

Eighth Edition

Surveying with Construction Applications



*Barry F. Kavanagh
Dianne K. Slattery*

Surveying with Construction Applications

EIGHTH EDITION

Barry F. Kavanagh, B.A., CET

Seneca College, Emeritus

Dianne K. Slattery, Ph.D., P.E.

Missouri State University

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Surveying with Construction Applications

PREFACE

Many technological advances have occurred in surveying since *Surveying with Construction Applications* was first published. This eighth edition is updated with the latest advances in instrumentation technology, field-data capture, and data-processing techniques. Although surveying is becoming much more efficient and automated, the need for a clear understanding of the principles underlying all forms of survey measurement remains unchanged.

NEW TO THIS EDITION

- General surveying principles and techniques, used in all branches of surveying, are presented in Part I, Chapters 1–11, while contemporary applications for the construction of most civil projects are covered in Chapters 12–19. With this organization, the text is useful not only for the student, but it can also be used as a handy reference for the graduate who may choose a career in civil/survey design or construction. The glossary has been expanded to include new terminology. Every effort has been made to remain on the leading edge of new developments in techniques and instrumentation, while maintaining complete coverage of traditional techniques and instrumentation.
- Chapter 2 is new, reflecting the need of modern high school graduates for the reinforcement of precalculus mathematics. In Chapter 2, students will have the opportunity to review techniques of units, conversions, areas, volumes, trigonometry, and geometry, which are all focused on the types of applications encountered in engineering and construction work.
- Chapter 3 follows with the fundamentals of distance measurement; Chapter 4 includes complete coverage of leveling practices and computations; and Chapter 5 presents an introduction to electronic distance measurement. Chapter 6 introduces the students to both theodolites and total stations, as well as common surveying practices with those instruments. Chapter 7 gives students a broad understanding of total station operations and applications. Chapter 8, “Traverse Surveys and Computations,” introduces the students to the concepts of survey line directions in the form of bearings and azimuths; the analysis of closed surveys precision is accomplished using the techniques of latitudes and departures, which allow for precision determination and error balancing so that survey point coordinates can be determined and enclosed areas determined. Modern total stations (Chapter 7) have been programmed to accomplish all of the aforementioned activities, but it is here in Chapter 8 that students learn about the theories underlying total station applications.
- Chapter 9 covers satellite positioning, the modern technique of determining position. This chapter concentrates on America’s Global Positioning System, but includes descriptions of the other systems now operating fully or partially around the Earth in Russia, China, Europe, Japan, and India. All these systems combined are known as

the Global Navigation Satellite System (GNSS). Chapter 10, “Geomatics,” reflects the advances modern technology has made in the capture of positioning data on Earth-surface features, the processing of measurement technology, and the depiction of the surface features in the form of maps, plans, screen images, aerial photogrammetric images, and digital imaging taken from satellites and aircraft. Chapter 11 covers horizontal and vertical control, both at the national level and at the project level.

- Part II includes specific applications in engineering construction and begins with Chapter 12, an introduction to machine guidance and control. This new technology has recently made great advances in large-scale developments, such as highway and roads construction and airport construction. It involves creating three-dimensional data files for all existing ground surface features and all new-design surface features. Equipment operators (dozers, scrapers, loaders, and backhoes) can view the existing ground elevations, profiles, and cross-sections on in-cab computer monitors. They can also see the proposed elevations, and the like, for the project, and the current location of the cutting edge (blade, bucket, etc.) of their machine. Being able to see all of this from the cab, the operators don't need further help with line and grade directions.
- The remainder of Part II covers engineering projects: “Highway Curves” (Chapter 13), “Highway Construction Surveys” (Chapter 14), “Municipal Street Construction Surveys” (Chapter 15), “Pipeline and Tunnel Construction Surveys” (Chapter 16), “Culvert and Bridge Construction Surveys” (Chapter 17), and “Building Construction Surveys” (Chapter 18). Chapter 19, “Quantity and Final Surveys,” introduces the student to the types of computations and records keeping that surveyors must do to provide data for the processing of interim and final payments to the contractors.
- To help streamline the text, some of the previous edition's appendices have been transferred to the Instructor's Manual (see below).
- Finally, this edition introduces coauthor Dianne K. Slattery, a professor in the Department of Technology and Construction Management at Missouri State University in Springfield, Missouri. Dr. Slattery has wide academic and practical experience in civil engineering and in engineering surveying, and has used previous editions of this text to teach undergraduate courses in Construction Surveying for more than 15 years.

SUPPLEMENTS

The available Instructor's Manual includes solutions for all end-of-chapter problems; a typical evaluation scheme; subject outlines (two terms or two-semester programs); term assignments, sample instruction class handouts for instrument use, and so on; and mid-term and final tests. Also included is a PowerPoint presentation that can be used as an aid in presenting text material and as a source for overhead transparencies. In addition, former text appendices are now also included in the Instructors Manual, including Steel Tape Corrections, Stadia Techniques and Calculations, Early Surveying, and Surveying and Mapping Web sites.

To access supplementary materials online, instructors need to request an instructor access code. Go to www.pearsonhighered.com/irc to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your text in the online catalog

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Technology continues to expand; improvements to field equipment, data-processing techniques, and construction practices in general will inevitably continue. Surveyors must keep up with these dynamic events. We hope that students, by using this text, will be completely up to date in this subject area and will be readily able to cope with the technological changes that continue to occur. Comments and suggestions about the text are welcomed and can be e-mailed to us at *barry.kavanagh@cogeco.ca* and *DianneSlattery@Missouristate.edu*.

Barry F. Kavanagh
Dianne K. Slattery

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SURVEYING PRINCIPLES

Part I, which includes Chapters 1–11, introduces you to traditional and state-of-the-art techniques in data collection, layout, and presentation of field data. Chapter 1 covers surveying fundamentals. Elevation determination is covered in the chapters on leveling (Chapter 4), total stations (Chapter 7), and satellite positioning (Chapter 9). Distance measurements are covered, using both conventional taping techniques (Chapter 3), and electronic distance measurement (EDM) techniques (Chapter 5). Data presentation is covered in Chapters 7 and 10. Angle measurements and geometric analysis of field measurements are covered in Chapters 6–8. Horizontal positioning is covered in Chapters 9 and 10, and control for both data-gathering and layout surveys is covered in Chapter 11.

Although most distance measurements are now done with EDM techniques, many applications still exist for steel taping on the short-distance measurements often found in construction layouts. Techniques for taping corrections can be found in Chapter 3 and in the online Instructors Manual (see the Preface for access to the Instructors Manual).

SURVEYING FUNDAMENTALS

1.1 SURVEYING DEFINED

Surveying is the art and science of taking field measurements on or near the surface of the Earth. Survey field measurements include horizontal and slope distances, vertical distances, and horizontal and vertical angles. In addition to measuring distances and angles, surveyors can measure position as given by the northing, easting, and elevation of a survey station by using satellite-positioning and remote-sensing techniques. In addition to taking measurements in the field, the surveyor can derive related distances and directions through geometric and trigonometric analysis.

Once a survey station has been located by angle and distance, or by positioning techniques, the surveyor then attaches to that survey station (in handwritten or electronic field notes) a suitable identifier or attribute that describes the nature of the survey station. In Chapter 10, you will see that attribute data for a survey station can be expanded from a simple descriptive label to include a wide variety of related information that can be tagged specifically to that survey station.

Since the 1980s, the term **geomatics** has come into popular usage to describe the computerization and digitization of data collection, data processing, data analysis, and data output. Geomatics not only includes traditional surveying as its cornerstone but also reflects the now-broadened scope of measurement science and information technology. Figure 10.1 shows a digital surveying data model. This illustration gives you a sense of the diversity of the integrated scientific activities now covered by the term *geomatics*.

The vast majority of engineering and construction projects are so limited in geographic size that the surface of the Earth is considered to be a plane for all X (easterly) and Y (northerly) dimensions. Z dimension (height) is referred to a datum, usually mean sea level. Surveys that ignore the curvature of the Earth for horizontal dimensions are called **plane surveys**. Surveys that cover a large geographic area—for example, state or provincial boundary surveys—must have corrections made to the field measurements so that these measurements reflect the curved (ellipsoidal) shape of the Earth. These surveys are called **geodetic surveys**. The Z dimensions (**orthometric heights**) in geodetic surveys are also referenced to a datum—usually mean sea level.

In the past, geodetic surveys were very precise surveys of great magnitude, for example, national boundaries and control networks. Modern surveys (data gathering, control, and layout) utilizing satellite-positioning systems are geodetic surveys based on the ellipsoidal shape of the Earth and referenced to the geodetic reference system (GRS80) ellipsoid. Such survey measurements must be translated mathematically from

ellipsoidal coordinates and ellipsoidal heights to plane grid coordinates and to orthometric heights (referenced to mean sea level) before being used in leveling and other local surveying projects.

Engineering or construction surveys that span long distances (e.g., highways, railroads) are treated as plane surveys, with corrections for the Earth's curvature being applied at regular intervals (e.g., at 1-mi intervals or at township boundaries). **Engineering surveying** is defined as those activities involved in the planning and execution of surveys for the location, design, construction, maintenance, and operation of civil and other engineered projects.* Such activities include the following:

1. Preparation of surveying and related mapping specifications.
2. Execution of photogrammetric and field surveys for the collection of required data, including topographic and hydrographic data.
3. Calculation, reduction, and plotting (manual and computer-aided) of survey data for use in engineering design.
4. Design and provision of horizontal and vertical control survey networks.
5. Provision of line and grade and other layout work for construction and mining activities.
6. Execution and certification of quality control measurements during construction.
7. Monitoring of ground and structural stability, including alignment observations, settlement levels, and related reports and certifications.
8. Measurement of material and other quantities for inventory, economic assessment, and cost accounting purposes.
9. Execution of as-built surveys and preparation of related maps, plans, and profiles upon completion of the project.
10. Analysis of errors and tolerances associated with the measurement, field layout, and mapping or other plots of survey measurements required in support of engineered projects.

Engineering surveying does not include surveys for the retracement of existing land ownership boundaries or the creation of new boundaries. These activities are reserved for licensed property surveyors—also known as professional land surveyors or cadastral surveyors.

1.2 SURVEYING: GENERAL BACKGROUND

Surveys are usually performed for one of two reasons. First, surveys are made to collect data, which can then be plotted to scale on a plan or map (these surveys are called **preliminary surveys** or **preengineering surveys**); second, field surveys are made to lay out dimensions taken from a design plan and thus define precisely, in the field, the location of the proposed construction works. The layouts of proposed property lines and corners as required in land division are called **layout surveys**; the layouts of proposed construction

*Adapted from the definition of *engineering surveying* as given by the American Society of Civil Engineers (ASCE) in their *Journal of Surveying Engineering* in 1987.

features are called **construction surveys**. Preliminary and construction surveys for the same area must have this one characteristic in common: Measurements for both surveys must be referenced to a common base for X , Y , and Z dimensions. The establishment of a base for horizontal and vertical measurements is known as **control survey**.

1.3 CONTROL SURVEYS

Control surveys establish reference points and reference lines for preliminary and construction surveys. Vertical reference points, called benchmarks, are established using leveling surveys (Chapter 4) or satellite-positioning surveys (Chapter 9). Horizontal control surveys (Chapter 11) use any of a variety of measuring and positioning techniques capable of providing appropriately precise results; such surveys can be tied into (1) state or provincial coordinate grids, (2) property lines, (3) roadway centerlines, and (4) arbitrarily placed baselines or grids. When using positioning satellites to establish or reestablish ground positions, the always-available satellite systems themselves can be considered as a control net—thus greatly reducing the need for numerous on-the-ground reference stations. At present, the only fully deployed satellite-positioning systems are the United States' Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS). Other countries plan to have positioning systems deployed within the next 5 to 10 years—for example, Europe's Galileo System, China's Compass System, Japan's system, and an Indian positioning system.

1.4 PRELIMINARY SURVEYS

Preliminary surveys (also known as preengineering surveys, location surveys, or data-gathering surveys) are used to collect measurements that locate the position of natural features, such as trees, rivers, hills, valleys, and the like, and the position of built features, such as roads, structures, pipelines, and so forth. Measured tie-ins can be accomplished by any of the following techniques.

1.4.1 Rectangular Tie-Ins

The rectangular tie-in (also known as the right-angle offset tie) was once one of the most widely used field location techniques for preelectronic surveys. This technique, when used to locate point P in Figure 1.1(a) to baseline AB , requires distance AC (or BC), where C is on AB at 90° to point P , and it also requires measurement CP .

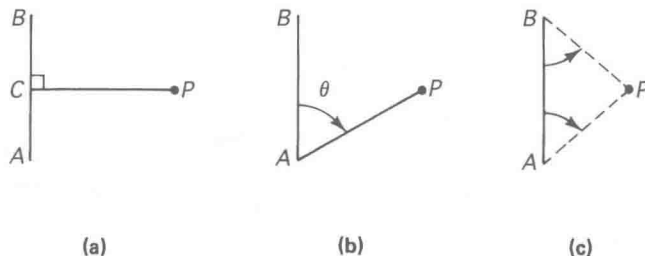


FIGURE 1.1 Location ties.