

# Methods and Procedures Used for Indiana State Highway Surveys

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In the years of its existence the Road Location Department of the State Highway Department of Indiana has adapted or developed survey methods and standards to provide field information necessary for the design and construction of our State Highways.

As the type of highway facilities required to meet the demands of traffic becomes more complex year by year, the field survey information required to build those facilities must be obtained in greater detail and with a greater degree of accuracy than for surveys made several years ago. Because of the rising right-of-way, engineering, and construction costs of our highways, complete and accurate field survey information is becoming increasingly more important. It is obvious that a first-rate highway facility cannot be constructed from second-rate construction plans, nor can accurate and complete plans be developed from incomplete or inaccurate survey information.

In the early years of highway construction, it was quite possible that a man making a field survey could sit at a drawing board; and with his own notes in hand, design the road and later provide the engineering control during the construction of the highway. However, in the field of highway engineering as in other professions and trades, the complexity of the work has resulted in ever increasing fields of specialization. Today, survey crews must provide field survey information that any assigned designer can use to develop plans; and in turn, that designer must provide plans that any assigned project engineer can use in the construction engineering for the highway.

Also, due to the greatly expanded highway programs of recent years and an increase in the number of state highway and consulting engineer's field crews making highway surveys, it is becoming even more necessary that uniformity of survey standards and methods of recording information be maintained.

It is the intent of our present standards to provide basic or fundamental requirements to be met; and at the same time, permit

enough latitude of action that those details and problems unique to each individual project can be satisfactorily handled by the survey crew. One of the basic rules guiding the surveyors is that all survey information is to be a matter of permanent record, and is to be placed in the field books. A second requirement is that only that information, which would normally be placed in the field notes, which clearly will not be required on any particular project, may be omitted from survey notes.

Surveys made for the State Highway Department must be under supervision of a registered professional engineer, licensed by the State of Indiana. The survey crews assigned to various projects vary in size from four to ten men depending on the magnitude of the project, and the desired rate of progress on the survey. The average crew consists of seven men, a party chief, two instrument men, a topographer, and three rodmen-chain men.

At the time the project is assigned to the surveyors, information is given to the party chief concerning type of facility for which the survey is being made, the terminal points of the project, the general route location, and critical horizontal control points to be used. Line designations and field book numbers are assigned to the job. All available information on previous State Highway surveys in the area is given to the field party. A listing of known permanent vertical control bench marks is made available. These bench marks include those which have been established by the U. S. Corps of Engineers, U. S. Geological Survey, U. S. Coast and Geodetic Survey, Indiana Flood Control and Water Resources Commission, and the State Highway Department. Aerial photographs of the area are made available to the survey crew. These photographs generally are prints obtained from the most recent series of the U. S. Department of Agriculture's Commodity Stabilization Service, although they may be those from the Highway Department's own Photogrammetry Section, or from private firms which provide aerial photographic services. In addition, in those areas in which they have been published, copies of the U. S. Geological Survey Quadrangle Maps are given to the surveyors.

Because of the size of the survey crews, it is generally possible for two or more operations to be underway at the same time. The responsibility for the day-by-day progress of the various operations falls to the party chief, and actual sequence of performance is adjusted by him to fit the conditions existing on the assigned project.

On most surveys, two field books are used to record field survey information. One of these, called the transit book, is used to record

alignment data, property information, and the topographic drawings. The other, referred to as the level book, is used to record bench mark information, cross-sections of ground elevations, and other pertinent elevations. The notes in the transit book are generally recorded by the topographer, with the level book being the responsibility of an instrument man.

A fly leaf is placed in each book listing the book number, the project number, the road number, the terminal points of the survey, the county in which the book is used, and a brief description of the survey lines included in the book. A title page and index is placed in each book listing the survey party personnel assigned to the project, and indexing the various notes included in the book, and noting the dates on which the survey was made. A key map is placed in the transit book showing the location of the project and the various survey lines included in the book. A list of descriptions and elevations of previously established bench marks, which were used to obtain level datum for the project, is placed in the level book. The beginning and end or continuation of each survey line is noted together with a cross-reference giving the location of the corresponding topography or level notes in the other book. At those points where ties were made to other survey lines, a notation is made as to the page number and field book number on which the notes of the other survey can be found. Daily notations are placed in the field notes listing date, personnel assigned to the operation, weather, and extremities of the day's work.

In so far as possible, all present day State Highway Survey level data are based on 1929 adjusted sea level datum, therefore, one of the first operations on field survey is the transfer of this datum from a previously established bench mark to the job site. This is accomplished by running a third-order level circuit from the established bench mark to the job site and return, using a Dumpy or Wye level and direct reading level rods, and with balanced lengths of sights taking readings to the nearest 1/100 ft.

As the survey progresses, additional tie-in circuits are run to other established bench marks within a reasonable distance of the job. At the same time, the proposed route is plotted on aerial photographs and a field review is made of the proposed location of the survey centerline and necessary revisions in the proposed routing are noted.

Another operation undertaken very early in the course of the field work, is the preparation of property plats, drawn at a scale of 1,000 ft. to the inch and one square mile is shown on each plat. The plats are prepared from the county auditor's, surveyor's, assessor's, recorder's

plat books, survey records and deed record books. Each parcel of property is plotted to scale, and the size and property owner is noted on the plat. The auditor's transfer books are used to provide the most recent owners of record for the properties. The section number, civil township name and the congressional township and range number, and the county are noted on each plat, as well as the project number and survey field book number. Copies of town plats or subdivision plats, if any exist along the survey route, are made at a convenient scale. Noted on these plats are the lot or parcel numbers and dimensions, street and alley right-of-way widths, name and location of the subdivision, and the ownership of the lots or parcels. As the survey line is established in the field, it is plotted on the plats also.

The county surveyor's office is contacted for information concerning the original U. S. Government land surveys, and particularly, any information concerning locations of any monumented land grant or section corners, or other survey markers or monuments, which should be noted and perpetuated. As the survey centerline is established, angular ties are made to the section lines and distances recorded to the section corners. Other survey lines which have been run in the vicinity are also tied-in by angle and station equations.

Establishment of the survey centerline is accomplished by the use of an engineer's transit, sight-rods, invar steel surveyor's tape and plumb bobs. Permanent horizontal control points are set approximately one quarter mile apart, and on all curve points, at crests of hills, banks of streams. Twelve inch iron boat spikes are used for the major control points, with smaller six or eight inch boat spikes or three inch road nails used where the larger pins cannot be set. In concrete pavements, a one-half inch star drill hole about  $\frac{3}{4}$  inch deep and filled with lumber crayon is used. The iron pins are set flush with the top of the ground in those areas where they will not be disturbed, or lightly buried in locations such as gravel roads or barn lots where minor disturbance of the ground surface is expected, and are buried below plow depth when set in cultivated fields. In establishing control, the line is prolonged either by sighting through one point and setting the next ahead or by plunging the line ahead by "double-centering" with one back sight taken with telescope in the normal position, and one made with telescope inverted, and the instrument error being removed by splitting the difference between the two foresights.

At the point of intersection of two tangent lines, the deflection angle is obtained by sighting along the back tangent, inverting the

telescope and turning the deflection angle to the fore tangent. The angles are turned a sufficient number of times to obtain one half minute accuracy. To remove instrument error, alternate back sights are taken with telescope normal or inverted.

All horizontal control points are referenced, whenever possible, to three objects within 100 feet of the point to aid in the recovery of the point at any later date. References to trees, utility poles or fence posts are made to a reference nail driven through a flasher. Distances between a central point and its references, are horizontal measurements made using an invar steel tape and plumb bobs. The stationing along the survey centerline progresses from south to north or from west to east, the stationing is always a horizontal distance established by use of invar steel surveyor's tape and plumb bobs. Centerline stakes or markings are set at each 100 foot station along the survey route.

While the chaining is done to the nearest  $1/100$  of a foot, no tension, temperature, or sag corrections are made, therefore, the stationing on horizontal control points is recorded only to the nearest  $1/10$  foot. Horizontal curve data are computed from standard tables of functions for one degree curves with length of curve and semitangent length being computed to the nearest  $1/10$  foot and the external distance being computed to the nearest  $1/100$  foot. The point of curvature and point of tangency are established on the tangent lines and the centerline curve is stationed.

Two memorandum books are kept, one by the instrument man and one by the head chain man in which all alignment data, stationing and type of horizontal control points and field calculations are recorded. The head chain man's book also contains references for the control points. Alignment information placed in the transit book by the topographer is taken from one of these memorandum books, and in turn, is checked against the other book.

The survey stationing is recorded on the left hand pages of the transit book at a scale of 100 feet to the inch. Horizontal control information is recorded on the same pages at the proper stationing together with the references for the control points.

True bearings are computed for each tangent along the survey line taken from previous surveys on which the bearings are known or by computations based on a Solar or Polaris observation to determine true meridian. Because of the ease of making the proper field observations and accuracy of the results, Polaris observations are generally the preferable method of determining true meridian.

Topography notes are plotted to a scale of 100 feet to the inch and are plotted on the right hand pages of the transit book in the proper station location. Right angle plus the distance method of detailing topography notes is used on State Highway surveys. That is, the distance along the survey centerline and the distance to right or left to the object as measured perpendicular to the survey centerline is recorded in the topography notes, as well as a description of the object. All physical features are noted such as buildings, trees, utility lines and poles, private and public drives, property lines and property corners, utility mains, pipelines, sewers, field drain tile, pavements, sidewalks, ditches, flowlines or draws, streams, ponds and lakes, railroad tracks, drainage structures, spoil banks, etc. Notations on soil conditions and land use are also recorded in the topography notes. Property owners are shown in the topography notes after being checked in the field against the prepared plats. Horizontal control points are noted and ties to section lines and section corners are shown as well as corporation, township, range, county and state lines.

Proper designations of lot numbers, subdivision names, county, civil and congressional township and range are noted in the topography notes. Particular attention is paid in noting cemeteries and the proper location of the near graves. Also noted in the topography notes are the traffic census of railroads, ownership of public utility lines and mains, information concerning high water or flooding conditions, and details of drainage structures up and down stream.

The property owners along the route of the survey are contacted for information concerning the existence of tile drains and high water or flood conditions in the vicinity as well as the location of their property lines.

Bench marks for vertical control are set about 1,000 feet apart along the route of the survey. Six inch boat spikes set in trees or a square or cross cut in concrete headwalls or abutments are generally used for bench marks. Whenever possible, the bench marks are set just outside the probable construction limits so they will be undisturbed during the actual building of the road. Third order differential leveling using a Dumpy or Wye level and direct reading level rods is the method for establishing sea level datum elevations on the bench marks.

Generally the bench levels are run in one direction only, with the cross-section levels providing the second circuit to check the bench elevations. The bench level circuit is recorded in the front of the level book on the left hand pages, referenced with a centerline sta-

tioning the distance to the left or right perpendicular to the centerline recorded on the right hand pages as well as a description of the bench mark. Additional tie-in bench circuits are made between bench marks set during the field survey and nearby permanent bench marks on which previously determined sea level datum elevations are known.

All ground elevations and other pertinent elevations are recorded in the level book. To permit calculations of earth work or other volumes, cross-sections are taken at each one hundred foot station along the survey centerline and between stations wherever breaks or changes in ground elevations require them. Cross-section rod readings are taken on the survey centerline and at the location of the centerline of the proposed payments, also rod readings are taken on each break or change in the ground. The cross-sections are taken along a line which is perpendicular to the survey centerline. The stationing on which the cross-section is being taken is recorded on the left hand pages in the level book. Rod readings are recorded beginning with the center of the right hand pages being the centerline and progressing to left and right as the sequence of rod readings is made on left or right side of the centerline and are recorded with the distance from centerline at which the reading was made being recorded below the shot. Notations explaining an individual reading are noted above that reading.

In addition to rod readings used for computations of various volumes, other side shots are taken on all existing drainage structures, pipelines, cables, utility valves and mains, sewers, drain tiles, man-holes, catch basins, drop inlets, etc. Notations describing the side shots are made on the left hand pages of the level book in proper sequence progressing along the centerline and the distance right or left of centerline measured perpendicular to the survey centerline is recorded on the right hand pages beneath the rod readings.

The cross-section levels are used as a closing circuit between bench marks, therefore, these levels are run as third-order levels.

The backsights and foresights are recorded on the left hand page in the cross-section notes with the height of instrument and turning point elevations calculated and recorded on those pages in the proper sequence. Using the computed height of instrument and the rod readings taken, the elevations of the shots taken along the survey centerline are computed and recorded on the right hand pages immediately above the rod reading. These are the only readings that are reduced to actual elevations in the field.

Profiles of roads, drives, sidewalks, lanes, ditches, flowlines, streams and railroad rails to show the existing gradients on these objects

are taken during the cross-sectioning operations. These are placed in the proper sequence progressing along centerline with the stationing recorded on the left hand pages with a notation describing the profile. The rod readings are recorded on the right hand pages in the same manner as cross-section readings, and the distances are measured along the meandering of the profile.

As the survey progresses, the county surveyor's office is contacted for information on the location and legal flowline elevations of existing county ditches for which drainage structures must be provided. The county surveyor's knowledge and advice concerning high water or flooding conditions, as well as the watershed area being drained by a waterway or through an existing structure is of tremendous value to the field survey crews. The drainage recommendations of the survey party are noted on the left hand pages of the transit book. These recommendations are based on the use of Talbot's formula, using a maximum rainfall of four inches per hour. The runoff factor used varies from one tenth in the flat sandy soils of northern Indiana, through  $5/10$  in the rolling terrain in the central part of the state to  $9/10$  in the rock hilly land of southern Indiana, with the type of soil and land use being considered as well as the actual slope of the ground.

The drainage divides along the survey centerline, the total number of acres to be drained, and direction of flow through the proposed structure are noted and the proper runoff factor is assigned, and the cross-sectional area required for the waterway through the structure is computed and recorded. The watershed area to be drained is obtained from testimony of local residents, information given by the County Surveyor, use of existing contour maps particularly U. S. Geodetic Survey Quadrangle Maps where they are available, and from aerial photographs. If stereoscopic photographic coverage such as the Department of Agriculture's commodity stabilization service photographs is available, stereoscopes are used to locate the outline of the watershed. If that coverage is not available, the locations of the drainage areas are plotted in reference to physical features identifiable on the photographs by actual field inspection. On large stream crossings for which a bridge is to be designed, a report is sent to the Bridge Location Department giving the road survey information, which the department in turn uses making the survey for the bridge.

If undesirable material, such as peat is encountered, soundings are made by hand auger or motorized continuous drill auger to locate the

bottom of the material and these soundings are placed in the back of the level book.

In the past few months, and only on a limited scale thus far, photogrammetric methods have been used on our highway surveys. After the survey line is established and monumented in the field, controlled aerial photographs are made and by use of various types of photogrammetric plotters, the topographic features which can be identified on the photographs are placed on a topographic map. At the same time these plotters develop the cross-sectional ground elevations to be used in computing the earthwork quantities for the project. Also the actual drainage divided and watershed areas are delineated by the plotters.

A tremendous amount of information must still be obtained by actual field survey operations, but photogrammetric methods, where they can be used, will relieve the survey crew of some of the more time consuming operations and still provide the information required to design the highway.

As the survey is completed a Field Book Checking Guide is used by the notekeeper, the party chief, and field engineer, to assure that all material required for the design of the facility has been included in the field notes.

The Guide for Checking Transit Book lists the following items:

Front fly leaf notations (Transit Book Number, Project Number, Road Number, Terminal Points of Project, County in which book is used, and brief description of each line).

Title page and index complete.

Key map complete, showing survey lines included in the book.

Pages numbered.

Section Plats complete with notations on county and state roads, streams, railroads, towns, villages, cornerstones, property owners, survey centerlines and section, township and range numbers given as well as name of county and civil township.

Complete plats of towns and subdivisions.

Line designation at top of each page.

Start and end or continuation of lines noted and cross-referenced within book and to Level Book.

Equations to other surveys noted and cross-referenced to other survey books.

Alignment data shown and checked.

References for control points shown and checked.

Bearings calculated, checked, and source fully described.

Daily notations showing date, party personnel, weather, extent of days work.

Centerline points plotted and curves red-lined in topography.

Details of topography complete.

Property owners and property lines field checked against section plats and recorded in topography notes.

Distance to near graves at cemeteries.

Section and property corners located.

Ownership of public utilities noted.

Corporation, township, county and state lines shown.

Names and populations of cities and towns noted.

State and county roads shown with type of surface noted.

Details of existing drainage structures near line and up and down stream.

Drainage areas and recommendations included.

Bridge reports sent in.

Traffic census of railroads included.

The "Guide for Checking Level Books" includes the following items:

Fly leaf notation (same as for Transit Book).

Title page and index complete.

Pages numbered.

Source of level datum given.

Bench turns, cross-section turns, and centerline elevations calculated and checked.

Bench mark descriptions complete.

Line letters noted on top of pages.

Daily notations included.

Railroad profiles included.

Legal flowline elevations of county ditches included.

Equations to other surveys noted and cross-referenced.

Start, end and continuation of lines noted and cross-referenced to

Transit Book.

Profiles of waterways, public and private drives shown.

High water testimony included.

Shots on near structures.

Shots on all drainage facilities, manholes and pipelines.

Depth and type of existing road surfaces noted.

Peat soundings included.

When the field books contain the information noted in the check lists, they are transmitted to the Road Design Department with a

reasonable assurance that complete plans can be developed from the survey notes.

No two highway projects are alike in every respect, and it is not possible to establish rules or standards which will satisfy all the situations and problems which will be met on highway surveys. The methods outlined in this report are for the guidance of the survey crew and are augmented and modified by verbal instructions to meet the requirements of each individual project.

In the final analysis, the accuracy and completeness of any survey depends on the capabilities, training, and experience of the personnel making that survey, more so, than on any set of standards which attempts to anticipate all conditions and requirements.