tape after the stake has been driven in place. Longitudinal measurements to succeeding stakes shall be made from these transverse marks.

Proceeding in this manner, the grade or R/W stake shall be set until the next control point is reached. At this point, a check on the accuracy of the longitudinal measurements will be obtained.

Another method which may be used in offsetting grade stakes from tangents with a fair degree of accuracy is that where the right-angle triangle is used. The triangle should be laid out with the right angle at the station from which the stake is to be offset. The triangle will be laid out with the tape with the sides being measured out in the ratio of six, eight, and ten with the base of the triangle on the centerline. To use this method, it is absolutely essential that a backsight or foresight be provided on the tangent.

In flat country and when narrow right-of-way is provided, it will be permissible to offset grade stakes from the tangents and long-radius horizontal curves by using one tape to make the offset measurement and estimating by eye the direction of the normal. The procedure outlined above for rough country shall be employed in offsetting grade stakes on all horizontal curves, with radius of 750 feet or less.

3.08.02 FIELD NOTES FOR SLOPE STAKES AND GRADE STAKES

Electronic field notes are acceptable but must follow KDOT guidelines.

The standard form for slope staking and grade stake field notes, which has been provided in the KDOT Field Book No. 1, is arranged in a logical and convenient order, which should make the form practicable for use on any type of highway cross section which will be encountered in work on the Kansas State Road System. FIGURE No. III-11 is a reproduction of the standard form and contains illustrating field notes. A study of the notes will reveal the manner in which the form is to be used. The following comments will aid in a ready comprehension of its use.

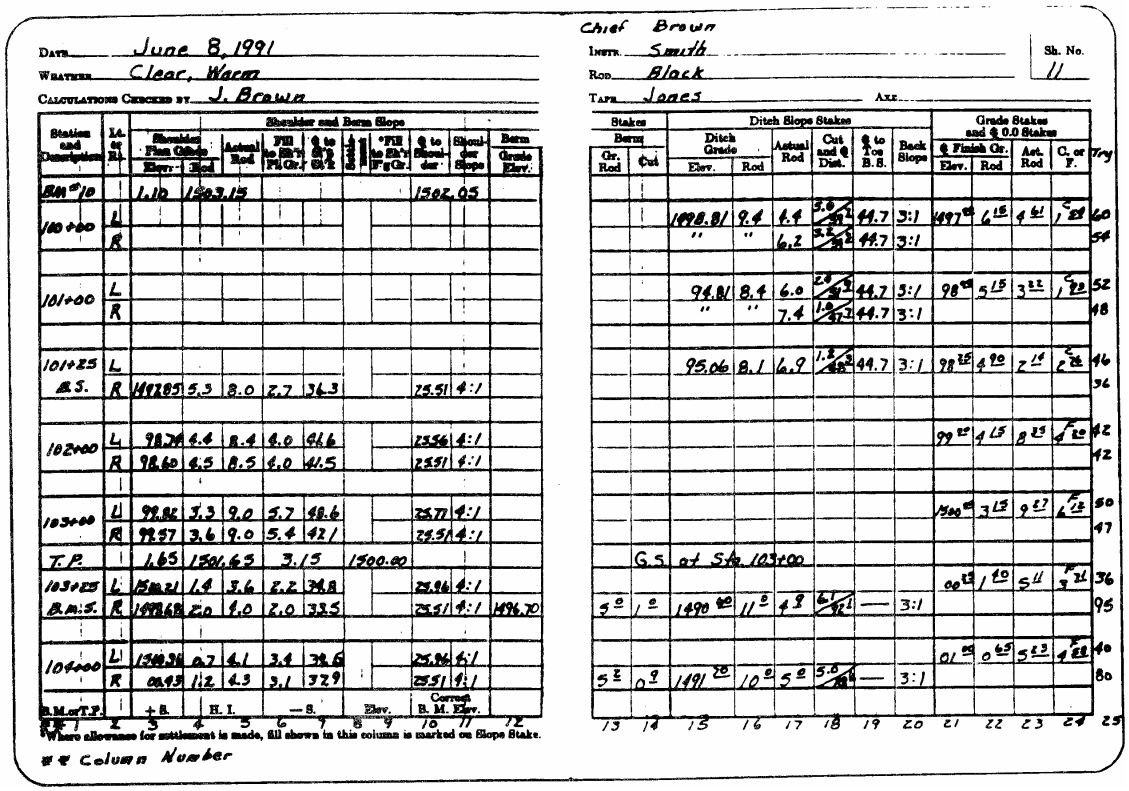
The notes which pertain to each station or plus station at which a grade stake or slope stake is set shall occupy two horizontal lines, or what will hereinafter be designated as a double depth station tier. The data for the left hand side of the road being recorded always above the data for the right hand side. The peg leveling notes by which the height of instrument is kept shall be recorded on the left half of the form in the single depth horizontal tiers which are located between the double depth station tiers. The bench mark number or the turning point designation, the plus sight, the height of instrument, the minus sight, the elevation of the bench mark or turning point as determined by these peg leveling notes, and the correct or adjusted bench mark elevation shall be shown in the vertical columns so labeled at the bottom of the sheet. The column headings at the top of the form refer only to the rectangular spaces formed by the intersection of the columns with the double depth station tiers; while the column labels at the bottom of the form refer only to the rectangular spaces formed by the intersection of the columns with the single depth horizontal tiers.

The description of the turning points may be shown in the single depth tiers on the right half of the form.

The uses of the rectangular spaces formed by the intersection of the vertical columns, which are labeled at the top of the form with the double depth station tiers are explained below.

For convenience, these spaces are referred to according to the column in which they are located. The columns are designated by numbers, the numbers beginning at the extreme left-hand side of the form and increasing to the right. The first column to the left side of the form is designated as column number 1; the next column going to the right is referred to as column number 2, etc.

FIGURE No. III -11
SLOPE STAKES AND GRADE CONTROL STAKES



(a) The double depth spaces in column number 1, which is labeled "Station and Description", are large enough for recording the station numbers, and indicating whether or not a P.C., P.T., B.S. (Beginning of Superelevation), E.M.S. (End of Maximum Superelevation), or any other similar point is located at the station indicated.

(b) In the second column, the letter "L" indicating "left" shall always be recorded above the letter "R" indicating "right". The data in the other columns to the right shall, of course, be recorded in the same order.

(c) In the third column shall be recorded the shoulder plan grade elevation for both the left and right shoulders.

(d) In the fourth column shall be recorded the shoulder plan-grade rod, which will be the difference between the H.I. and the shoulder plan-grade elevation.

(e) In the fifth column shall be recorded the actual rod reading when the rod is held on the point at which the embankment-slope stake is to be set. The fill from the point on the ground at the stake to the shoulder plan-grade elevation will be determined by subtracting the shoulder plan-grade rod from the actual rod reading. When the planned grade elevation is above the H.I., a plus grade rod is recorded and the fill is equal to the sum of the grade rod and the actual rod.

(f) In the sixth column shall be recorded the fill to the plan-grade elevation of the shoulder.

(g) In the seventh column shall be recorded the distance from the centerline to the slope stake. This distance will be determined as indicated herein before.

(h) In the eight column shall be recorded the allowance for settlement. The percentages of settlement which should be allowed for fills of various heights are shown on FIGURE III-12.

The calculations of the allowance for settlement shall be based upon the fill at the centerline of the project. Allowance for settlement should be figured only to the nearest 0.1 foot.

(i) In the ninth column shall be recorded the fill to the shoulder finishing-grade elevation. This fill shall be determined by adding to the fill for the shoulder plan-grade elevation, as recorded in the sixth column, the allowance for settlement. Where allowance is made for settlement of the embankment, the fill shown in the ninth column shall be the one that is marked on the face of the slope stake. If no settlement is anticipated, the fill shown in the sixth column shall be recorded on the slope stake.

(j) In the tenth column shall be recorded the distance from the centerline to the edge of the shoulder.

(k) In the eleventh column shall be recorded the shoulder-slope ratio. If the shoulder-slope ratio at one location is 3:1 and at the next location is 1½: 1 the shoulder-slope ratio for any intermediate point shall be determined by interpolation. For example, if the distance between the two shoulder slopes mention above is 300 feet, then the slope ratio would be 2 ½: 1 at a point 100 feet from the first station toward the station at which the slope ratio is 1:1 ½.

(1) Where there is a berm to be cut to grade, the berm-grade elevation shall be recorded in the twelfth column.

(m) In the thirteenth column shall be recorded the berm-grade rod, which shall be determined by subtracting the berm-grade elevation from the H.I.

(n) In the fourteenth column shall be recorded the berm cut, which shall be determined by subtracting the actual rod which is recorded in the fifth column from the grade rod as shown in the thirteenth column.

(o) In the fifteenth column shall be recorded the ditch-grade elevation.

(p) In the sixteenth column shall be recorded the ditch-grade rod, which shall be determined by subtracting the ditch-grade elevation from the H.I.

(q) In the seventeenth column shall be recorded the actual rod reading taken at the point on the ground where the ditch-slope stake is set.

(r) In the eighteenth column shall be recorded the cut from the ground, at the point where the slope stake is set to the bottom of the ditch. The distance from the centerline to the slope stake shall also be recorded in this column. The cut shall be recorded above the centerline distance, a horizontal or sloping line being drawn between the two numbers. The cut will be determined by subtracting the actual rod reading from the ditch-grade rod. The distance from the centerline to the cut slope stake will be determined as indicated herein before.

(s) In the nineteenth column shall be recorded the distance from the centerline to the toe of the back slope. This distance will usually be a constant. It shall be computed rather than scaled from the plan cross sections.

(t) In the twentieth column shall be recorded the ditch back-slope ratio. If the back-slope ratio at one location is 2:1 and at the next station 1:1, the back-slope ratio for any intermediate point shall be determined by interpolation. For example, in the case mentioned above the back-slope ratio at a point midway between the two locations would be 1 ½: 1.

(u) In the twenty-first column shall be recorded the centerline finishing-grade elevation.

(v) In the twenty-second column shall be recorded the centerline finishing grade rod. This rod shall be determined by subtracting the centerline finishing-grade elevation from the H.I.

(w) In the twenty-third column shall be recorded the actual rod reading which is taken on top of the grade stake. This rod reading shall be recorded to the nearest 0.01 foot.

(x) In the twenty-fourth column shall be recorded the cut or fill from the top of the grade stake to the centerline finishing-grade elevation. The cut or fill will be equal to the differences

between the actual rod and the centerline finishing-grade rod. The cut or fill shall be marked on the guard stake, which is driven beside the grade stake, only to the nearest 0.1 foot.

(y) A twenty-fifth column may be included as an aid to slope staking if desired. This column labeled "Try" is the distance from the centerline to the slope stake as determined from the cross sections. This distance may be entered when the slope stake book is made up in the

When the construction does not include earthwork compaction, the percent shrinkage as determined by earthwork computations based on end areas obtained by plotting the final cross sections against the construction survey original cross sections is not a true percent shrinkage according to the above definition. It is based on only a partial shrinkage since an indefinite period of time is required for any embankment to obtain its full shrinkage, and the embankment will continue to shrink after the final cross sections have been taken. However, the percent shrinkage as determined by the earthwork computations based on end areas obtained by plotting the final cross sections against the original cross sections is the percent which should be shown on KDOT Form No. 266 in the column labeled "Computed % Shrinkage of Earth".

Settlement - the vertical distance which the surface of the embankment settles, after completion of the construction operations, shall be known as the "settlement" of the fill.

Allowance for Earthwork Shrinkage and Settlement - When preparing plans, the Design Department includes calculated lump sum quantities for initial consolidation and settlement in addition to a Volume Multiplication Factor to be applied to the excavation quantities. This is necessary to balance the earthwork quantities.

These items are defined as follows:

(a) Initial Consolidation: The additional embankment quantity resulting from foundation treatment as shown on the plans and compaction from general limits. This also includes additional quantities resulting from losses in the bottom six inches due to compaction in cuts in soil mantle.

(b) Settlement: The additional embankment quantity resulting from consolidation of soil mantle under embankment sections.

(c) Volume Multiplication Factor: This factor is used on the plans in lieu of a shrinkage and swell factor. The Volume Multiplication Factor is the quantity of embankment which can be constructed from one cubic yard of excavation.

The computation of earthwork quantities is not an exact science. This is due in part to the fact that initial consolidation and settlement can not be measured in the field. However, the combined effect of these three items can be measured by a comparison of the excavation quantities with the embankment quantities as determined from the original final cross sections.

In FIGURE III-12 are shown the allowances which should be made for settlement of fills of various depths, built with various types of equipment, without compaction of the earthwork except that obtained by the hauling equipment.

The allowance for settlement as shown in FIGURE III-12 will not be applicable to all conditions. It is thought that the table should be a helpful guide to the Engineer in determining the amount of settlement which should be allowed for various types of work. The amount which a fill will settle after the construction work has been completed will depend upon the composition of the fill; that is, the type of soil and the percent of rock. Other factors, such as the weather conditions during construction and the speed or expedition with which the work is prosecuted, have important bearings upon the amount which a fill will settle after construction has been completed. These factors cannot be predetermined at the time the slope stakes and grade stakes are set and no allowance can be made for them when estimating the amount of settlement which should be allowed when setting slope and grade stakes. In general, the same allowances for settlement shall be made when setting the finishing stakes as was made when

setting the slope and grade stakes; and such factors as the weather conditions and the speed of construction shall be disregarded throughout.

FIGURE No. III-12
ALLOWANCE FOR SETTLEMENT OF EARTHWORK
(Without Compaction)

Type of Work	Depth of Fill	Allowance of Settlement
Casting	0'-1'	0.00
	1'-2'	0.2'
	Over 2'	10%
Hauling	0'-1'	0.00
	1'-10'	5%
	Over 10'	0.5'

On sections where compaction of earthwork is specified, the stakes shall be set to plan-grade elevation. The Engineer shall require the finish grade to conform to the stakes as set.

When compaction of earthwork is not specified, fills containing a large percent of rock, for instance, from 25 percent to 50 percent, will probably settle more than fills which do not contain rock. Fills, however, which contain as much as 75 percent rock will probably settle very little. It is suggested that no allowance for settlement be made in cases where a fill contains as much as 75 percent rock.

Swell of Rock - It is obvious that in case a balance contains rock as well as common excavation, either the (percent shrinkage) for earth or the volume Multiplication Factor (percent swell) for rock must be known or assumed before the other can be computed. In such a case the percent shrinkage for earth may be assumed to be the same as the percent shrinkage for earth in an adjacent or nearby balance which contained no rock excavation, or it may be assumed to be equal to the average percent shrinkage for two adjacent balances or several nearby balances which contain no rock excavation. After the percent shrinkage of earth has been determined the volumes of earth and rock in the fill can be determined.

Completed earthwork quantities are shown on both the plan-profile and the summary of quantity sheet.

The following example indicates a minimal type listing of balance notes and information on plan-profile sheets and earthwork tabulations on summary of quantity sheets. Also shown is a basic example of a computer printout of end areas and accumulated quantities which may be included in the plans. See FIGURE III-13A & III-13B.

CHANGE AT STA. 465+00 VOLUME MULTIPLICATION FACTOR 'MANTLE' 0.8
MODIFY VOLUMES AT STA. 469+25 'FILL' 1000 $ SETTLEMENT FROM STA. 465+00 TO STA. 470+00
MODIFY VOLUMES AT STA. 469+50 'FILL' 1000 $ INITIAL CONSOLIDATION FROM STA. 465+00 TO STA. 470+00
MODIFY VOLUMES AT STA. 469+75 'FILL' 1000 $ SELECT SOIL FROM STA. 465+00 TO STA. 470+00
FORCE SUMMARY STA. 470+00

BASELINE STA.	MATERIAL NAME	END AREAS	—UNADJUSTED VOLUMES— INCR	FROM BAL	ACCUM	MULT FACTOR	—ADJUSTED VOLUMES— INCR	FROM BAL	ACCUM
465+00	CHG IN MULT FACT								
	FILL	305	0	0	0	1.000	0	0	0
	MANTLE	329	0	0	0	0.800	0	0	0
	ARGT1LSR	400	0	0	0	1.400	0	0	0
469+00	FILL	919	9067	9067	9067	1.000	9067	9067	9067
	MANTLE	72	2970	2970	2970	0.800	2376	2376	2376
	ARGT1LSR	100	3704	3704	3704	1.400	5186	5182	5186
469+25	MODIFY VOLUMES								
	FILL	841	1815	10822	10822	1.000	1815	10882	10882
	MANTLE	124	91	3061	3061	0.800	73	2449	2449
	ARGT1LSR	0	46	3750	3750	1.400	64	5250	5250
469+50	MODIFY VOLUMES								
	FILL	763	1743	12625	12625	1.000	1743	12625	12625
	MANTLE	176	139	3200	3200	0.800	111	2560	2560
469+75	MODIFY VOLUMES								
	FILL	685	1670	14295	14295	1.000	1670	14295	14295
	MANTLE	229	187	3387	3387	0.800	150	2710	2710
470+00	FILL	607	598	14893	14893	1.000	598	14893	14893
	MANTLE	281	236	3623	3623	0.800	189	2899	2899
470+00	FORCED SUMMARY								
	FILL		598	14893	14893	1.000	598	14893	14893
	MANTLE		236	3623	3623	0.800	189	2899	2899
	ARGT1LSR			3750	3750	1.400		5250	5250
	BORROW				8430	0.800		6744	

14,893	Total Emb.
-2,000	Initial Const. & Settlement
12,893	
-1,000	Select Soil
11,893	Plan Quantity

FIGURE No. III-13A
END AREA QUANTITIES

EXAMPLE OF CURRENT METHOD OF SHOWING EARTHWORK BALANCE ON PLAN–PROFILE SHEET AND SUMMARY OF QUANTITIES

* 2 583 cu.m. Common Excavation (V.M.F. = 0.8)
** 5 083 cu.m. Common Excavation - Contractor Furnished (V.M.F. = 0.8)
371 cu.m. Rock Excavation (Pavement Removal)
• 6 132 cu.m. Embankment
* Includes 380 cu.m. Com. Exc. (Bridge & Channel)
* Includes 338 cu.m. Com. Exc. (Side Road Sta 6+297.92)
** Includes 970 cu.m. Com. Exc. Contractor Furnished (Side Road Sta 6+297.92)
• Includes 1 308 cu.m. Embankment (Side Road Sta 6+297.92)

EARTHWORK

Sta	to Sta.	Excavation Common CU. m.	Excavation Common Mull Fac	Excavation Rock CU. m.	Excavation Rock Mull Fac	Compaction Cu. m TYPE AA MR-B	Compaction Cu. m TYPE B MR-B		Thru Cuts Not Subgraded Com. Exc. CU. m.	Thru Cuts Not Subgraded Type AA CU. m.	Embankment ※ Cu. m. Initial Consol.	Embankment ※ Cu. m. Settlement	† Placing Select Soil Cu. m.
46+500	47+000	12,053	0.8	3,750	1.4	2,222	9,671		600	900	1,000	1,000	1,000
Totals		12,053		3,750		2,222	9,671		600	900			1,000

※ Subsidiary (See General Note) † See General Note

FIGURE No. III-13B
EARTHWORK TABULATIONS

3.09 FINISHING STAKES

3.09.01 FINISHING STAKES

The Engineer shall set finishing stakes on all work which has been graded to a reasonable conformity with the plans. The number of finishing stakes required will depend on the type of finishing equipment to be used by the contractor. The use of automatic equipment operating off of a string line will require considerably less stakes than conventional blade finishing. The Engineer should insist that the Contractor keep his work finished as close as possible to the rough grading. If a section of road is finished to the satisfaction of the Area Construction Engineer and District Engineer, it may be accepted and taken over for maintenance by the State.

Finishing stakes shall be set for both line and grade. They may be set on both shoulder lines and driven to shoulder finish grade elevation. The roadbed in both cut and fill shall be finished as indicated by the plan cross sections. The finished roadbed shall conform with the line of the finishing stakes as well as to the elevations of the tops of the stakes. At least one set of finishing stakes should be set over the entire length of each grading project.

No stakes should be set until the Grade Inspector has checked the grade, checked the roadbed for width, and inspected the shoulder for alignment and slope. In other words, the Engineer should obtain a fair job of rough grading before setting the finishing stakes. If this is done, one set of finishing stakes will probably be sufficient to obtain a good finished roadway. When necessary, however, two or more sets of finishing stakes may be set over the entire project or portions of the project. The cost for extra staking necessitated by carelessness or gross lack of skill on the part of the finishing crew may be charged to the Contractor when in the opinion of the Area Construction Engineer and District Engineer such action is justified.

Bridge-approach fills shall be finished to plan-grade elevation near the ends of the bridge. The grade approaching the bridge should start at a sufficient distance from the end of the bridge wearing surface to produce a smooth-riding approach.

Finishing stakes may be set at 100 feet intervals on tangents, flat vertical curves, and horizontal curves with a radius longer than 750 feet. They may be set every 50 feet intervals on sharp vertical curves and on horizontal curves with a radius of 750 feet or less. Finishing stakes may also be set opposite the P.T. and P.C. of horizontal curves, at all points where the width of the roadbed changes, at all points where superelevation begins and ends, at all points where maximum superelevation begins and ends, and at the P.C. and P.T. of sharp vertical curves.

The shoulder finishing-grade elevation to which the finishing stakes shall be driven, shall be calculated to the nearest 0.01 foot. Finishing stakes shall be driven to within 0.02 foot of the finishing-grade elevation.

On tangents, one shoulder line may be established with the surveying instrument and chain setting a Type “C” stake each station or at breaks in shoulder grade or alignment. The opposite shoulder line may be offset from the line of stakes established with the surveying instrument. The normal line may be established by eye or by placing the stakes on a line between the right-of-way stakes.

On curves, the centerline shall be reestablished with the surveying instrument and chain before the shoulder stakes are set. After the centerline has been established, the finishing stakes shall be offset onto the shoulder lines, the normal or radial directions being estimated by eye. Where a short-radius horizontal curve is on a steep grade, however, it may be advisable to offset the shoulder-finishing stakes more accurately. When this is thought necessary, the stakes may be offset on the shoulder lines in a manner similar to that explained in a previous article. When the finishing stakes have been set, they shall be driven to grade.

3.09.02 FINISHING STAKE NOTES

The current field book now printed for blue top staking or finish staking is designated DOT Field Book No. 4.

The four-lane highway type of construction has brought about the needs for a field book that will enable the note keeper to set seven or more finishing stakes across the road bed at any one point.

The peg-leveling notes by which the height of instrument is kept, shall be recorded in the single-depth horizontal tiers which are located between the double-depth station tiers. The bench-mark number or the turning-point designation, the plus sight, the H.I., the minus sight, the elevation of the bench mark or turning point as determined by these peg-leveling notes, and the correct or adjusted bench-mark elevation shall be recorded in the vertical columns so labeled at the bottom of the form. The column headings at the top of the form refer only to the rectangular spaces formed by the intersection of the columns with the double-depth station tiers, while the column labels at the bottom of the form refer only to the rectangular spaces formed by the intersection of the columns with the single depth tiers.

Each point to be graded will require the use of both decks of the double-deck rectangular blocks. The distance from the alignment control will be entered in the upper left block, the finish elevation grade is placed in the upper right block, and finally the grade rod is entered in the lower right block as it is computed in the field.

On single lane roadbeds, the centerline column and adjoining left and right columns may be used as required. Some columns may not be needed, as the stationing will be carried in the left column in all cases.

The item "Theo. Rod" is the actual grade rod required to place the finishing stake at the elevation shown. This reading is determined in the field by subtracting the elevation of the finished grade from the elevation of the instrument or H.I.

Finishing stakes should be set to the nearest 0.02 foot and all notes recorded to the nearest 0.01 foot.

Finishing grade stakes are normally Type "C" stakes with the tops colored blue; however other types of stakes may be used if the condition warrants. The color coding blue is universally known and accepted as a finish grade. Do not abuse this traditional acceptance by using the color blue on stakes or by using stakes that have been marked with blue tops for other staking.

If at some particular point, it is impossible to drive the finishing stake to the finishing-grade elevation, the amount of cut or fill from the top of the stake to the shoulder finishing-grade elevation shall be indicated on the front side of the stake. Finishing stakes should not be set until the roadbed has been brought so nearly to finish-grade that most of the stakes can be set to finishing-grade elevation. There will be an occasional stake, however, on which cut or fill must be indicated. When this is necessary, the top of the stakes shall not be blued, and the stakes should be driven solid with the cut or fill necessary written on the stakes.

A wooden stake driven to grade and blue topped for identification is of the utmost value to the KDOT and the Contractor. It should be driven to grade true and plumb. Only a soundly placed stake that retains a solid top will render its intended purpose.

FIGURE No. III-14 may be reviewed to show one type of four lane construction that has been blue-topped for finishing.

3.09.03 OFFICE PREPARATION OF NOTES

The finish grade staking notes may be partially completed prior to going to the field. The station, the distance the stake will be set from the alignment control and the relative elevation of each stake will be taken from the plans.

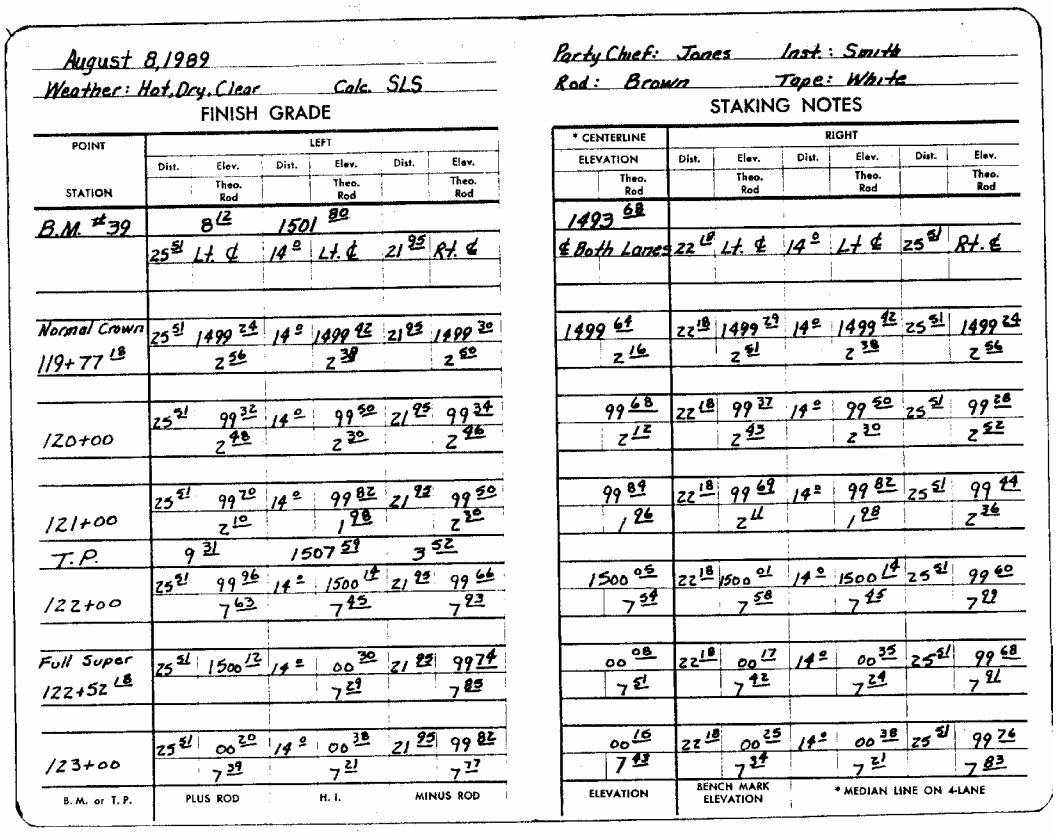
The grade rod of theoretical rod reading can be computed only after the instrument is set up and the H.I. determined.

3.10 FINAL CROSS SECTIONS AND COMPUTATIONS

3.10.01 GENERAL

When Plan Quantities are accepted by both the Engineer and the Contractor as the basis of final payment, no final cross sections will be required. However, if the plans have been altered or when disagreement exists between the Contractor and the Engineer as to the accuracy of the plan quantities in any balance or the entire project, either party shall have the right to request and cause the quantities to be measured in accordance with measured quantities. When quantities are to be measured, final cross sections shall be taken after the grading work has been completed. The actual volume as determined from the original and final cross sections shall be computed and used as the basis for final payment.

FIGURE No. III-14
FINISH GRADE STAKING NOTES



3.10.02 FIELD NOTES

In order to reduce the work load in the field, the Bureau of Design (Contract section and/or photogrammetry section) has developed a program for calculating earthwork quantities by the electronic computer. To facilitate their work and for the purpose of uniformity, all note taking should comply with the following procedures for either the computer or field calculations.

It is important where the notes are to be sent to another office for processing, such as when they are sent to the Bureau of Design, that the procedures suggested below are followed. It is particularly important that the cross section notes be neat and in order.

Advise the Bureau of Design as soon as possible of your intention to send in the final cross section notes. If they know the quantities have to be computed, preparatory work of punching originals may be completed prior to receipt of the final notes. This advance knowledge will enable the entire process to be speeded up, and result ultimately in a quicker payment of the final voucher.

Record all notes on loose leaf paper. Write large and clear. Leave ample space between rod shots and sections.

Record the complete H.I. elevation on each turn as 1225.10 instead of just 25.10.

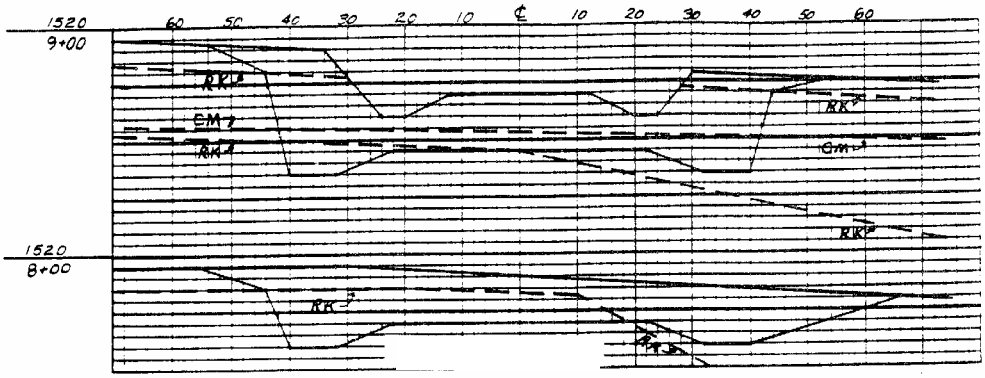
If there is a deviation from standard field note practice, indicate left and right for that section when facing in the direction of increasing stationing. When a station is recorded in reverse it should be marked as “Reverse Section”. These notations should be made, whenever a deviation occurs, on all sections whether they be originals or finals.

There must be a final section for all 0.0 subgrade-and 0.00 rock sections. If rock layers exist and the 0.0 section left is different than the 0.0 section right, a final section must be taken at each location.

The procedure just described, is contrary to how this problem would be handled in the field. It is necessary to have the final section, since the computer is carrying two sets of figures, a common quantity and a classified quantity.

Originals must be available for all final stations. The computer can make straight line interpolations between stations to provide the extra originals needed. If there is ever a case when this type of interpolation is incorrect, the additional originals needed must accompany the final notes.

FIGURE No. III - 15
LAYER CROSS SECTIONS



The Finals for these sections would be recorded as follows:

FINAL SECTIONS

Sta	H.I														
8+00	1520.00	OG 50	TR 6° 24	16° 40	16° 32	12° 22	12° ℄	12° 22	16° 32	16° 40	OG 60				
9+00	1520.00	OG 54	TR 8° 24	BR 18° 42	TR 20° 47	26° 40	26° 32	20° 22	20° ℄	20° 22	25° 32	25° 40	BR 20° 22	TR 12° 44	

In addition to the final section, the layer sections must be recorded separately beginning with the lowest layer and working up as follows:

(℄ must be indicated but no rod is needed unless the layer breaks at that point.)

LAYER SECTIONS

Sta	H.I.	Label													
8+00	1520.00	RK						6° 44	6° 20	℄	8° 10	12° 15			
9+00	1520.00	RK						20° 47		27° ℄		26° 18			
9+00	1520.00	CM						18° 42		℄		20° 42			
9+00	1520.00	RK	8° 24	9° 30	16° 24	15° 20	16° 12	℄	14° 10	15° 15	15° 24	11° 25	13° 22		

If rock is involved on the project, follow the directions for recording rock layers shown in this section. In the illustration (FIGURE III-15) both stations create a problem because the rock information taken with the final cross section is not complete enough to calculate the rock. Station 8+00 shows one rock shot in the left backslope, but it cannot be determined where it goes from there. At station 9+00, incomplete information exists for the first rock layer on the right side, but seems to be all right otherwise. However, the top rock layer, if connected from TR to TR, would slice across the old roadbed and would give an additional rock volume of that amount. The rock information must be separated and recorded by itself, as shown, to enable the Computer Section to determine the correct quantity. The illustration shows rod and distance, but elevations and distance may also be used as long as the complete elevation is shown. These rock layer s must also be in from the field even if photogrammetry is being used to determine the final cross sections.

If the rock was bid the same as common, or for any reason it is desired not to calculate the rock, advise the Computer Section when the finals are sent in that an over-all quantity computation is all that is needed.

Be sure to have layer sections recorded as above for all sections that require them. Follow the Construction Manual procedure for the taking of original cross sections prior to construction in order to have original sections for all final sections needed. Interpolate all originals needed that were not taken prior to construction.

In order to compute the Rock and Common quantities accurately, we must have an

original section and a final section wherever you wish to have the rock zero out on one side or the other or on both sides at once. This applies to the beginning and ending of subgrade sections. Where rock excavation is anticipated, both original and final cross sections should be taken at intervals of 50 feet or less, in order to insure a more reliable determination of the quantities. This will normally give sections close enough to use as zero rock sections.

Be sure to have layer sections recorded for all sections that require them. Follow the procedure in Section 3.06 for taking original cross sections prior to construction.

It is necessary to take a section at all equations. Note, along with the section, the equation as it appears on the plans, such as: Station 238+00 = 95+66

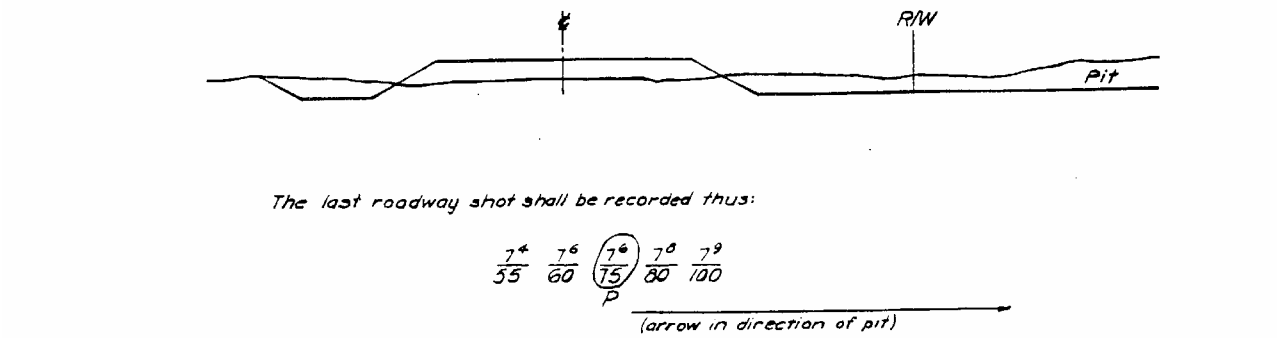
A copy of the original cross section notes may be requested from the Design Department to use as a guide for matching finals and for making sure prior to construction whether extended originals must be taken. If original cross sections are determined by photogrammetry, computer cross section listing's show all information taken on each section and are available upon request. On the computer slope stake listing, if the cross section had to be extended on the slope of the last two original ground shots in order to find the slope stake intercept, an E shows next to the slope stake distance that fell outside the originals. Extended originals should be taken at these places and the slope stakes recalculated in order to be more correct. New original cross sections are needed frequently, especially on interstate type facilities and on interchanges. New originals must be taken on ramps and loops if their stationing is going to be used for computing final quantities. There may be cross sections shown in the plans for the relocated side roads, ramps, loops, channels, and frontage roads, but this does not mean actual originals exist in many cases. Be particularly dubious of new work that is separated from the actual project roadway like ramps or frontage roads that are separated from the new roadway by the two existing lanes. Actual originals are seldom available on the separated new work. This condition frequently occurs where four lanes are being created by adding two lanes to the existing lanes.

Label and group the notes so all original and final notes for the roadway are grouped together, all side roads labeled and grouped, all borrow area information, all channel information, rock layer information, etc. Each group should be in the natural sequence of stationing as they appear on the plans. Split H.I. sections or extensions should indicate where to find the rest of that section. Each pit location, side road, etc., should be clearly referenced to the roadway stationing.

Each beginning and ending rod shot of a final section is treated by the Computer Section as original ground at 0.1 foot further out. Original ground may also be indicated by O.G. and distance and will be tied to the original ground at that distance. Original ground may be used within a section as long as an ending O.G. and beginning O.G. are indicated next to each other. If these are left and right of centerline, the centerline must be shown between them without a rod shot. The centerline indication is the only thing that can be between the intermediate original ground shots.

If the pits, side roads, and incidentals other than roadway do not amount to much, the Computer Section can generally return the roadway computations by the time the rest is calculated in the field. In some cases, such as bridge headers, a portion of the roadway may be calculated by field forces. In such instances when the first and last station of the omission is not a 0.0 section, mark these stations as vertical sections. If a borrow pit parallels the roadway and the pit sections are taken as a continuation of the roadway section, a rod shot must be recorded and circled at the R/W line where the roadway and pit join. Show a "P" under the distance and an arrow in the direction of the pit as shown in the illustration in FIGURE III-16.

FIGURE No. III – 16
BORROW PIT



In the letter of transmittal that accompanies the cross section notes indicate which sections are to be computed in the field.

Plan carefully how the final section on interchanges are to be handled. Make a thorough study of the interchange, and the original sections that cover the area where it is to be located. Often interchanges lack coverage as well as for needing additional sections. In many cases, it will save much time and trouble if new originals, taken through interchanges wide enough and at the correct stationing, will be available for the finals. The only criterion is to determine the cut-off limits and carry all sections out to those limits. These cut-off limits could be laid out in the field with the use of a surveying instrument and lime lining machine similar to that used on baseball diamonds and football fields.

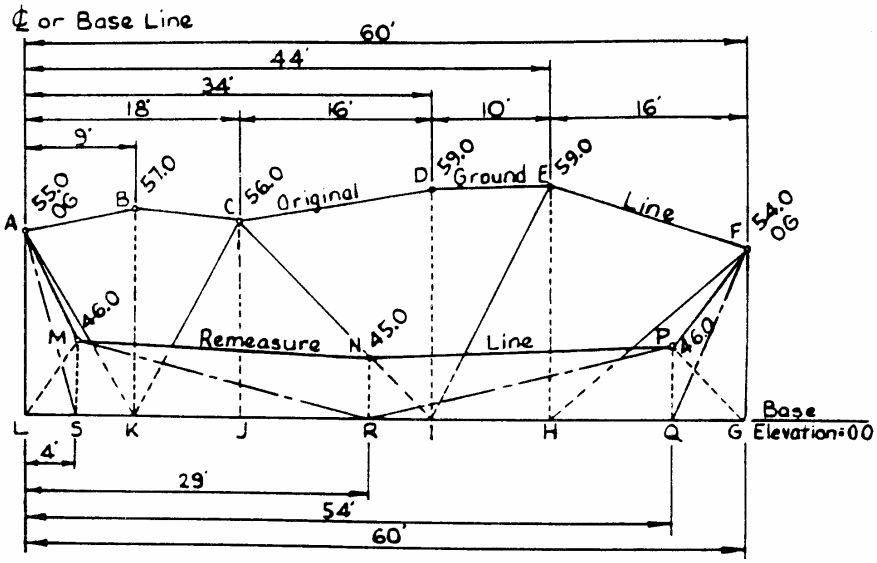
This method is suggested because design originals are taken from centerline of project and at right angles.

3.10.03 DETERMINATION OF END AREAS

After the cross sections have been plotted, it is necessary to determine the end area in square feet of the excavation and/or the embankment shown on the cross section. This measurement is accomplished by a method ordinarily referred to as "stripping". In stripping, the area to be measured is divided into trapezoids having uniform bases, usually one to five scaled feet depending on the size of the area. The midordinate of the trapezoids are then measured by the use of a piece of paper, generally a section of adding machine paper. The edge of the paper is laid along the mid-ordinate of the trapezoid and a pencil mark made at each end of the ordinate. By using the end mark of the previous mid-ordinate as the beginning of next measurement, as accumulative total measurement is determined by laying the strip of paper on the cross section paper in the same direction the ordinates were measured and then reading the total scaled length. This length multiplied by the uniform base gives the area of total figure. Each area should be checked by a second person, and while the determined areas will not be exactly the same, they should be within reasonable tolerance. When two determinations are within tolerance, they should be averaged to obtain the final end area for the section.

An alternate method for determining the end area is the Crisscross Methods For Determining The Area of Any Prism as detailed in FIGURE No. III-17.

FIGURE No. III-17
CRISSCROSS METHODS FOR DETERMINING THE AREA OF ANY PRISM



The above figure may represent a cross section of a roadway, a cross section of a borrow area or a prism on an horizontal plane in each case the area of the prism being desired. It has been divided into triangles in order to explain the procedure in the method of computation. There are two methods that can be used: one, by computing gross area from common ordinates and abscissas and deducting areas outside the area being measured; the other, by a rotating calculation around the limits of the area being measured. Both of the following methods are predicated on the figure shown as being a borrow cross section, on which the original ground line and remeasure line are shown by elevations.

Method No. 1: In this problem the ordinate lies through one extreme point of the borrow section, A, and the abscissa is a horizontal line, or base elevation, which is common to both the original section and remeasure section. The area of the remeasured prism is subtracted from the area of the original prism, and would be represented in the field notes in the following manner:

Original Ground

0.0	55.0	57.0	56.0	59.0	59.0	54.0	0.0	Area = 3426.5
0	0	9	18	34	44	60	60	
	1	2	3	4	5	6		

Remeasure

0.0	55.0	46.0	45.0	46.0	54.0	0.0	Area = 2777.0
0	0	4	29	54	60	60	
	7	8	9	10	11		Net Area = 649.5

This can be explained by the following combination of triangles, the net value of which must be divided by 2 since no recognition has been given in the computations to the formula for the area of a triangle or bh/2.

Original Ground

Triangles AKL	No. 1	55.0 x (9- 0)	= 495
Triangles ABK & BCK	2	57.0 x (18- 0)	= 1026
Triangles KCJ & JCI	3	56.0 x (34- 9)	= 1400
Triangles CDI & DEI	4	59.0 x (44- 18)	= 1534
Triangles IEH & EHF	5	59.0 x (60- 34)	= 1534
Triangles HFG	6	54.0 x (60- 44)	= 864
		Total	= 6853

6853.0 / 2= 3426.5 Area in Sq. Ft.

Remeasure

Triangles AML	No. 7	55.0 x (4- 0)	= 220
Triangles LMS & SMR	8	46.0 x (29- 0)	= 1334
Triangles MNR & RNP	9	45.0 x (54- 4)	= 2250
Triangles RPQ & PQG	10	46.0 x (60- 29)	= 1426
Triangles GPF	11	54.0 x (60- 54)	= 324
		Total	= 5554

554.0 / 2= 2777.0 Area in Sq. Ft.

Net Area = 649.5 Sq. Ft.

As illustrated, the area of the prism bounded by the original ground, the two extreme ordinates and the base elevation or abscissa is computed from which is deducted the prism bounded by the remeasure line, the two extreme ordinates and the base elevation. In order to include all of the area in each case, the horizontal distance from the extreme elevation to the base elevation, or zero, must be indicated. In the field notes above, this is represented by $\frac{0.0}{0}$ and $\frac{0.0.}{60}$

The ordinates and abscissas may be located in any convenient position as long as all elevations or distances are normal to them.

This method may also be used for computing volumes of borrow pits; first by computing the volume above an assumed plane; and later by computing and subtracting the remeasured volume above that plane. By computing volumes in this manner, it is not mandatory that intermediate points of remeasure be taken at the same points or sections as the originals.

In the use of this method it is necessary to remember that the extremities of a plane figure or the horizontal boundaries of a borrow pit must be identical, both for the original measure and for the remeasure, interpolation in some instances being required.

Method No. 2: The ordinate and abscissa may be established the same as for Method 1. In this method, however, the original and remeasure elevations are combined into a single step in the determination of the area. The extremities of the section may have to be interpolated if original ground elevations were not taken at those points. Field notes would be recorded as follows for this method:

Original Ground	55.0	57.0	56.0	59.0	59.0	54.0
	0	9	18	34	44	60
	9	1	2	3	4	5

Remeasure	46.0	45.0	46.0
	4	29	54
	8	7	6

This is explained by the following combination of triangles, the net value of which must be divided by 2, as explained in method 1.

Triangles ABK & BCK	No. 1	57.0 x (18- 0)	(plus)	= +1026.0
Triangles KCJ & CJI	2	56.0 x (34- 9)	(plus)	= +1400.0
Triangles CDI & DEI	3	59.0 x (44- 18)	(plus)	= +1543.0
Triangles IEH & EFH	4	59.0 x (60- 34)	(plus)	= +1543.0
Triangles HFQ	5	54.0 x (54- 44)	(plus)	= +540.0
Triangles QPF & RPQ	6	46.0 x (60- 29)	(Minus)	= -1426.0
Triangles MNR & RNP	7	45.0 x (54- 4)	(Minus)	= -2250.0
Triangles SMR & AMS	8	46.0 x (29- 0)	(Minus)	= -1334.0
Triangles AKS	9	55.0 x (9- 4)	(Plus)	= +275.0
			Total	= 1299

1299.0 / 2 = 649.5 Area in Sq. Ft.

In computing the area of a prism by this method, the following rules should be observed:

1. Be sure to supply the original ground readings at the outer terminals of the original elevations and rule out any other original elevations beyond these outer terminals.
2. Record all of the remeasure elevations inside of the outer terminal points directly below the original elevations.
3. Go entirely around the section to form a complete closure; that is, use every elevation in the complete section as a base for the computation of the triangles once, and only once.
4. When the base line, or centerline, lies at or outside of an outer terminal point, begin the computations at the point of least recorded distance. Proceed in the direction the distances are increasing and go completely around the section in that direction. As the distances are increasingly larger, the product of the base and altitudes will be additive, and when the distances are decreasing, that product will be subtractive.
5. When the baseline, or centerline, lies within the area involved, commence at the centerline elevation of the original elevations which will be additive, proceed in one direction from centerline and around the section in that direction until the centerline distance on the remeasure elevations has been reached. Continue the computations from the centerline of the original elevations in the other direction and around the side of the section until the remeasure centerline has been reached. Complete the closure of the section across centerline of the remeasure elevation, which is a subtractive computation. Excepting for the first computation across centerline of the original elevations, and the closing computation across the remeasure centerline, the rule in each direction from the starting point remains the same, that is, when the distances are increasing, the product of the base and altitudes will be additive, and when the distances are decreasing, that product will be subtractive.

3.10.04 COMPUTATIONS

Earthwork computations will be made on KDOT Form No. 101. In case rock excavation is encountered, a separate sheet will be used to compute rock quantities. These computations shall be made in the same manner as those for earth excavation. The volume of each class of excavation shall be determined for each balance. The station limits of balances shall be the same as those shown on the plans or change in plans. All computations shall be carefully checked before attempting to balance the quantities.

The earthwork computation sheets shall be accompanied by Recapitulation of Earthwork Quantities, KDOT Form No. 266. Individual quantities or excavation, embankment and compaction shall be listed separately under the proper column on the face of the form. Each entry should reflect the quantity of each item which enters into the total for the balance and should be described as pit, channel, roadway, side roads, entrances, etc., and show the stationing involved. One line shall be used for each separate pit, channel, entrance, side road, or the roadway as it appears on KDOT Form No. 101. The various entries so itemized shall be totaled to reflect the balance totals.

The last column of this form is reserved for remarks. Any necessary remarks or explanation concerning the totals for a balance should be recorded in this column. In case a particular balance shows an abnormal shrinkage of earth or swell of rock, the Engineer should again check the computations and correct any errors that may have been made. If after checking the computations the percent shrinkage or swell is unreasonably high or low, the Engineer should record in the remarks column any known information which might explain the apparent irregularity. In the ninth column should also be indicated the volume of rock which was taken from stone fences and placed in the fill, the quantity of wasted material, etc.

In case the final quantities for a particular balance do not check reasonably close with the plan quantities the Engineer should record in the remarks column any known information which might explain the underrun or overrun.

After final cross sections have been plotted and checked, they should be compared with the slope-stake notes to determine whether the finish lines conform to those lines indicated by the construction stakes. In cases where it is evident that the Contractor has gone beyond reasonable construction limits in the excavation or embankment sections, the excess quantities shall be computed and deducted from final pay quantities.

On all Federal Aid projects, except County Secondary projects, it is necessary to prepare a Summary of Borrow Areas (KDOT Form No. 471) showing the location of the State owned borrow areas, plan volume shown to come from the areas, adjusted quantity (if appropriate) and the actual volume excavated.

Form No. 471 is to be submitted with the Final Papers for the project. The form is to notify Fiscal Management of the volume removed from the borrow areas. This information is used for billing the Federal Highway Administration for a proportionate share of the borrow cost. See the Form Manual for instructions on preparing the form.

3.11 MISCELLANEOUS NOTES AND STAKING

3.11.01 STAKES FOR GUARD FENCE AND GUIDEPOSTS

On horizontal curves a tacked line stake should be set a uniform and convenient distance inside of each point at which a guidepost or guard fence post is to be placed. When the guard fence or guide posts are to be installed on an alignment tangent, tacked line stakes shall be set at intervals of not more than 50 feet. Since the posts often vary in depth, the inside face of the post should be set an even distance from the tack point. Setting the posts in this manner will insure a straight or uniformly curved line on the inside face of the guard fence, any irregularity in the

depth of the posts being thrown to the outside face of the fence.

Guard fence at the ends of bridges shall be constructed as nearly as possible in conformity with the prevailing plans.

Type "B" stakes should be used for line stakes.

On curves, the guideposts on the inside, or intrados shoulder, shall be set slightly less than the designated intervals and those on the outside, or extrados shoulder, shall be set at slightly greater than the designated intervals, so that the intrados post and the extrados post at a given station or plus station will both be on the radial line passing through the centerline point. Stakes on curves shall be offset in this manner even though guideposts are to be set on only one side.

On all vertical and horizontal curves, a Type "C" stake should be set to grade for each post. When the location of the proposed guard fence or guideposts is on a grade tangent as well as an alignment tangent it will be sufficient to set a grade stake beside each alignment stake which may be at intervals of not more than 50 feet. The grade stake should be set so that the top is 24 inches below the elevation to which the top of the guidepost is to be set, or in other words, 6 inches above the shoulder finishing grade elevation and shall be set so that the top is of a uniform determined distance below the bolt hole in the guard fence posts. On projects where the driving of stakes is not possible, such as a project with stabilized shoulders, a concrete nail may be driven into the roadway surface for alignment. The top of the nail may be graded, and the fill to a predetermined point on the post may be written on a guide stake or on the shoulder material itself if practicable.

No stakes shall be set for guard fence or guideposts until the roadbed and shoulders have been satisfactorily finished to the grade line and slope indicated by the finishing stakes and slope stakes.

Field notes for guard fence and guideposts stakes should be kept in the field book set aside for miscellaneous field notes. The alignment notes for a particular section of guard fence or guideposts should immediately precede the grade-stake notes. Notes should be prepared as completely as possible before going to the field.

3.11.02 RIGHT-OF-WAY MONUMENTS

Right-of-Way Monuments shall be set on the right-of-way lines at all deflections in alignment, including each P.C., P.T., and P.C.C. on horizontal curves, at all points where the width of right-of-way changes, and at points not greater than one quarter mile apart where the right-of-way line is straight or on a continuous horizontal curve of constant radius.

The locations of all right-of-way monuments shall be indicated on the Completed-Construction Plans. No right-of-way monuments shall be set on County Secondary Projects.

See Standard Specification and Special Provisions for Contractor Construction Staking for more information on Right-Of-Way Monuments.

3.12 HORIZONTAL AND VERTICAL CONTROL FOR CONSTRUCTION PROJECTS

When you are first assigned a project and receive a set of plans, you should research them for the name of surveyor and the Design Squad Chief, whether he is one of our own KDOT staff or those of a consulting engineering firm.

Check the title sheet or the first and last plan and profile sheets for coordinates. These may be state plane coordinates, Lambert adjusted coordinates, or may be just project coordinates. Whichever they might be, it will be an indication they have used coordinates to design the project. Therefore, the coordinates for all centerline control points, baseline points, section line

points, R/W points, horizontal control monuments, (if any were set by the original survey crew) are available through the Bureau of Design.

Check your plans to see if the original survey crew set any permanent control monuments. If they were set by KDOT crews, they will probably show on plans as a standard KDOT disk set in concrete and stamped with letters and numbers such as HCP-JO 202, etc. If set by a consulting firm, they may be stamped with the firms initials and a set of numbers such as T3, T4, T5, etc. If any of these monuments exist, you will know you have a controlled survey and you can proceed accordingly.

If the project was designed by KDOT, you should request the coordinate data from the squad leader shown on the plans in either the road design section or the bridge design section of the Bureau of Design.

If the project was designed by a consulting engineering firm, you should request the coordinate data from the squad leader in charge in the Consulting Services section of the Bureau of Design.

If permanent monuments exist, you may find that they have been set a mile or more apart as they were only set as needed to gather information to design plans for the project. You will need to set additional monuments for construction layout and permanent R/W points. In some cases, you may find the actual centerline of project or portions thereof may never have been laid out on the ground. All information for the plans may have been taken from an offset baseline or from the horizontal control traverse line. In a case such as this you find there are no control points within 1/2 mile of each other, you are to contact the Land Survey Engineering Coordinator, in the Survey Section of the Bureau of Engineering Support, and he will send out a crew to set control points within 1/2 mile or closer.

Before starting to set your construction control monuments, it will be advantageous to review the Design Manual Volume II developed by the Coordinating Section of the Bureau of Design. It has information on horizontal control surveys and monuments.

When selecting locations for your construction control monuments, you will have to visualize what the project will look like at various stages of construction. Keep in mind how high the fills will be, how deep the cuts, keep away from railroad as much as possible. You should try to set enough monuments that when occupying one, you can see two others and be able to reset all centerline and R/W points for that portion of the project. When setting control points, you should keep a record of the location, approximate distance Rt. or Lt. of centerline, approximate station and some short ties to fence corners and a short description of the monument and location.

3.13 SURVEYS FOR BITUMINOUS OVERLAYS AND REFERENCE STRING LINES

The Standard Specifications require that a reference string line be used on some types of bituminous bases and bituminous overlays. The Construction Staker will make the survey required to establish a reference string line.

3.14 FENCING

Generally the right-of-way stakes will be sufficient staking for the construction of fencing when the fence follows the right-of-way line. On locations where the fence does not follow the right of way and is within the right of way, the beginning, all the corners and the ending should be staked as well as alignment stakes every 100 feet or less on the straight runs. Special fencing details should be worked out with the contractor and stakes provided as needed.

3.15 SIGNING AND DELINEATION

On signing projects, it is necessary to establish the centerline stationing as all signs and delineators are located by the stationing.

After the signing plans are received, it will be necessary to set a temporary stake at the location of each sign so that the location may be checked in the field. After the final location has been approved, the center of the posts should be located as shown on the plans. The center points will be destroyed during construction; therefore, temporary nails or stakes should be used on these points. Offset hubs or reference points should be set outside of the construction area to maintain the alignment of the sign. If the final grade has been completed at the sign location, actual field elevations should be taken to determine the footing elevations and the lengths of the posts. Because all elevations are relative to the edge of the pavement, it is not necessary to establish bench marks and carry an H.I. The elevation of the off-set hubs should be determined and the cut or fill to the adjacent footing should be marked on the flat. If the grading or shouldering is not complete these elevations and post lengths may be determined from the typical section. It is generally sufficient to indicate the location of delineators, the elevation is determined from the existing shoulder.

3.16 CONTROL FOR AERIAL PHOTOGRAPHY

On some projects it will expedite the calculation of final payment quantities by requesting the Bureau of Design, Survey Section, to fly the project for final earthwork quantities. From aerial photographs, they can determine the final sections and compute the final excavation and embankment quantities. This aerial survey requires a specific ground control to be placed by a field survey party. The specific details of this control are contained in the Design Manual Volume II. Developed by the Coordinating Section of the Bureau of Design and is available to all engineers. Contact the Bureau of Design, Survey Coordinator, and he will send someone out to advise you on what information and targets are needed. This may save you considerable work in accomplishing aerial control.

3.17 ROADSIDE IMPROVEMENTS

The Construction surveys for roadside improvements are quite varied and each item has to be staked to meet the circumstances. The item of staking should be discussed and agreed upon with the contractor at the pre-construction conference.

3.18 ELECTRIC LIGHTING

The item of construction stakes should be discussed and agreed upon with the contractor at the pre-construction conference.

3.19 EROSION CONTROL

Before staking wash checks or ditch lining, the ditch or channel should be shaped to the dimensions shown on the plans or as revised. The existing ditch or channel should then become the control for both alignment and elevation of the wash checks or ditch lining. The actual location or offset of stakes may be worked out with the Contractor. Generally, one hub offset from each end of the wash check on the highest side with cuts to the flowline will be adequate. The ends and each break in grade or width of ditch lining should be staked with a hub offset on each side and showing a cut and distance to the edge of the liner and a cut and distance to the flowline of the liner. These stakes should not be over 25 feet apart along the length of the lining.

The construction of riprap on berms and slopes may require the setting of blue tops to the

subgrade elevation and later to the finish elevation in order to maintain uniform slopes and transitions. The limits of the riprap may be outlined with reference stakes.

3.20 SEEDING

Generally, the only staking required on a seeding project will be the limits of mulch areas.

3.21 TERRACES

Generally, the only staking required is a stake or plastic flag on a wire placed every 100 feet along the flowline of the proposed terrace. The local Soil Conservation Service office will supply information as to the percent of grade used in terraces in their area and will provide advice as to their location. Terraces are normally used only in borrow pits.

3.22 HIGH WATER MARKS

In the interests of obtaining information and in developing a file of flood marks for use by all interested parties, the Kansas Water Office (KWO) initiated a statewide high water marking program.

The Kansas Department of Transportation has for several reasons agreed to participate in this program. The following is a summary of the procedures to be used in establishing high water marks as recommended by the KWO.

There are at present two types of markings which are acceptable to the KWO. The first is the use of an aluminum disc which is obtainable from the KWO. They are to be nailed to objects preferably two to six feet above the ground. The other type of mark is a painted stripe on concrete, steel or rock ledge. The bottom edge should indicate the high water level. All markings should be placed to protect them from malicious damages. These marks should be set in relatively straight portions of the stream and in areas free of obstructions.

These marks should not be set in areas of high stream velocity, where the body of water is large enough to permit wind waves, and in sites of heavy drift deposits. Also to be avoided are major obstructions, bends in the stream where heavy debris might accumulate, and the upstream and downstream sides of trees, bridges, and other obstructions in the main channel area.

The high water mark may be determined by the remains of seed or mud lines on trees, posts, and other objects; by debris left in the fields or on roadsides and by the testimony of local residents who observed the depth of the water or the extreme edge of the high water. These elevations may be transferred to suitable locations through the careful use of a hand level.

The number of flood marks to be set is up to the discretion of the individual. Usually one good flood mark per mile of stream will be adequate. However, where there is a dam, fill or structure that tends to cause abrupt changes in flood profile, several marks should be set. They might be set at 100, 200, and 300 yards above and below the obstruction. At embankments crossing the valley or where several structures are located in the flood plain, it is desirable to set high water marks of flood which cause flooding of bottomlands even if the flood is lower than others that have been recorded. High water marks of several floods at the same location are very useful for comparative purposes. The desirability of setting the marks on both sides of the stream should also be decided by the individual setting the marks.

FIGURE No. III – 18
KANSAS WATER OFFICE – HIGH WATER MARKS

KANSAS WATER OFFICE
HIGH WATER MARKS

Stream: Little Blue River
County: Washington
Flood date: July 11-14, 1951 Elev. _____
Crest date: July 12, 1951 Hour 10PM
Basis of flood mark: Seed & debris line
Reliability: good X fair _____ poor _____
Source of information: Personal observations; or name and address of Witness.

Legal Description & Location
NE 1/4, Sec. 32, T 2 S, R 5 E
Disc No: 3,725 Rt. bank _____ Lt. bank X
An aluminum disc marks the seed and debris line on the river ward side of an 457 mm elm tree, 1.4 m above ground. The tree is located 100 meter North (upstream) from the centerline of US-36 at the East end of the Little Blue River bridge and 18 m landward from a lone 1 m. Cottonwood tree on the left bank of the river.

Set by: John Brown Date: 7-20-51
Elev. by: _____ Date: _____
B. M.: _____ Elev: _____
Datum: _____
Field Book: _____

Mail the forms to:
Kansas Water Office
109 SW 9th St.
Suite 300
Topeka, Kansas 66612-1249

Copy to:
Kansas Department of Transportation
Bureau of Design
Harrison Center, 700 SW Harrison St.
Topeka, Kansas 66603-3754

Information to be collected: when the marker is set, the date of the flood crest, if known, or the approximate date should be stamped on the disc with a die set or marked on the disc with a sharp edge (month-day-year as mm-dd-yy).

The Kansas Water Office provides a standard form with the aluminum discs which serves as a guide in locating and describing marks left by floods on streams. This form if completed in detail will provide the information by which the level party later can find and identify the high water mark preparatory to determining its elevation. The postcard forms should be filled out with all information possible at the time the markers are installed. It is not necessary to determine the elevations at the time of installation of the markers. Use the previous illustration as an example for completing the forms.

3.23 SURVEYS FOR STRUCTURES

3.23.01 GENERAL

In staking out structures, it is essential that all lines and measurements be absolutely correct. The Engineer should keep in mind a mental picture of the completed structure, and the manner in which it should fit the stream and roadbed. He should use all possible refinements in his work, and thoroughly check his staking. When practicable, another person should check the work in order to avoid any possible errors.

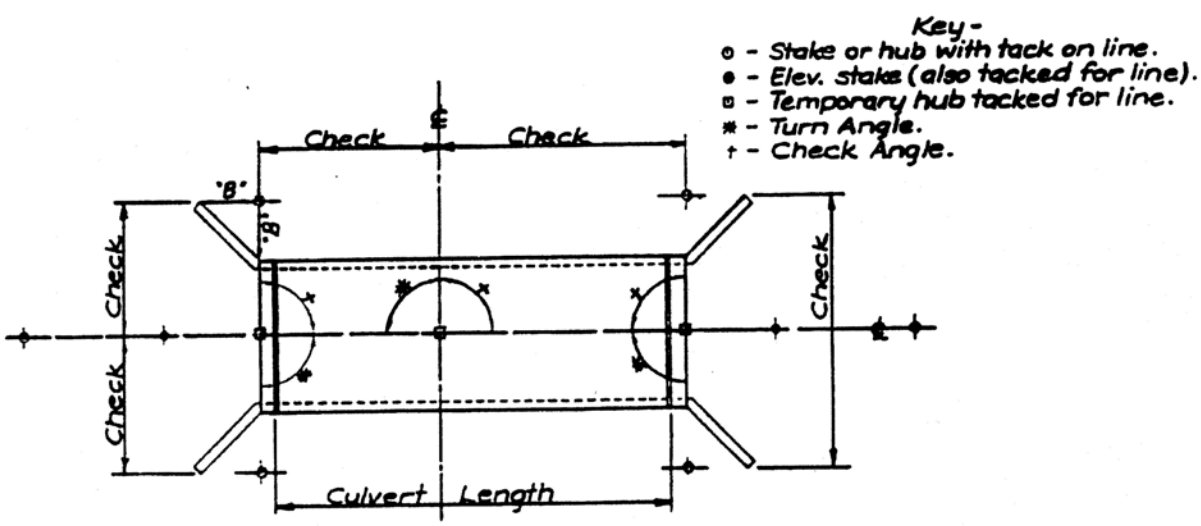
The methods of staking various types of structures are illustrated in the FIGURES III-19 & 20. All possible cases which might arise are not covered in the illustrating figures. The fundamental theory of staking, however, is sufficiently delineated that the Engineer should be able to stake special structures in a manner which will be consistent with the general method illustrated.

It is recommended that, where possible, the entire structure be completely staked out before the contractor starts work. Additionally. it may be required that an independent re-survey be performed by a different "qualified" surveyor to verify critical bridge locations and elevations. See Standard Specifications and Special Provisions for Contractor Construction Staking.

The line on the outside of all culverts and multiple-box bridges should be staked and the stakes should be offset a distance sufficient to clear the excavation.

The system of staking each pier and abutment should be thoroughly explained to the Contractor or his foreman, particular attention being called to the fact that the transverse centerlines of the piers are staked, but that the stakes for the abutments which are usually set on the centerline of bearing may be set on the centerline of piling or centerline of abutment.

FIGURE No. III-19
EXAMPLE-CULVERT STAKING



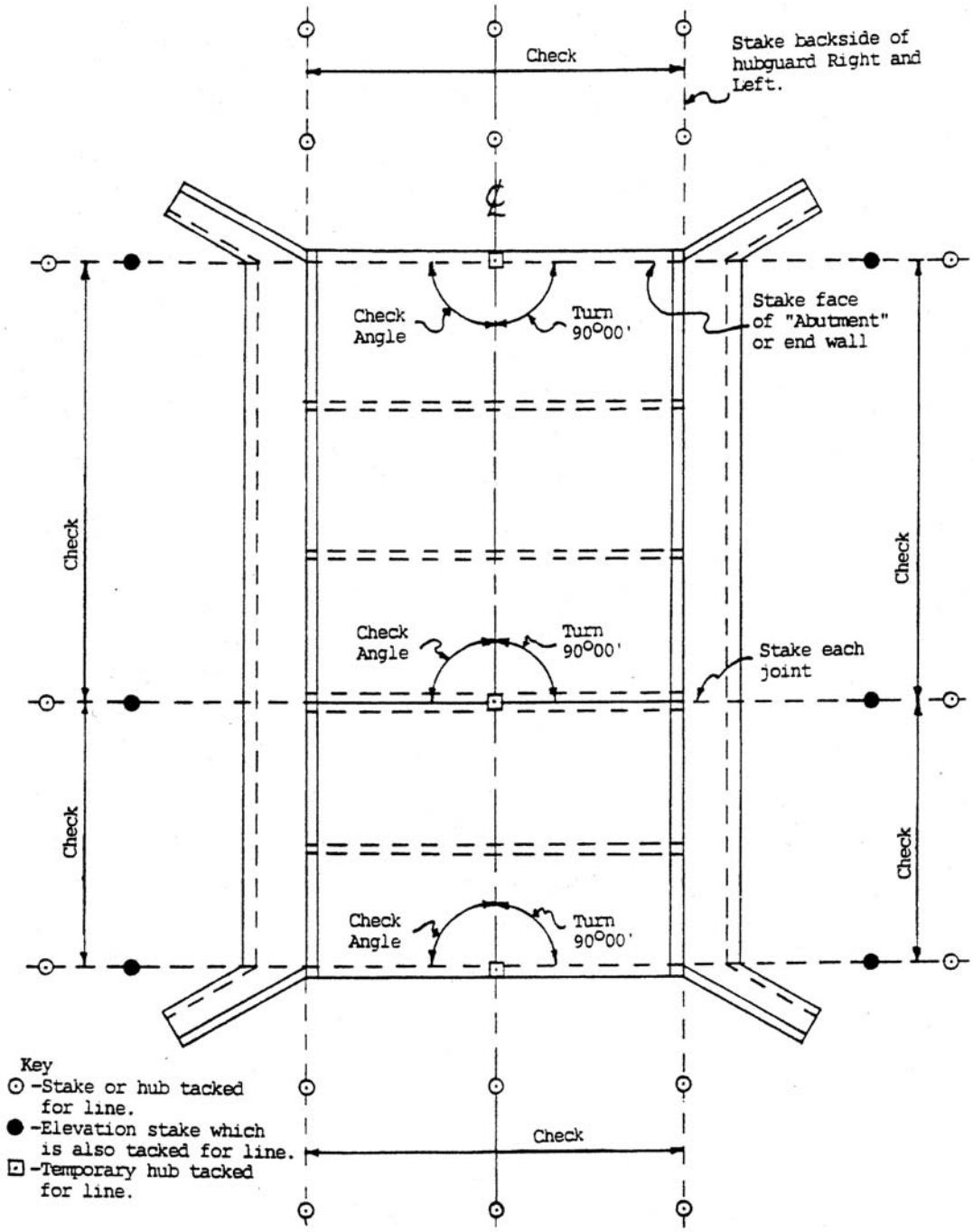
Stakes on the outside of the hubguard preferably should be set on the "B" distance from the side of the culvert, but in all cases should be set to clear the channel excavation.

Note: The vernier shall be set at 0°0' to check angle.

Elevation stakes shall indicate the cut to F.L. elevation on the end of the culvert on which the stakes are set.

Stakes on the centerline of the culvert are optional and in some locations their removal is necessary.

FIGURE No. III - 20
EXAMPLE-MULTIPLE BOX BRIDGE STAKING



Note: Linear and angular check measurements as indicated must be taken in all cases. All distances shall be checked at least once in addition to check measurements indicated.

The vernier shall be set at 0°00' to check angles.

Elevation stakes shall indicate the cut to flow line elevation on the side on which the stakes are set.

Particular attention should be given to the centerline of the structure. On multi-lane roadways, centerline of the lanes and centerline of structures may not coincide due to the different width of shoulders on inside and outside of the lanes. In this case, it must be understood by all parties involved, which line is being used.

Several methods of determining size of structures are in use. The Federal Highway Administration has derived a series of charts, nomographs, and tables for use in designing culverts. This information is available in the Bureau of Design for use in checking and designing culverts.

3.23.02 ALIGNMENT AND STATIONING

As set out in Section 3.22, hubs should be set on each side of each bridge and culvert at the time the centerline is reestablished. These hubs should be set in their true position and tacked for line. One hub shall be set on the centerline of the project on each side of each culvert and in the immediate vicinity thereof. At least two hubs shall be set on centerline back of each bridge abutment. It is not always possible to see from one side of the stream to the other along the centerline during the period of construction due to obstructions such as equipment or materials. For this reason it is desirable to have the centerline independently established on each side of the stream. Two stakes on each side should be sufficient for this purpose; but on large bridges, which may be under construction for a year or more, it is good policy to set a third stake 100 feet back from the abutment to insure the preservation of the centerline. It should be kept in mind that once the work has started the location must not be altered.

Care shall be taken to see that all measurements are sufficiently accurate to locate the bridge exactly on the station where the plans show it. An appreciable error may place the bridge on foundations quite different in character than those for which it was designed. The spacing of the abutments and piers should be checked frequently and by different methods to insure that they are properly located. It is very important that the spacing of piers and abutments be correct on all structures, but it is particularly important in the case of steel or concrete girders and arch structures. The use of Electronic Distance Measuring Equipment may be very beneficial and recommended in various situations and conditions. For accurate measurement of distances, it is necessary to set the atmospheric pressure and temperature settings on an EMD or Total Station before taking a measurement.

It is recommended that when measuring over a bank or bluff at the edge of a stream, no attempt is to be made to determine the horizontal distance directly by use of a tape and plumb bob. It is suggested, instead, that a stake be set on top of the bank and another on the lower level and that the difference in elevation between the two stakes be determined, or if this difference is too large to determine in one set-up, that the vertical angle from the top of one stake to the top of the other be determined. The distance between the two stakes should then be measured along the slope with the tape held in a taut position from the top of one stake to the top of the other. The correct horizontal distance between the two points shall then be calculated from the sloping distance, and the vertical angle or difference in elevation. Distance computed from a vertical triangle may be checked quickly by laying off a perpendicular base line and computing the distance from a horizontal triangle.

3.23.03 TURNING ANGLES FOR PIERS AND ABUTMENTS

When the instrument is set up on the centerline of a project, for the purpose of laying off the angle for the face or back of an abutment, or the transverse centerline of a pier, extreme care must be exercised to see that the angle is turned of f accurately and in the right direction. All

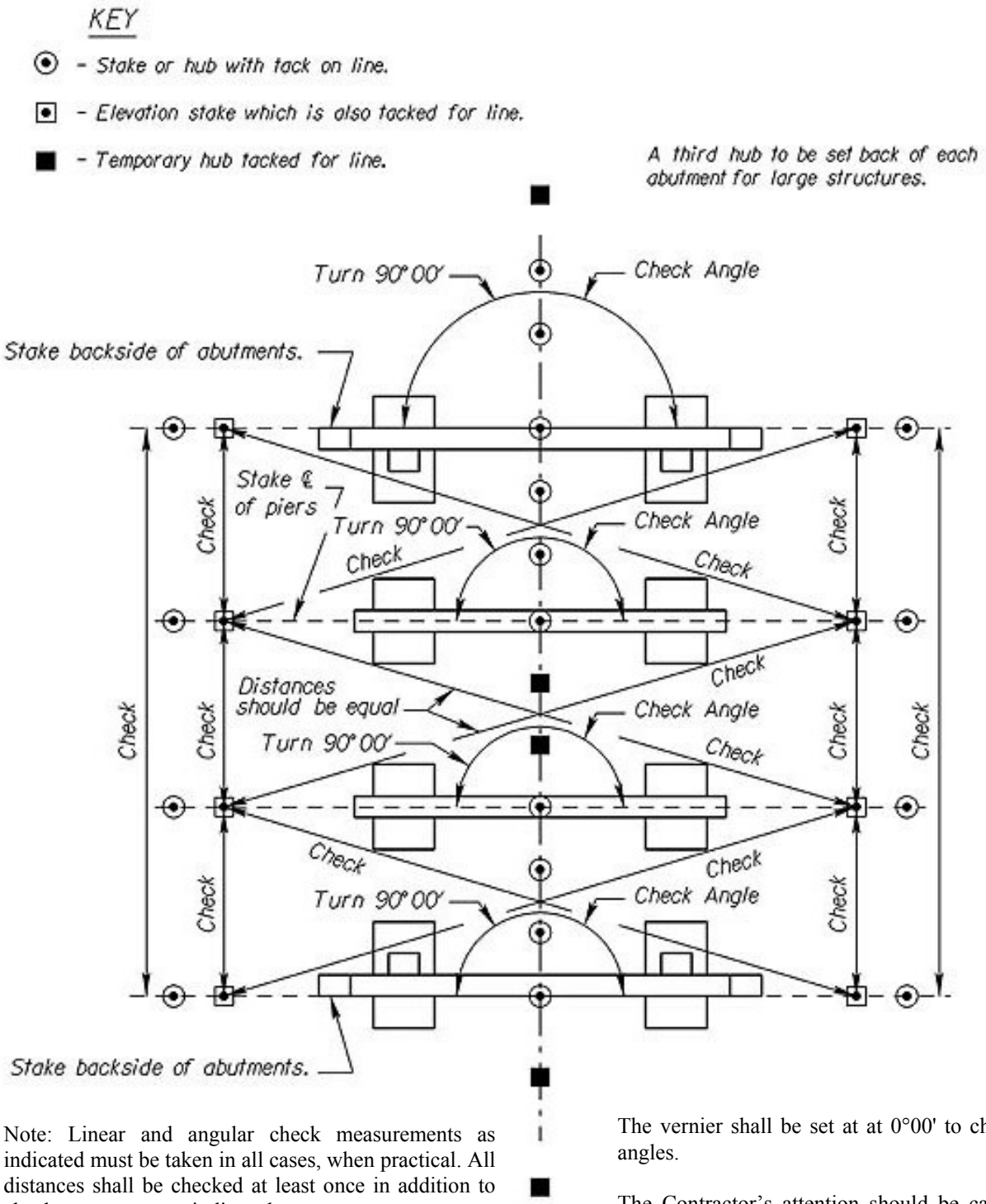
angles should be turned from a foresight, thus eliminating the necessity of reversing the telescope. After an angle has been turned off and the stakes set along the line of sight, the horizontal vernier should be set at 0°00" or at any random reading and the supplemental angle measured as a check on the angle laid off a structure is to be built on a skew, extreme care should be exercised to see that the stakes are set with the skew in the proper direction and that the skew angle is accurately established. All handrail posts for structure shall be lined and set to grade with an instrument. The alignment and elevation of the forms for posts should be checked before pouring has been started.

3.23.04 TRIANGULATION

In case a stream is so wide that the water cannot be spanned with a 200 foot tape and Electronic Distance Measuring Equipment is not available, a tacked stake shall be set on centerline on each side of the stream at a safe distance back of each proposed abutment. The distance between the stakes shall then be determined by triangulation.

To determine the distance between the two stakes by triangulation, a base line should be laid off on one bank of the stream. If possible, this base line should be perpendicular to the centerline, as this will simplify the computations. The base line should be of such length that the triangle determined by it and segment of the centerline will have no angle smaller than 30°. If it is necessary, however, to lay out the base line on rough ground, it is recommended that stakes be set at intervals of approximately 50 feet and the elevation of each stake be determined. The sloping distance from the top of each stake to the succeeding stake shall then be determined, and the horizontal distance between stakes shall be calculated.

FIGURE No. III-21
BRIDGE CONSTRUCTION STAKING DIAGRAM



Note: Linear and angular check measurements as indicated must be taken in all cases, when practical. All distances shall be checked at least once in addition to check measurements indicated.

The vernier shall be set at at 0°00' to check angles.

The Contractor's attention should be called to the fact that stakes are set for the back side of abutments, but for the CL of piers

For accurate measurement of distances, it is necessary to make corrections in chained distances; therefore, the calibrated tension and temperature must be known for the chain being used.

In determining the length of the base line for triangulation work pertaining to important structures, a calibrated steel tape with tension scales should be used.

In triangulation work, the angles shall be measured by repetition; each angle of the triangle or other figure being measured at least twice with the telescope in direct position and an equal number of times with the telescope in reverse position. When measuring angles by this method, the first value of the angle with the telescope in direct position should be recorded as a check against the mean angle which will be determined by dividing the final reading by the number of observations. Three angular values should be recorded: The first reading with the telescope in direct position, the final reading resulting from three repetitions, and the mean value of the angle. Using a surveying instrument with a vernier reading to minutes, the mean value of the angles should check at least within 30" of the first value of the angle. If this check is not obtained, the indications are that either the instrument is not in proper adjustment or some error has been made in measuring the angle; the angle should, therefore, be measured again. Another check upon the accuracy of the measured angles is obtained by adding together the mean values of the angles of each figure to ascertain whether or not the figure closes. The figure must be adjusted to eliminate any angular error of closure before any computations are made.

3.23.05 ELEVATIONS

There shall be at least two bench marks near each structure. For large bridges across wide or otherwise difficult streams there shall be at least two bench marks on each side of the stream near the ends of the structure. The elevations of all the bench marks shall be thoroughly checked as explained in Section 3.05 before any construction stakes are graded. Area Construction Engineers are cautioned that they must never set up an instrument to do level work without checking at least one bench mark other than that from which the first H.I. was determined. In other words, at least two bench marks shall be sighted upon each time the instrument is set up for leveling work. The last rod reading at the close of any piece of leveling work should be taken on a bench mark.

The first level work done on a bridge or culvert should be that of checking the elevation of the stream bed, the low-water elevation, and the high-water elevation. The elevation of the natural ground surface on either side of the stream or the elevation of the existing roadbed may also be checked. In cases where a railroad bridge is near the site of the proposed bridge, the clearance elevation of the railroad structure should be checked. Before staking a grade-separation structure, whether it is an overpass or underpass, the elevations of the tops or bases of the rails should be checked. All of these elevations when determined, should be carefully compared with the corresponding elevations shown on the plans, in order that any errors on the plans or in the field work may be detected before the structure has been staked. Extreme care should be exercised to see that each structure is built to the relative elevations with respect to the stream bed, etc., for which it was designed. Molding shall be set and checked for elevation after the concrete is poured and just before the finishing operations have been started.

3.23.06 STAKES

The minimum dimensions for elevation and line stakes used in staking bridges or culverts shall be 1½" x 1½" x 12", on large structures which require a considerable length of time for construction it may be advisable to use heavier stakes. All stakes should be driven flush with the

ground surface in locations where they will not be covered over with materials or disturbed by traffic or construction operations. Each stake should be flagged and guarded by a substantial guard. Since the grade and line stakes are to be driven flush, it will be necessary to mark the cut or fill, the distance to centerline, and any other data on the guard stake or a separate guide stake driven in place for that purpose. Where large, smooth-finished wooden guard stakes are used, any data referring to the grade or line stake may be shown on the guard stake. If a steel bar is used as a guard, a Type "A" guide stake (see FIGURE No. III-2) shall be driven in place and the data recorded thereon. The distance from the line stakes to the centerline of the project, to the face of the structure, or to some other similar line or point should be shown on the guide or guard stake, and recorded in the field notes as an aid in finding stakes which might become covered.

When a culvert or multiple box is staked for construction, it should be located at the station shown on the plans, unless there is a definite reason for changing the location. This will avoid overruns and underruns in culvert excavation and backfill.

3.23.07 CROSS SECTIONS FOR BRIDGES AND CULVERTS

Current practice is to pay common excavation for channels through box culvert and pipe culvert sites and not to pay for necessary excavation below the flow line of the culvert except for miscellaneous structures for which the plans specifically include an item of Class III excavation. Excavation quantities must be determined for all channels through culverts and for all bridges and miscellaneous structures such as manholes, catch basins, inlets, retaining walls, etc., for which the plans specifically provide for payment for excavation.

For the determination of excavation for channels through structures and excavation for bridges and miscellaneous structures, accurate and complete cross sections must be taken at each structure site prior to construction. In most cases, the cross sections should be taken at the time the structure is staked out. Cross sections are to be taken at right angles to the centerline of the structure and at the critical points indicated by irregularities in the surface of the ground, points of change in the excavation limits and at points where there is a change in the flow-line grade. The cross sections shall be recorded on the page following the staking notes for each structure. The field notes recorded as described above should be plotted, using the same method as that employed on regular roadway sections. The excavation limits for each section should then be determined and plotted, and the end areas run. The excavation volume for the barrel and wings should then be computed, using the regular Earthwork Computation sheet, KDOT Form No. 101, with a separate calculation for the toe-wall excavation.

Classification of Excavation: Class I Excavation and Class II Excavation shall normally apply only to the classification of excavation for bridges and the classification shall be made as follows with reference to an "Excavation Boundary Plane" which shall be a horizontal plane shown at a given elevation on the plans.

Class I Excavation shall include all material of whatever nature, except water, found above the "Excavation Boundary Plane".

Class II Excavation shall include the entire volume of whatever nature found below the "Excavation Boundary Plane".

Regardless of water level during construction, no water above the "Excavation Boundary Plane", shall be considered as excavation in measuring quantities of Class I Excavation for payment; and Class II Excavation shall include the total volume below the "Excavation Boundary Plane" and within other limits specified for measurements.

Class III Excavation shall apply to excavation for bridges not classified as Class I or Class II Excavation and to excavation for catch basins, manholes, inlets, retaining walls, and such other miscellaneous structures for which the plans specifically list an item of Class III

Excavation. Class III Excavation shall otherwise be unclassified and shall include any and all materials, including water encountered during the construction of the work. The water level for determining quantities of Class III Excavation shall be interpreted as the average or mean water level during construction at which pumping or bailing becomes necessary in the work of excavating. No measurement will be made of excavation for entrance-pipe culverts or headwalls for entrance-pipe culverts regardless of the type of pipe used.

Excavation for bridges other than box bridges and underfill arch bridges will be that actually removed, except that no measurement will be made of material removed outside of a volume bounded by vertical planes 24 inches outside the footings and tie beams unless shown otherwise on the plans. In such cases where the plans show special excavation dimensions, the excavation to be measured will be that actually removed as limited by the dimensions shown. The term "actually removed" as used in this paragraph shall not be interpreted to preclude payment for a volume of air between the "Excavation Boundary Plane" and the elevation of water or solid material.

Excavation for box bridges and underfill concrete arch bridges will be that actually removed except that no measurement will be made of material removed outside a volume bounded by vertical planes 24 inches outside of the footings.

Excavation for catch basins, manholes, inlets, retaining walls and all other miscellaneous structures shall be that actually removed except that no measurement will be made of material outside a volume bounded by vertical planes one foot outside the footings.

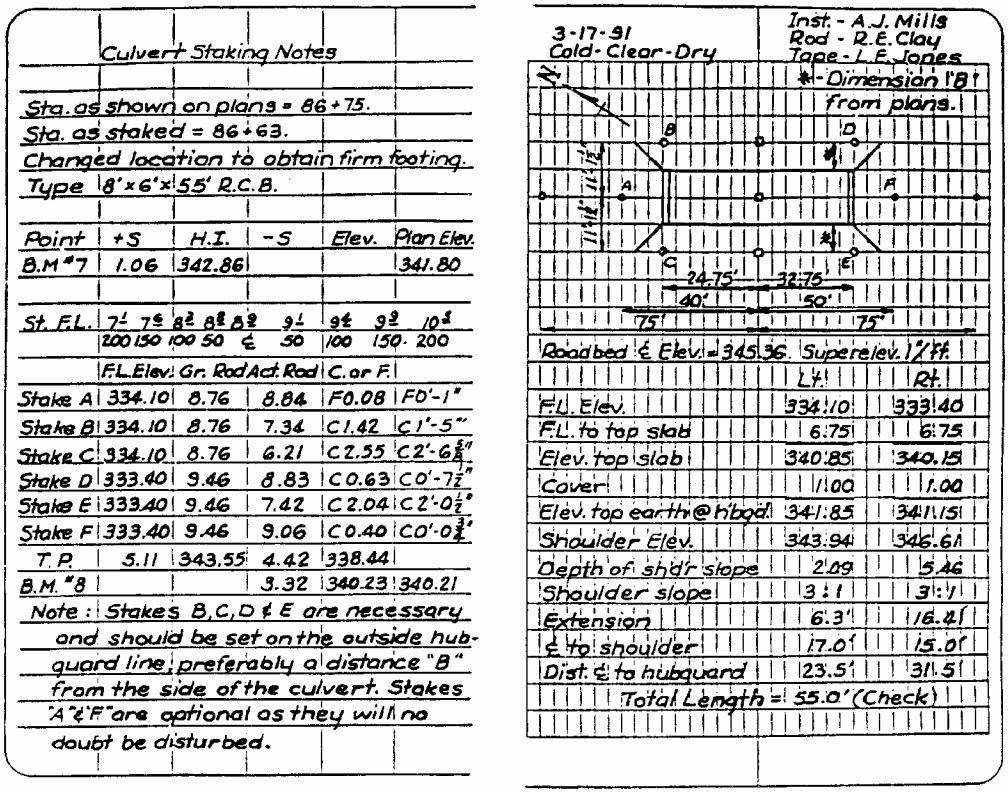
Adequate and accurate cross sections shall be taken at all locations before excavation is started. Although no classification is made of the various classes of material, such as gravel, shale, rock, etc., and no differentiation is made between wet and dry excavation, the water elevation and the elevation of the various classes of material should be taken and recorded for permanent record and placed on the Completed Construction Plans.

3.23.08 NOTES

The field notes for a large bridge shall be kept in a separate field book. In this book shall be shown all the sketches and notes pertaining to the staking as well as the record of pile driving, pouring records, cross section notes, and all other notes pertaining to the structure. Field notes shall be kept for every field operation, checking operations included. Notes shall be supplemented with neat sketches when the sketches may be of aid in recording or interpreting the notes.

In the case of small bridges, the complete notes for several such structures on the same project may be kept in the same field book. If two bridges are under construction at the same time, however, it will probably be more convenient to keep the notes for each bridge in a separate book, in order that the Inspector on each structure may have the complete notes at all times. Each notebook shall be thoroughly indexed as the field entries are made.

FIGURE No. III-22
CULVERT STAKING NOTES



Culvert Staking Notes

Sta. as shown on plans = 86+75.
Sta. as staked = 86+63.
Changed location to obtain firm footing.
Type 8'×6'×55' R.C.B.

Point	+S	H.I.	-S	Elev.	Plan Elev.
B.M #7	1.06	342.86			341.80

St. F.L.	7+	7+50	8+	8+50	8+	9+	9+	9+	10+
	200	150	100	50	℄	50	100	150	200

	F.L. Elev.	Gr. Rod	Act. Rod	C. or F.
Stake A	334.10	8.76	8.84	F0.08 F0'-1"
Stake B	334.10	8.76	7.34	C1.42 C1'-5"
Stake C	334.10	8.76	6.21	C2.55 C2'-6 5/8"
Stake D	333.40	9.46	8.83	C0.63 C0'-7 1/2"
Stake E	333.40	9.46	7.42	C2.04 C2'-0 1/2"
Stake F	333.40	9.46	9.06	C0.40 C0'-0 3/4"
T.P.	5.11	343.55	4.42	338.44	
B.M. #8			3.32	340.23	340.21

Note: Stakes B, C, D & E are necessary and should be set on the outside hub-guard line, preferably a distance "B" from the side of the culvert. Stakes "A" & "F" are optional as they will no doubt be disturbed.

3-17-91
Cold-Clear-Dry

Inst. - A.J. Mills
Rod - R.E. Clay
Tape - L.E. Jones

*-Dimension "B" from plans.

Roadbed ℄ Elev. = 345.36. Superelev. 1"/ft.

	Lt.	Rt.
F.L. Elev.	334.10	333.40
F.L. to top slab	6.75	6.75
Elev. top slab	340.85	340.15
Cover	1.00	1.00
Elev. top earth @ h'bgd	341.85	341.15
Shoulder Elev.	343.94	346.61
Depth of sh'd'r slope	2.09	5.46
Shoulder slope	3:1	3:1
Extension	6.3'	16.4'
℄ to shoulder	17.0'	15.0'
Dist. ℄ to hubguard	23.5'	31.5'

Total Length = 55.0' (Check)

A separate field book shall be set aside for culvert field notes. A complete record of all staking operations and all level work pertaining to the culverts shall be recorded in this book. FIGURE No. III-22 is a typical example of culvert-staking field notes. Immediately following the staking and field notes, the cross section notes shall be recorded. Culvert construction records shall be kept in the same book with the other field notes. Two or three blank sheets immediately following the staking and cross section notes for each culvert should be reserved for construction records.

3.23.09 SURVEY FOR STRUCTURES ON SECONDARY PROJECTS

Surveys for structures on Secondary Projects shall be as complete and accurate as for those on the State System. This is especially true when soundings have been made to determine the geology under the structure or on railroad structures. Pipe culverts and box culverts on linear grading projects may be located to fit field conditions without strict adherence to the stationing shown on the plans.

3.24 SURVEYS FOR PAVEMENTS

3.24.01 GENERAL

These surveys may be of three types:

(a) Staking for subgrade control
(b) paving stakes
(c) staking for drainage

3.24.02 STAKING FOR SUBGRADE CONTROL

The method of staking for subgrade control should be discussed and decided on at the pre-construction conference. It is very important that the contractor understands the method to be used.

Never use the color coding blue on the top of any stake that is not set to grade.

3.24.03 PAVING GRADE AND LINE STAKES

There are two basic types of paving to be considered: Concrete and bituminous bases.

(a) Concrete Pavement - A line of type "B" stakes (hubs) shall be set on each side of the pavement subgrade at an offset of two to four feet from the form line, as the contractor may prefer. In all cases, one line of hubs will be tacked or otherwise permanently marked for line. The second line of hubs need not be tacked.

Paving grade stakes shall be set at 50 foot intervals on tangents and flat and vertical and horizontal curves. In the case of an exceptionally sharp curve, it may be necessary to set graded hubs at intervals of 25 feet or less.

Graded hubs will also be set on all necessary points in transitions to super- elevation, in accordance with the transition diagram shown on the plans. Graded hubs should also be placed at all points of beginning or ending or pavement widening. In no case will hubs be moved or otherwise disturbed after tacking. See Subsection 3.23.05 and 3.23.06 for establishing offset line.

There are two common methods of setting graded hubs for concrete paving forms. The actual method to be used must be discussed and agreed upon by the Contractor and Engineer. Each method has some advantages and disadvantages.

Method No. 1: The hubs after being placed on line are then driven to the edge of pavement grade. This is also the top of form grade. The form setter simply sets the form line by leveling off of the paving hub. It is also possible to set all grade stakes at some agreed fill (such as 0.50' to 0.75'), but this is a condition and all parties should be advised. In this method hubs must be graded before tacked for line. It may be faster and more convenient to use surveying instrument and level at the same time.

Method No. 2: By this method the hubs are driven on line and tacked before grading. After hubs have been tacked they are shot with a level, and an individual cut or fill to top of form line computed for each hub. The great advantage of this method of staking for concrete pavement lies in speed of operation and increased productivity of a survey staking crew.

(b) Bituminous Bases - the most common method is to place grade stakes on centerline of each pair of lanes throughout the length of the project. On horizontal curves with superelevation, grade stakes should be set for the outside edge of pavement and offset in the same manner, as concrete pavement stakes.

All grade stakes are usually driven flush with the bottom of pavement grade.

The interval for grade stakes will have the same measurements as previously stated for concrete paving stakes.

An offset alignment control should be set so centerline may be reestablished for succeeding lifts of the bituminous base.

3.24.04 STAKING FOR GUTTERS

When staking is necessary on edge curbs and gutters, the method of paving hubs is usually applicable. Grade should be given to top of form line. Care should be taken to maintain at least 0.2 feet drop per 100 feet, whenever possible. Where the gutter is constructed after the pavement has been poured, a stake at the beginning and the end may be all that is required.

When setting inlets in vertical curves, care should be taken to find the low point on the pavement edge. Often, it will be found to be a few feet from the point shown on the plans.

3.24.05 Off-SETTING STAKES FROM ALIGNMENT TANGENT

For all types of pavement staking, control points such as P.O.T.'s, P.T.'s, P.C.'s, etc., should be referenced by setting a stake at right angle to the control point on each offset line. These stakes should be set with a surveying instrument and tacked for line and offset distance. The offset line is then run with a surveying instrument and steel tape.

3.24.06 OFF-SETTING ON HORIZONTAL CURVES

When off-setting form stakes on a horizontal curve, the centerline may first be established. The form stakes may be offset by using two tapes in a manner similar to that explained in Subsection 3.04.12. It is also expedient to set the instrument on an offset control point then chain in the offset line using the intrados corrections. The interval on stakes should not exceed 50 feet (centerline distance), and it should be shortened to 25 feet for short radius curves. All other types of stakes may be offset by similar methods.

3.24.07 NOTES

Subgrade and pavement grade notes may be kept in KDOT Field Book No. 4 (Blue Top Book).

3.25 COMPLETED CONSTRUCTION PLANS

3.25.01 GENERAL

Completed (As-built) construction plans shall be prepared for all grading, paving and bridge projects by the Area Construction Engineer. For projects with the bid item of Contractor Construction Staking see the Standard Specifications and Special Provisions for compliance. As-built plans should include major and minor changes in plans as well as project alignment, land monuments, project control and bench marks.

The minimum depths of all monuments should be ½ inch below finish grade in concrete, 6 inch below finish grade in asphalt and 12 inch below finish grade in earthwork.

3.25.02 LAND MONUMENTS

The location of all land monuments "Section Corners" with 6 reference ties shall be recovered, reset and verified as stated in section 3.04.16 by a Land Surveyor or under his direct supervision. The Land Surveyor shall submit the appropriate Land Survey Reference Reports for archiving and project records.

The location of all Right-of-Way monuments shall be recovered, reset and verified as stated in section 3.11.02 by a Land Surveyor or under his direct supervision.

3.25.03 PROJECT CONTROL

Project control centerline or baseline with 4 reference ties shall be recovered, reset and verified as stated in sections 3.04.08 and 3.04.12.

3.25.04 BENCH MARKS

Project and government bench marks shall be recovered and/or permanently established as well as verified as stated in sections 3.05. When establishing permanent bench marks it is preferable to place them in RCB hubguards, bridge wing walls or at the exit ends (as traffic

flows) of bridge handrails, light standard bases and in reinforced "cast in place" concrete cylinders at the R/W.

FIGURE No. III - 23
ADDITIONAL REFERENCES

The references listed below are included as sources of additional information and procedure on construction surveys. Since it is impossible to cover all aspects of surveying in the Construction Manual, the following references should be consulted frequently for computational details, formulas, tables, care of equipment, etc.:

(a) Searles, W. H., Ives, H. C., & Kissam, P., Area Construction Engineering, John Wiley & Sons, Inc., New York.

(b) Breed, C. B., Hosmer, G. L., Bone, A. J. Elementary Surveying, John Wiley & Sons, Inc., New York

(c) Hickerson, T. F. Route Location and Design, McGraw-Hill Book Co., Inc., New York.

(d) Barnett, J., Transition Curves for Highways, United States Government Printing Office, Washington, D.C.

(e) Solar Ephemeris for 19-- and Surveying Instrument Manual, Keuffel & Esser Co., New York.

(f) Operating manuals as issued with instruments.

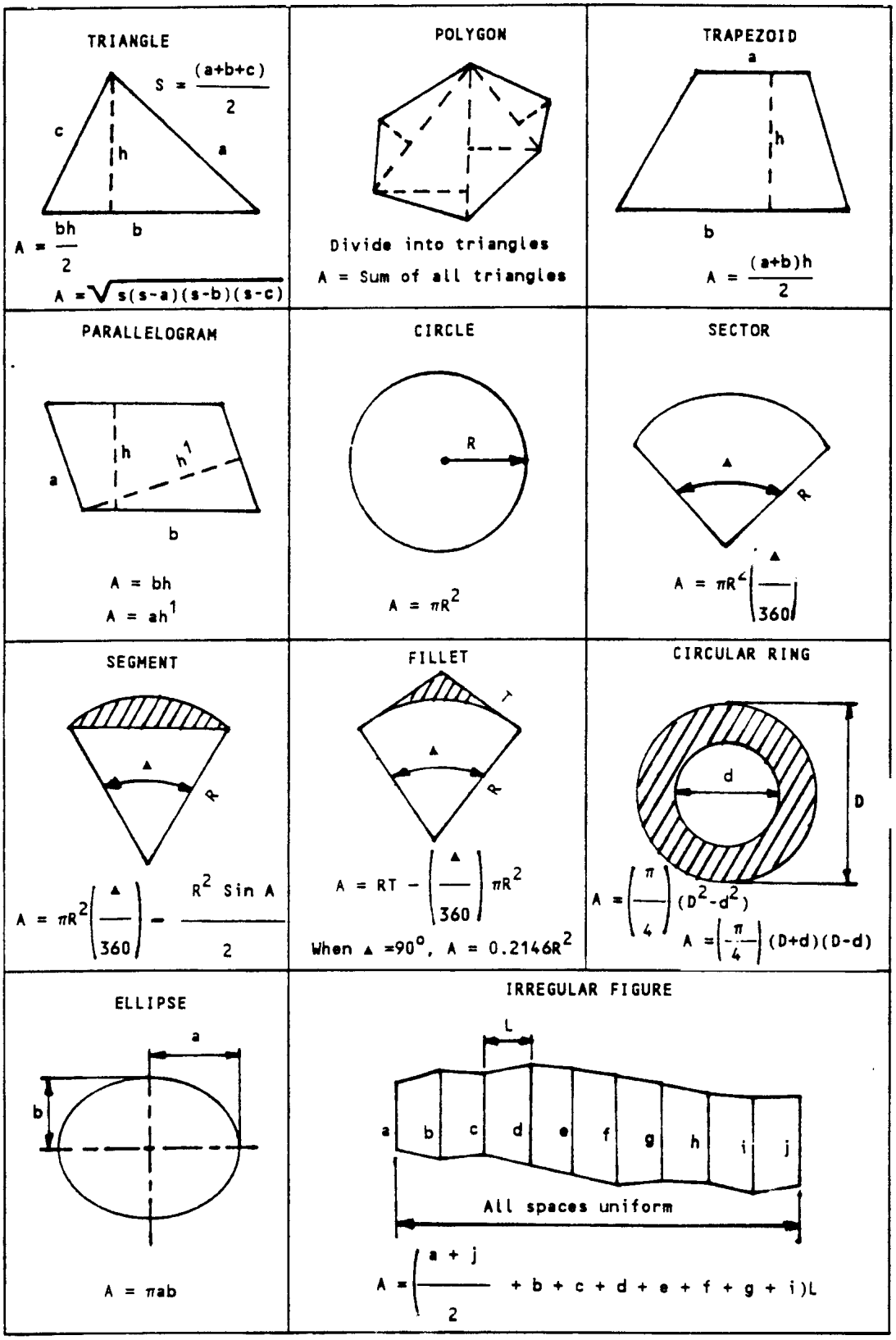
FIGURE No. III-24
CONVERSION FACTORS

Multiply	by	To Obtain
Acres (ac)	4046.87300000	Square meters (m^2)
Acres (ac)	0.40468730	Hectares (ha)
Acres (ac)	43560.00000000	square feet ($ft^{2)}$
Acres (ac)	0.00156200	square miles (mi^2)
board foot	0.00235974	cubic meters (m^3)
bushels	2150.40000000	cubic inches (in^3)
bushels (U.S.)	0000.0.523907	cubic meters (m^3)
Centimeters (cm)	0.39370000	Inches (in)
Centimeters (cm)	0.03281000	Feet (ft)
Cubic Feet (ft^3)	0.02831685	Cubic meters (m^3)
Cubic Feet (ft^3)	28.31685000	Liters (L)
cubic inches (in^3)	0.00001639	cubic meters (m^3)
cubic meters (m^3)	35.31466247	cubic feet (ft^3)
cubic meters (m^3)	1.30795055	cubic yards (yd^3)
cubic meters (m^3)	1000.00000000	Liters (L)
cubic meters (m^3)	264.17203728	Gallons (gal)
cubic meters (m^3)	0.26417200	1000 gallons (M gal)
cubic yards (yd^3)	0.76455490	cubic meters (m^3)
cubic yard/mile (yd^3/mi)	0.47507150	cubic meter/kilometer (m^3/km)
degree celsius (°C)	(°Cx1.8)+32	degree fahrenheit (°F)
degree celsius (°C)	°C+273.15	Kelvin (K)
degree fahrenheit (°F)	(°F-32)/1.8	degree celsius (°C)
degree fahrenheit (°F)	(°F+459.67)/1.8	Kelvin (K)
Feet (ft)	0.30480000	Meters (m)
Feet (ft)	0.00018940	miles (mi)
feet/second (ft/sec)	0.68180000	miles/hour (mi/hr)
feet/second (ft/sec)	1.09728000	kilometer/hour (km/hr)
foot-pound force (ft-lbf)	1.35581800	Joule (J)
gallons (gal)	3.78530000	Liters (L)
gallons (gal)	0.00378541	cubic meters (m^3)
1000 gallons (M gal)	3.37854126	cubic meters (m^3)
1000 gallons (M gal)	3785.41260000	Liters (L)
gallons/square yards (gal/yd^2)	4.52731774	liters/square meter (L/ (m^2)
gallons/minute (gal/min)	0.63090200	liters/second (L/sec)
Hectares (ha)	2.47100000	Acres
Hectares (ha)	1000.00000000	square meter (m^2)
Inches (in)	25.40000000	Millimeters (mm)
Inches (in)	2.54000000	Centimeters (cm)
Joule (J)	0.73756212	Foot-pound force (ft-lbf)

Multiply	by	To Obtain
Kilograms (kg)	2.20460000	pounds (lb)
Kilograms (kg)	0.23453430	sacks of cement (94 lbs)
Kilograms (kg)	0.00100000	Megagram (Mg)
Kilograms (kg)	9.80665000	Newton (N)
kilogram/cubic meter (kg/m^3)	0.06242797	pound/cubic foot (lb/ft^3)
kilogram/cubic meter (kg/m^3)	1.68555500	pound/cubic yard (lb/yd^3)
Kilometer (km)	3280.83989500	Feet (ft)
Kilometer (km)	0.62140000	Miles (mi)
Kilometer (km)	32.80839895	station (100 ft)
kilometer/hour (km/hr)	0.91134440	feet/second (ft/sec)
kilonewton (kN)	0.22480892	Kip
kilopascal (kPa)	0.14503774	pounds/square inch (psi)
Kip	1.44822200	kilonewton (kN)
kip/square inch (ksi)	6894.75700000	kilopascal (kPa)
Liters (L)	0.00100000	cubic meter (m^3)
Liters (L)	0.26420000	gallons (U.S.) (gal)
liter/square meter (L/m^2)	0.22088144	gallon/square yard (gal/yd^2)
Meters (m)	39.37007800	Inches (in)
Meters (m)	3.28080000	Feet (ft)
Meters (m)	0.00062140	Miles (mi)
Meters (m)	1.09360000	Yards (yd)
Megagram (Mg)	0.98420000	tons (long)
Megagram (Mg)	1.10230000	tons (short)
Miles (mi)	1.60930000	Kilometers (km)
Miles (mi)	5280.00000000	Feet (ft)
miles/hour (mi/h)	88.00000000	feet/minute
miles/hour (mi/h)	1.60934700	kilometer/hour (km/h)
Millimeters (mm)	0.03940000	Inches (in)
Newton (N)	1.00000000	kilogram meter/sq second (kg m/s^2)
Newton (N)	0.22480892	pound force (lbf)
pascal (Pa)	1.00000000	newton/square meter (N/m)
pounds-force (lbf)	4.44822200	Newtons (N)
pounds-mass (lbm)	0.45335924	Kilograms (kg)
pounds/foot (lb/ft)	14.59390000	newton/meter (N/m)
pounds/cubic foot (lb/ft^3)	16.01846000	kilogram/cubic meter (kg/m^3)
pounds/cubic yard (lb/yd^3)	0.59327640	kilogram/cubic meter (kg/m^3)
pounds/square foot (lb/ft^2)	4.88242800	kilogram/square meter (kg/m^2)
pounds/square foot (lb/ft^2)	47.88092600	pascal (Pa)
pounds/square foot/hour (lb/ft^2/hr)	4.88242800	kilogram/square meter/hour (kg/m^2/hr)
pounds/square inch (psi)	6.89475700	kilopascal (kPa)
Pounds (lb)	16.00000000	Ounces (oz)
Quart (qt)	0.00094635	cubic meter (m^3)

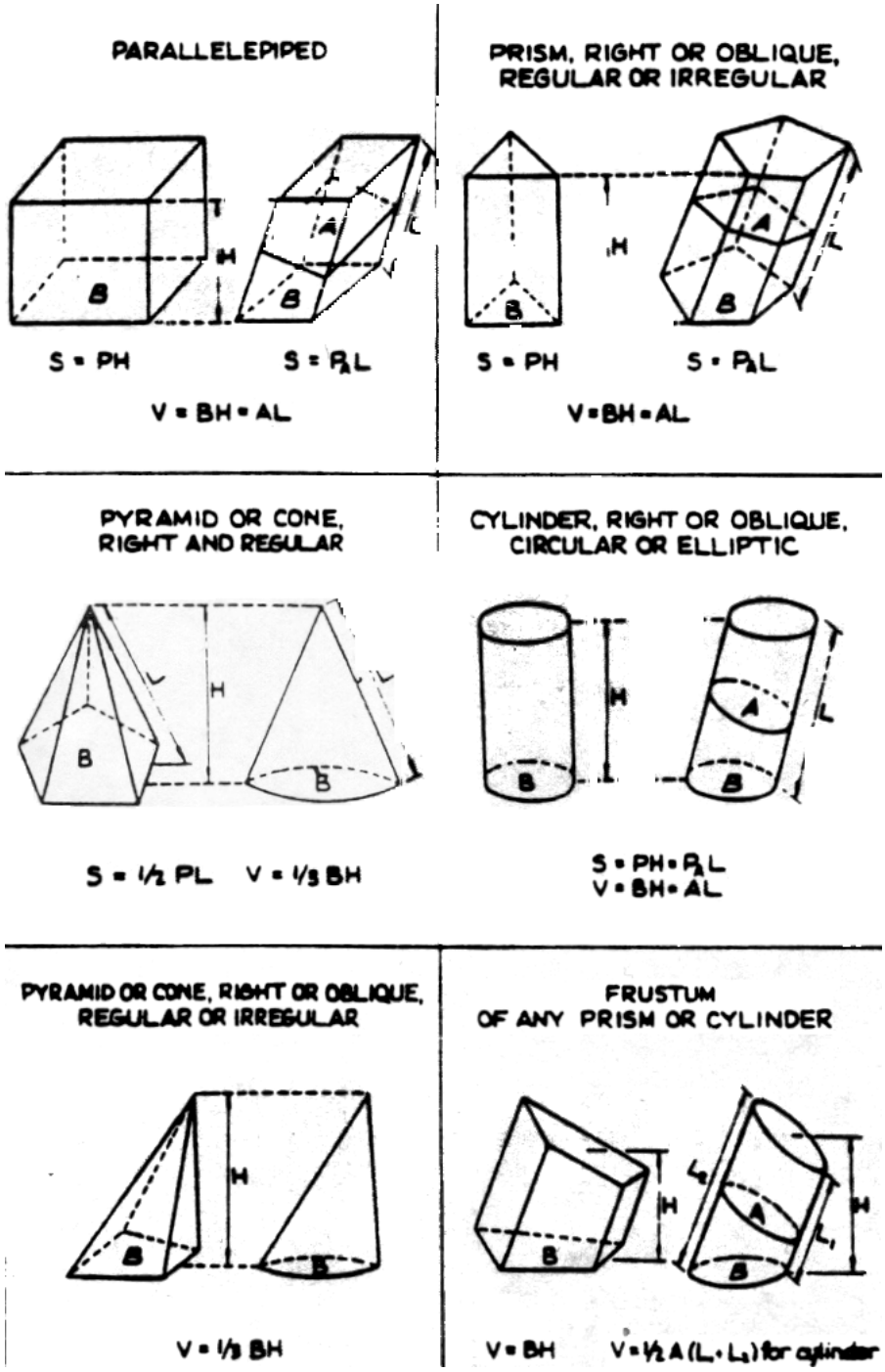
Multiply	**by**	**To Obtain**
Quart (gt)	0.94630000	Liters (L)
Radians	57.30000000	Degrees
rods	5.02900000	Meters (m)
rods	16.50000000	Feet (ft)
sacks of cement (94 lb)	42.63768560	Kilogram (kg)
square inches (in^2)	0.00064516	Square meters (m^2)
square feet (ft^2)	0.09290000	Square meters (m^2)
square kilometers (km^2)	0.38610000	square miles (mi^2)
Square meters (m^2)	10.76390000	square feet (ft^2)
Square meters (m^2)	1.19600000	square yards (yd^2)
Square meters (m^2)	0.00024710	Acres (ac)
Square meters (m^2)	0.00010000	Hectares (ha)
square miles (mi^2)	2.59000000	square kilometers (km^2)
square yards (yd^2)	0.83610000	Square meters (m^2)
station (100 ft)	0.03048000	Kilometer (km)
ton (long 2240 lb)	1016.04700000	Kilogram (kg)
ton (long 2240 lb)	1.01600000	Megagram (Mg)
ton (short 2000 lb)	907.18470000	Kilogram (kg)
ton (short 2000 lb)	0.90720000	Megagram (Mg)
tons (long)	2240.00000000	Pounds (lb)
tons (short)	2000.00000000	Pounds (lb)
Megagram (Mg)	1000.00000000	Kilogram (kg)
Megagram (Mg)	0.98420640	ton (long 2240 lb)
Megagram (Mg)	1.10231136	ton (short 2000 lb)
Megagram (Mg)	2204.62248000	Pounds (lb)
Yards (yd)	0.91440000	Meters (m)
Yards (yd)	0.00056820	Miles (mi)

FIGURE No. III – 25
SURFACES AND VOLUMES OF SOLIDS

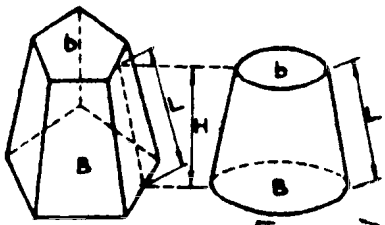


SURFACES AND VOLUMES OF SOLIDS
(Continued)

SYMBOLS	
S = Lateral Surface Area	P_A = Perimeter of Section Perpendiculer to Sides
V = Volume	R = Radius of Shers or Circle
A = Area of Setion Perpendicular to Sides	L = Slant Height of Lateral Length
B = Area of Base	H = Perpendicular Height
P = Perimeter of Base	C = Circumference of Circle of Sphers



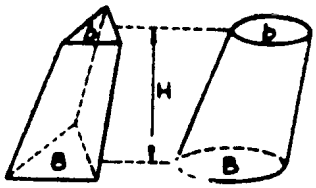
FRUSTUM OF PYRAMID OR CONE RIGHT AND REGULAR, PARALLEL ENDS



$S = \frac{1}{2} L (P + p)$ $\quad V = \frac{1}{3} H \left[(B + b) + \sqrt{Bb} \right]$

(p = perimeter of top base)
(b = area of top base)

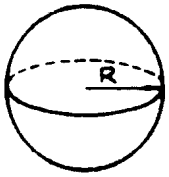
FRUSTUM OF ANY PYRAMID OR CONE. PARALLEL ENDS



$V = \frac{1}{3} H (B + b + \sqrt{Bb})$

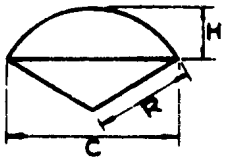
b = Area of top base

SPHERE



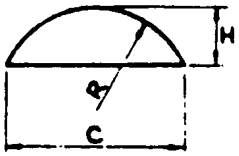
$S = 4 \pi R^2$ $\quad V = 4/3 \pi R^3$

SPHERICAL SECTOR



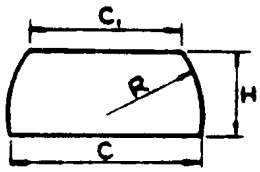
$S = \frac{1}{2} \pi R (4H + C)$ $\quad V = \frac{2}{3} \pi R^2 H$

SPHERICAL SEGMENT



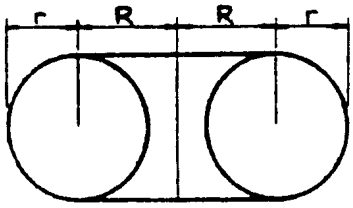
$S = 2 \pi R H = \frac{1}{4} \pi (4H^2 + C^2)$ $\quad V = \frac{1}{3} \pi H^2 (3R - H)$

SPHERICAL ZONE



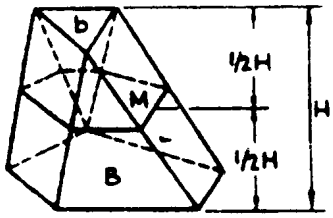
$S = 2 \pi R H$ $\quad V = \frac{1}{24} \pi H (3C_1^2 + 3C^2 + 4H^2)$

CIRCULAR RING



$S = 4 \pi^2 R r$ $\quad V = 2 \pi^2 R r^2$

PRISMOIDAL FORMULA

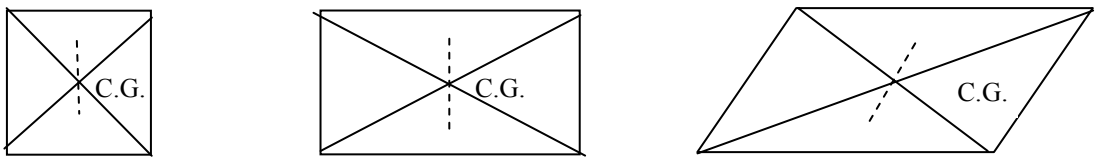


$V = \frac{H}{6} (B + b + 4M)$

M = Area of Section Parallel to Bases, Midway between them.

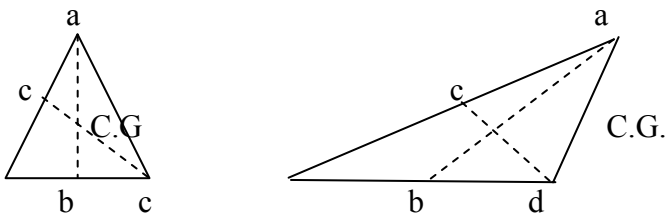
FIGURE No. III – 26
CENTERS OF GRAVITY OF ORDINARY PLANE FIGURES

Squares, Retangles & Paralleograms



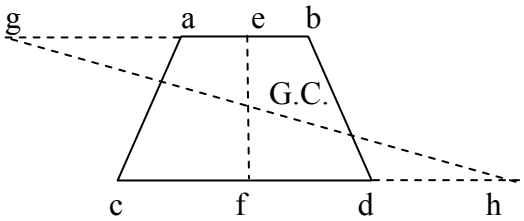
Center of gravity is at the intersection of the diagonals or midway between the bases on a line drawn between the centers of those bases.

Triangles



Center of gravity is at the intersection of the medial lines a b and c d: a medial line is a line drawn from any apex to the middle of the opposite side. The distance b (C.G.) = 1/3 a b: that is, the center of gravity is on the medial line 1/3 of the distance from the base to the apex.

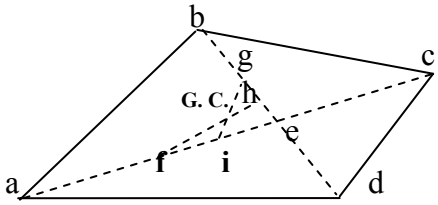
Trapezoid



Graphic Method. Prolong b a to g, making a g = c d. Prolong c d to h, making d h = a b. Connect g h. Bisect a b at e. Bisect c d at f. Connect e f: the intersection of g h and e f is the center of gravity

$$\text{The distance f (C.G.)} = \frac{ef}{3} \times \frac{2ab+cd}{ab+cd}$$

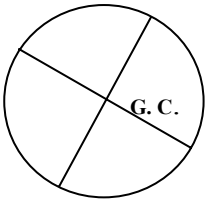
Any Quadrilateral



Graphic Method. Drawn the diagonals ac and bd intersecting at e. Lay off a f = e c. Lay off b d = e d. Bisect e g at h; bisect e f at i. The intersection of f h and g i is the center of gravity of the figure.

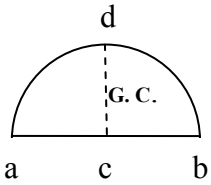
CENTERS OF GRAVITY OF ORDINARY PLANE FIGURES
(Continued)

Circles



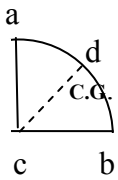
Center of gravity at the center

Semicircle



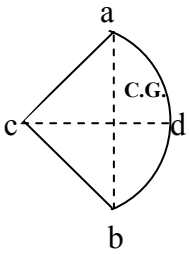
The center of gravity lies on the radius perpendicular to the diameter. The distance c (G. C.) = radius x 0.4244

Quadrant



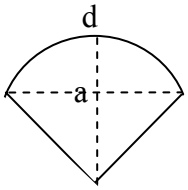
The center of gravity lies on the radius which bisects the ∟acb. The distance c (C.G. = radius x 0.6002

Sector



The center of gravity lies on the radius bisecting the ∟acb. The distance c (C.G.) = 2/3 radius x $\frac{\text{cord ab}}{\text{arc adb}} = \frac{\text{radius x chord}}{\text{3 x area}}$

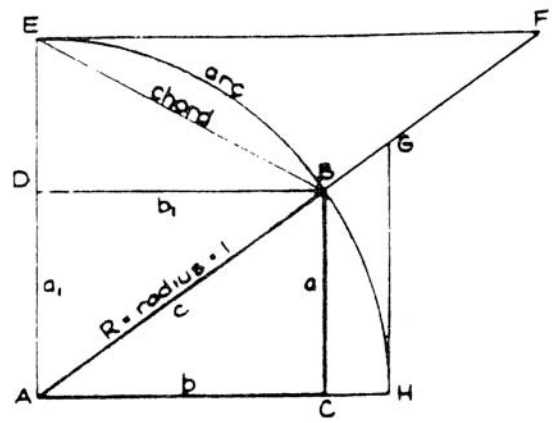
Segment



The center of gravity lies on the perpendicular erected at the center of the chord ab.

The distance c (C.G.) = $\frac{\text{Chord ab3}}{\text{12 x area of segment}}$

FIGURE No. III – 27
TRIGONOMETRIC FUNCTIONS



$\tan \angle BAC = GH = (\tan \angle BAC)R = a/b = \cot \angle ABC$

$\sin \angle BAC = BC = (\sin \angle BAC)R = a/c = \cos \angle ABC = \sqrt{c^2 - b^2}$

$\cos \angle BAC = AC = (\cos \angle BAC)R = b/c = \sin \angle ABC = \sqrt{c^2 - a^2}$

$\sin \angle ABD = AD = (\sin \angle ABD)R = a/c = \cos \angle DAB$

$\cos \angle ABD = BD = (\cos \angle ABD)R = b/c = \sin \angle DAB$

$\sec \angle BAC = AG = \left(\frac{1}{\cos \angle BAC}\right)R = c/b = \operatorname{cosec} \angle ABC$

$\operatorname{cosec} \angle BAC = AF = \left(\frac{1}{\sin \angle BAC}\right)R = c/a = \sec \angle ABC$

$\cot \angle BAC = EF = \left(\frac{1}{\tan \angle BAC}\right)R = b/a = \tan \angle ABC$

$\operatorname{exsec} \angle BAC = BG = \left(\frac{1}{\cos \angle BAC} - 1\right)R = \frac{c-b}{b} = \operatorname{coexsec} \angle ABC$

$\operatorname{vers} \angle BAC = CH = (1 - \cos \angle BAC)R = \frac{c-b}{c} = \operatorname{covers} \angle ABC$

$\operatorname{coexsec} \angle BAC = BF = \left(\frac{1}{\sin \angle BAC} - 1\right)R = \frac{c-a}{a} = \operatorname{exsec} \angle ABC$

$\operatorname{covers} \angle BAC = DE = (1 - \sin \angle BAC)R = \frac{c-a}{c} = \operatorname{vers} \angle ABC$

$\text{Chord of } EB = \left(\sin \frac{\angle EAB}{2}\right)2R = \sqrt{ED^2 + DB^2}$

$\text{Arc of } EB = \frac{100\,(\angle EAB)(R)}{5729.58}$

$\text{Length of } R = AB = \frac{a}{\sin \angle BAC} = \frac{b}{\cos \angle BAC} = \sqrt{a^2 + b^2}$