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surveying practice

third edition

Third Edition

SURVEYING PRACTICE

The Fundamentals of Surveying

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Surveying Practice, Third Edition

Preface

Surveying Practice, Third Edition, is designated for use in introductory surveying courses in junior colleges, technical institutes, engineering technology schools, and on-the-job training programs, as well as for self-instruction. Like its two very successful former editions, the book prepares the student to perform the duties of any member of a surveying party, including chief-of-party, both in the field and in the office. The book also serves as a firm foundation for future studies in surveying and helps develop the competencies necessary to obtain a position that is recognized as one of the best starting points in many types of industrial and engineering organizations.

This third edition has been improved by the inclusion of new material and changes recommended by users of the previous editions. Significant additions include metric conversion tables, new material on laser-beam surveying, a chapter on drawing maps and keeping records, and a more complete treatment of conducting property surveys. Moreover, both text and illustrations have been updated to reflect modern practices and attitudes.

The book is written clearly and simply, and nearly every principle is explained with the help of an illustration. End-of-chapter activities consist of problems and suggested field exercises. Problems are given in pairs; the problems in each pair are similar except in detail. Answers to the even-numbered problems are given at the end of the book, and answers to odd-numbered problems are given in a separate solutions manual available from the publisher.

A review of plane trigonometry and logarithms is covered in chapter 14.

The book assumes a very elementary knowledge of algebra and the ability to use the A, B, C, and D scales of a slide rule. Since most surveying computations are now made on desk and pocket calculators, however, machines of this type should be available to students and instruction should be given in their use. It is also recommended that copies of "Eight-place Table of Trigonometric Functions for Every Sexagesimal Second of the Quadrant" by J. Peters, published by Edwards Brothers, Inc., Ann Arbor,

Michigan, be available for computation. This table gives the values of the natural sines, cosines, tangents, and cotangents to eight places for each second of arc. The student would then be able to fit into office routine with very little difficulty.

If it is desired to study celestial observations, an ephemeris for the year is required. "The Solar Ephemeris and Instrument Manual," published by Keuffel and Esser Co., Morristown, New Jersey 07960, contains instructions for observations and computation and all the data required. It is sent free on request. The procedures for celestial observations and computations in this manual are written by the author and have therefore been omitted in this book.

Philip Kissam

Acknowledgments

UNITS OF MEASURE
LENGTH

U. S. System				*Metric System*	
1 mile (mi)	=	5280	feet	1 kilometer (km)	= 1000 meters
1 chain (ch)	=	66	feet	1 meter (m)	= 1000 millimeters
1 rod (rd)	=	16.5	feet	1 millimeter (mm)	= 1000 microns
1 yard (yd)	=	3	feet	1 micron (μ)	= 1000 millimicrons
1 foot (ft)	=	12	inches (in)	1 millimicron (mμ)	= 1000 millionth microns ($\mu\mu$)
1 nautical mile	=	6076.1155–	feet	1 meter	= 10 decimeters
1 fathom (fm)	=	6	feet	1 decimeter (dm)	= 10 centimeters (cm)
				1 millimicron	= 10 angstroms (A)

Conversion 1959-Foot System and Metric System

1 kilometer	=	0.62137119+	miles	1 mile =	1.609344	kilometers
1 meter	=	3.2808399–	feet	1 foot =	0.3048	meters
1 meter	=	39.370079–	inches	1 inch =	25.4	millimeters

AREA and VOLUME

1959-Foot System			*Metric System*	
1 sq. mile	=	640 acres	1 sq. kilometer	= 100 hectares (ha)
1 acre (A)	=	10 sq. ch.	1 hectare	= 100 ares
1 acrew	=	43560 sq. ft.	1 are	= 100 sq. meters

Conversion 1959-Foot System and Metric System

1 hectare	=	2.4710538+	acres	1 acre	= 0.40468564+	hectares
1 cu. meter	=	1.30795+	cu. yards	1 cu. yard	= 0.764555–	cu. meters
1 cu. cm.	=	0.0610237+	cu. in.	1 cu. inch	= 16.3870+	cu. cm.

Note. In 1959, the Foot System was redefined by agreement among officials of the nations where it is used, as follows: 1 yard = 0.9144 International Meter exactly. This reduced the lengths of units of the existing United States Foot System approximately 2 parts in 1,000,000. The then existing United States system was defined as follows: 39.37 inches = 1 International Meter and the foot in that system is now called the American Survey Foot. The American Survey Foot is still used by the U. S. Coast and Geodetic Survey and therefore applies to all the horizontal and vertical control nets in the United States. This exception is essential, as all data in feet published by that Bureau are the result of conversion from International Meters according to the definition 39.37 inches = 1 International Meter.

The meter is now defined in terms of light waves which can be produced under precisely defined conditions so that its length can be reproduced wherever and whenever required.

(Keuffel & Esser Co., Morristown, N. J.)

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Part 1

BASIC SURVEYING OPERATIONS

1

Introduction

1-1. Definition of Surveying.   Surveying is the art of making relatively large precise measurements with a maximum of accuracy and with a minimum expenditure of time and labor.

1-2. Basis of Surveying.   Surveying is based on method and on the two chief instruments employed, the transit and the level. By adroit use of the method and skillful use of the instruments, almost any measurement problem can be solved and the work facilitated. Conversely, it is difficult to solve any problem of relatively large measurement with reasonable facility without resorting to surveying methods and surveying instruments.

1-3. Importance of Surveying.   The present-day development in technology is both expanding the need for surveying in its customary applications and introducing many new fields in which surveying plays an essential part. The demand for high accuracy in property surveys, the new regulations for land subdivisions, the construction of high-speed highways and modern interchange facilities, the increasing use of steel

and prefabricated housing, the development of aerial mapping—all are increasing the need for accurate surveys. The newer developments that would be impossible without accurate surveys include testing equipment like rocket tracks, accelerators for atomic research, and cinetheodolite installations, as well as control for both position and direction of rockets, intercontinental missiles, and spacecraft (Fig. 1-1).

It is clear that an ever-increasing number of people must be available to carry out the fundamental surveying operations on which these great new developments depend.

1-4. Uses of Surveying.   Surveying is used for two specific purposes. The first is to make maps, charts, and profiles; to measure land boundaries; and often to determine precise sizes, shapes, and locations. Survey-
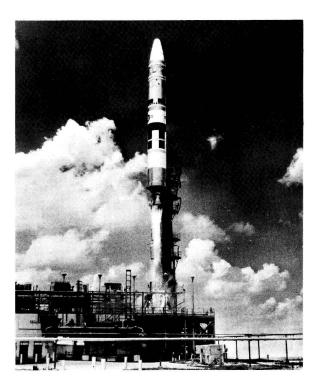
Fig. 1-1. Without surveying procedures, no self-propelled missile could be built to the accuracy necessary for its operation; its guiding devices could not be accurately installed; its launching equipment could not be constructed; it could not be placed in position nor oriented on the pad, nor could its flight be measured for test or control. Moreover, its launching position, the position of its target, and the gravitational forces which affect its flight would be a matter of conjecture. Surveying is an integral part of every project of importance that requires actual construction. Ewing Galloway (*Keuffel & Esser Co.*)

Fig. 1-2. Practically every line recorded on this photograph was laid out with a transit, a steel tape, a level instrument, and a rod—the primary equipment of the surveyor. The roads, streets, houses, drainage facilities, property lines, highways and highway interchanges—all were planned on maps created by surveying, and their positions marked on the ground by survey operations. (*Keuffel & Esser Co.*)

ing is thus a means of **measuring the relative positions of existing objects.** In this capacity, it serves as the only means of providing the information required for planning or designing all but the very smallest projects, as well as a means of checking how closely the finished work conforms to the original plan. The process is often called the **preliminary survey.**

The second purpose is to lay out, or mark, the desired positions and elevations of objects to be built or placed as directed by a completed plan, or to mark the boundaries of property either according to the findings of the land surveyor, according to a court decision, or as directed by a subdivision plan. In this capacity surveying comprises the first step in any actual building process or boundary location and is often called **location surveying** or **construction surveying.** As nearly every detail of a large project must be laid out by surveying methods, this type of surveying continues throughout the building process and entails by far the largest proportion of surveying operations carried out today (Fig. 1-2).

1-5. Surveys Must Be Correct. All surveys **must be free from mistakes.** A mistake in either the preliminary or the location survey

may result in large expenditures for altering or removing and rebuilding finished construction. Since everyone makes a mistake occasionally, three rules are necessary which **must be followed** in all surveying operations. They are:

1. Record all field data carefully in a field book at the moment they are determined. The recorder must never allow the field party to give him data faster than he can record it. The record must be in a standard form and clearly written. The record should be erased[1] and changed if the data or the record is found to be incorrect immediately after it is recorded. Otherwise it must never be altered. If later on, or in the office, a mistake is discovered, the record should be crossed out so that it remains legible, and the new value should be circled or written in some distinctive color.

   If the data taken in the field are copied for one reason or another, the original record must not be destroyed. It follows that it is **unpardonable to lose a field book.** In the office, field books are usually kept in a safe. Also, if a field book is lost before the data are used, the survey must be repeated.

2. All data must be checked at the time they are recorded, either by adopting a method which automatically checks them or by having two people take the same reading independently.

3. The survey must be arranged so that the results can be checked by office computation.

It is absolutely essential that these rules be followed, even if they may seem to be ridiculous. In the descriptions of the procedures that follow, note that these rules are always carried out.

1-6. Accuracy versus Economy.   No measurement can be perfect. The more nearly perfect it is, the more highly **accurate** it is said to be. Almost any desired accuracy can be attained in surveying. More comprehensive methods or more precise instruments will give more accurate results. However, since higher accuracy requires more time in the field, usually more costly equipment, and more extensive computation, it is always more expensive. The degree of accuracy necessary for a survey depends on the purpose of the survey and therefore, the accuracy desired varies widely. Thus, to keep the costs at a minimum, the instruments and methods to be used must be chosen so that the desired accuracy is attained but too high an accuracy is avoided.

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[1] Most surveyors feel that **any** erasure in a field book is bad practice. They recommend that incorrect entries found immediately after they are recorded should be neatly lined out and the correct data entered.

2

The Surveying Method

2-1. The Elements of Surveying. The surveying method is based on certain elements that facilitate operations and increase the accuracy of the work. These elements are described in the following paragraphs.

Gravity as a Reference Direction. The direction of gravity is used as a reference for all measurements. By **vertical** is meant the direction of gravity, and by **horizontal** is meant the direction perpendicular to gravity. Since the earth's surface is not a plane,[1] the direction of gravity is different at every position on the earth's surface.

The effect of the differences in the direction of gravity on horizontal measurements is so slight within a radius of 12 miles or so that it is almost impossible to measure it. For all small surveys, therefore, the curvature of the earth is neglected in the use of horizontal measurements. Plane geometry and plane trigonometry are used for the computation of results, and such a survey is said to be a **plane survey.** It is the only

[1] It is nearly an oblate spheroid, i.e., the solid generated by an ellipse rotated on its minor axis.
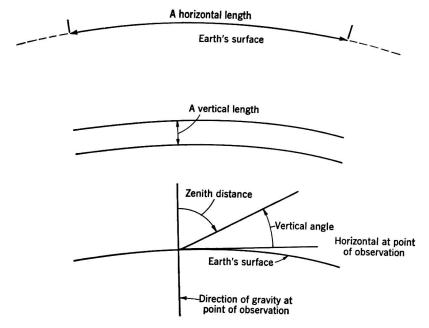
Fig. 2-1. Surveying measurements.

type of survey covered in this text. When spherical trigonometry or elliptical formulas are used, the survey is called a **geodetic survey.**

Measurements Made.   Measurements are made of only four types of dimensions. They are (1) **horizontal lengths,** (2) **vertical lengths,** (3) **horizontal angles,** and (4) **vertical angles.**

Horizontal Length. A length measured horizontally throughout, that does not change in horizontal direction, is called a horizontal length or **distance** (Fig. 2-1). Sometimes a distance is measured on a slope and immediately reduced to the horizontal equivalent.

Vertical Length. A vertical length is measured along the direction of gravity and is equivalent to a difference in height (Fig. 2-1).

Horizontal Angle. A horizontal angle is an angle measured in a plane that is horizontal at the point of measurement. When a horizontal angle is measured between points that do not lie in this plane, it is measured between the perpendiculars extended to this plane from these points (Fig. 2-2).

Vertical Angle. A vertical angle is sometimes called the **altitude angle, angle of elevation,** or **site angle.** The vertical angle of a point is measured in a plane that is vertical at the point of observation and contains the point. Vertical angles are always measured up or down from the horizontal. Those measured upward are called **plus,** and those