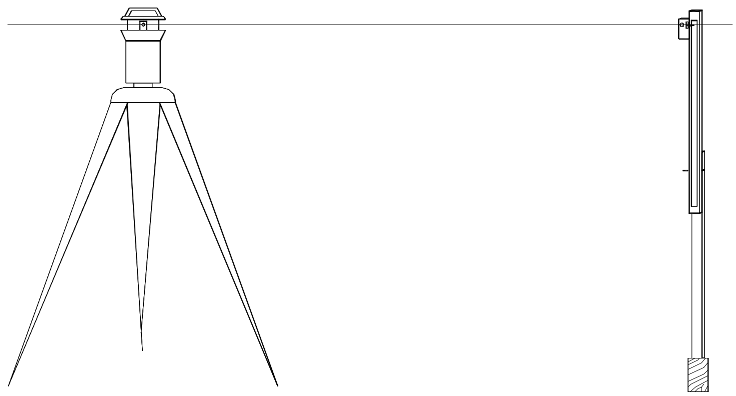
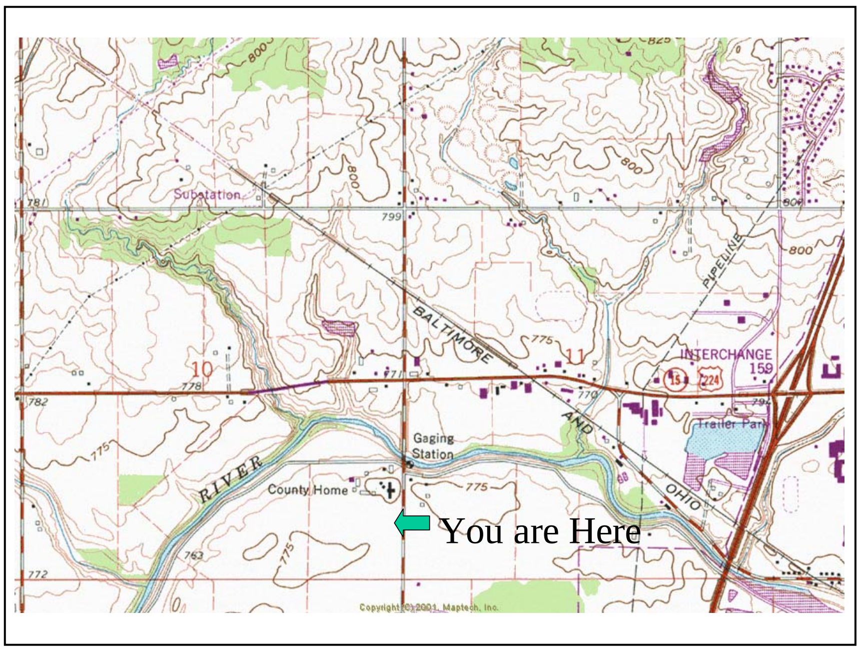
Laser Surveying, Topographic Mapping, and Mapping Drainage Systems using GPS

Designing Agricultural Systems to Balance Production and Environmental Objectives





Sponsors and Partnerships

Overholt Drainage Education and Research Program

Department of Food, Agricultural, and Biological Engineering

Ohio State University Extension

Ohio Agricultural Research and Development Center

College of Food, Agricultural, and Environmental Sciences

The Ohio State University

USDA-Natural Resources Conservation Service (NRCS)

Ohio Land Improvement Contractors Association (OLICA)

Ohio Department of Natural Resources

Ohio Agricultural Water Management Guide Working Group

Miscellaneous Bulletin
OAWMGWG No. 1-2/2005

2005 Overholt Drainage School
March 7-11

Waterman Agricultural and Natural Resources Laboratory
The Ohio State University
Columbus, Ohio

2005 OVERHOLT DRAINAGE SCHOOL
SESSION I:

Laser Surveying
Topographic Mapping
Mapping Drainage Systems using GPS

Monday, March 7
Waterman Agricutural and Natural Resources Laboratory
Columbus, Ohio

Presented by:

OVERHOLT DRAINAGE EDUCATION AND RESEARCH PROGRAM

Department of Food, Agricultural, and Biological Engineering
Ohio State University Extension
Ohio Agricultural Research and Development Center
College of Food, Agricultural, and Environmental Sciences
The Ohio State University

In Cooperation with:

USDA-Natural Resources Conservation Service
Ohio Land Improvement Contractors Association/Associates
Ohio Department of Natural Resources
Soil and Water Conservation Districts
USDA-Agricultural Research Service, Soil Drainage Research Unit
Others

For information, additional copies of this manual, or suggestions, please contact
Dr. Larry C. Brown at 614.292.3826 or brown.59@osu.edu

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2005 Overholt Drainage School

Session I

Laser Surveying, Topographic Mapping, Mapping Drainage Systems using GPS

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2005 Overholt Drainage School

Session 1

Laser Surveying (Leveling), Topographic Mapping and Mapping Drainage Systems using GPS

Monday, March 7 – 8:30 AM to 9:00 PM

MORNING Moderator: Larry C. Brown

8:00-8:30 Check-in, Main Meeting Room, Waterman Agricultural and Natural Resources Laboratory, The Ohio State University, Columbus, Ohio

8:45 School begins, Welcome, Introduction, Instructors, Notebook, etc. (Brown)

Instructors: Ron Cornwell, Rick Galehouse, Fred Galehouse, Paul DeMuth
Louis McFarland, Mark Seger, others

- ♦ Introduction to Lenker Rod
- ♦ Field Notes with Lenker Rod
- ♦ Principles of Laser Surveying
- ♦ Rod Readings and Notes for Leveling with Laser
- ♦ Completing Turning Points and Field Notes
- ♦ Assignment of Teams and Instructors (Brown)

Break

- ♦ Field Exercises at Waterman Lab
- ♦ Application of Laser Leveling to Topographic Mapping
- ♦ Waterman Lab Field Problem - Laser Surveying for Drainage Design (Brown)

LUNCH At Waterman Lab Office Building

AFTERNOON Moderator and Field Leaders: McFarland//Larry Brown

Team Leaders: Fred Galehouse, Rick Galehouse, Paul Chester, Mark Seger, Louis McFarland, Paul DeMuth, Nathan Davis, Bruce Atherton, Nick Miller, others

- ♦ Review of Field Problem and Topographic Mapping
- ♦ Walk to Field Site, Begin Field Survey Problem to completion (15+ ac, 100' grid)
- ♦ Return to Waterman Lab
- ♦ Review of Field Problem (Cornwell/McFarland/Brown)
- ♦ Features of Topographic Maps (Seger)
- ♦ Review of Drawing Contours (Seger/Galehouses/others)

SUPPER Own Your Own PLEASE BE BACK BY 6:30 PM sharp.

2005 Overholt Drainage School
Laser Surveying (Leveling), Topographic Mapping and Mapping Drainage Systems using GPS
Monday, March 7 – Continued

EVENING 6:30–9:00 PM

Moderator: Larry Brown
Instructors: Mark Seger, Fred Galehouse, Rick Galehouse, Ron Cornwell, Louis McFarland, Paul DeMuth, and team leaders

- ♦ Plotting Waterman Field Data (team leaders working with students)
- ♦ Drawing Contour Map from Plotted Field Data (team leaders working with students)
- ♦ Completed Topographic Map of Field Problem
- ♦ Applications - as Time Allows:
    - Profile information from topographic map
    - Slope, grade, earthwork information from topographic map
- ♦ Wrap-up, evaluation, review of Monday's and Tuesday's program (Brown)

9:00 PM **Evening Ends – Program Continues Tuesday Morning at 8:00 AM SHARP - sleep well**

Tuesday, March 8 – 8:00 AM to 12:00 PM
Laser Surveying (Leveling), Topographic Mapping and Mapping Drainage Systems using GPS

MORNING Moderator: Larry C. Brown

8:00-8:30 Review of Monday's Program and Accomplishments (Brown and other Instructors)
Overview of Tuesday Morning Program (Brown)
Instructors: Larry Brown, Nick Miller, William Northcott, Eric Schuler, others

- ♦ Overview and Demonstration of Computer Applications for Drawing Contours
- ♦ GPS Introduction
- ♦ GPS Applications and Drainage System Mapping
- ♦ GPS Mapping Demonstration
- ♦ Group Q/A, Discussion

Noon End Session 1, Wrap-up, evaluation, review of Tuesday's program (Brown)

Box LUNCH At Waterman Lab Office Building, and transition to Session 2, Subsurface Drainage Design

VIRGIL OVERHOLT
DRAINAGE EDUCATION AND RESEARCH PROGRAM
in the
Department of Food, Agricultural, and Biological Engineering
College of Food, Agricultural, and Environmental Sciences
THE OHIO STATE UNIVERSITY
Columbus, Ohio
March 15, 2005

Dr. Larry C. Brown, Professor and Executive Director
International Program for Water Management in Agriculture

Introduction

The program is named in honor of the late Professor Virgil Overholt, who devoted 42 years to education and research on agricultural drainage in Ohio. It also recognizes the outstanding contributions of Ohio industry through the development of drainage materials and equipment. Ohio continues to be a world leader in agricultural drainage and land improvement. Two of the largest corrugated plastic-tubing manufacturers in the nation have their corporate offices and research laboratories in Ohio. The world's largest producer of grade-control equipment for earth-moving machines, two major trencher manufacturers, and several large concrete and clay tile plants are also located in the state. A drainage contractors' school has been held annually for 40 years and an active drainage research program has been underway for more than 41 years.

Ohio leads the nation in the installation of underground agricultural drains. Also, the USDA Agricultural Research Service Soil Drainage Research Unit is housed in the Department of Food, Agricultural, and Biological Engineering, and has been an integral part of the Department's soil and water program for many years. For these and other reasons, the proposed national water management laboratory for humid agricultural lands is planned for Columbus. Such activity indicates that the state has been and should continue to be a leader in agricultural drainage.

The Overholt Drainage Education and Research Program, which includes the International Drainage Hall of Fame Award and the Drainage Design School, is now part of the International Program for Water Management in Agriculture. This program, initiated in 1984, is an outgrowth of nearly 60 years of drainage education and research at The Ohio State University by eminent scholars and educators, such as Virgil Overholt, Mel Palmer, Glenn Schwab, and Byron Nolte.

Program Objectives

The program has three major objectives:

1. To recognize outstanding educators, researchers, contractors, farmers, and/or industrialists who have made significant contributions to the development and use of drainage in agricultural production.
2. To conduct continuing education and outreach education programs in drainage engineering and technology through annual in-depth schools for teachers, researchers, contractors, technicians, industry personnel, and engineers in private or public practice.

3. To conduct drainage research programs to meet current and future needs including: crop response, timeliness of tillage and harvesting, economics, environmental impacts and remediation, and other management factors influencing the installation and operation of agricultural drainage systems.

International Drainage Hall of Fame
Dedicated to Virgil Overholt (1889-1978)

The "Drainage Hall of Fame" was established in the Agricultural Engineering Department at The Ohio State University in 1979. It is dedicated to Virgil Overholt, Professor of Agricultural Engineering (1915-1956) for 42 years of outstanding service in education and research on agricultural drainage. The Drainage Hall of Fame at The Ohio State University was dedicated to the memory of Virgil Overholt on March 9, 1979.

Recognition of Professor Overholt

Superior Service Award, USDA, 1956
John Deere Medal, American Society of Agricultural Engineers, 1961
Ohio Agricultural Hall of Fame, 1969
Distinguished Service Award, OSU, 1971
Honorary Life Member, Ohio Land Improvement Contractor's Association
Registered Professional Engineer
American Society of Agricultural Engineers, Chair, Soil & Water Division
Soil Conservation Society of America, Member
Ohio State University Council, Member
Extension Professors Association, Member
Gamma Sigma Delta, President, Ohio Chapter
Evangelical-United Brethren Church, Chair, Board of Trustees

Professor Overholt's outstanding achievement was the 42 years which he spent as a teaching and extension specialist in Agricultural Engineering at The Ohio State University. He was a gentle and sensitive person with high regard for his fellow man. His keen interest in people and helping solve their problems was one of his outstanding abilities. His specialty was agricultural drainage and other related soil and water conservation problems. He developed many charts and mimeographed materials for making sound recommendations prior to development of present standards. He was one of the leaders in this field of work. In Ohio he was commonly referred to as "Mr. Drainage," and was highly regarded by his students, his colleagues, and farmers throughout the state. Throughout his career he developed a keen sense of observation and an outstanding ability to remember names, places, and events.

Starting in 1979, an annual Hall of Fame award has been given to an outstanding person who has made significant contributions to the development and use of drainage in agricultural production for an extended period of time. The Drainage Hall of Fame Award, in honor of Virgil Overholt, has international scope. Persons eligible for nomination include those who have provided extensive service to the science, art, engineering, and/or practice of agricultural drainage and water management in any of the following areas: teaching, extension education, research, technology development, consulting, contractor training, implementation and practice, leadership in the agricultural drainage industry at the state or national level, etc. Nominations are due before October 1 of each year for that year's award. Each nomination is considered for a total period of three years before a new nomination form must be submitted. Forms and instructions are available from the Executive Director of the International Program for Water Management in Agriculture, The Ohio State University.

Previous Honorees

Don Kirkham – 1979	William W. Donnan - 1991
Jan van Schilfgaarde - 1980	Ted L. Teach - 1992
James N. Luthin - 1981	Robert S. Broughton - 1993
Fred H. Galehouse - 1982	Wiebe H. van der Molen - 1994
Glenn O. Schwab - 1983	Lyman S. Willardson - 1995
R. Wayne Skaggs - 1984	Walter J. Ochs – 1996
Brian D. Trafford - 1985	Carroll J.W. Drablos – 1997
Marion M. Weaver - 1986	Gordon Spoor – 1998
Jans Wesseling - 1987	1999 - No Award
Melville L. Palmer - 1988	Ronald C. Reeve – 2000
Ray J. Winger, Jr. - 1989	2001 – No Award
James L. Fouss - 1990	2002 – Norman R. Fausey

Note: Nominations must be received by October 1 to be considered for that year. A *Jury is selected, and the award announced in January or March, the following year*.

Overholt Drainage School

A drainage school is held each year, usually in Columbus. Since 1999, the school has been held at different locations around the state. Topics range from drainage and subirrigation design, basic and laser surveying for soil and water conservation, and specialty topics in water management. Highly competent, experienced drainage and water management experts help organize and conduct the school. The drainage school is open to participants from any state and country on a first-come basis. Pre-registration is necessary as enrollment is limited to the number that can be accommodated for a quality educational program. School dates are usually announced in advance, i.e., the 2006 school is tentatively scheduled for the week of March 13 (location yet to be determined). A registration fee is charged for books and supplies, and other school related expenses. Interest from the endowments and contributions to the program defray a portion of the costs.

Drainage Research

The program supplements an on-going research effort in cooperation with the U.S. Department of Agriculture and the Ohio Agricultural Research and Development Center. Training of young engineers and scientists, and the support of plot-scale and long-term field research, and computer modeling are emphasized. The collection of reliable data for evaluating the economics and environmental impact of agricultural drainage, water table management with controlled drainage and subirrigation, drainage water management, and performance of drainage installation equipment have major emphasis.

Advisory Group

An advisory committee provides advice and suggestions for program direction, and selects the jury for the Drainage Hall of Fame Award. Committee membership includes: a representative from each Overholt Club contributor; the Ohio Land Improvement Contractors Association; the USDA Soil Conservation Service (Ohio); the Ohio Department of Natural Resources; and the Ohio Section, American Society of Agricultural Engineers, as well as faculty members from the Agricultural Engineering Department at The Ohio State University, and The Land Improvement Contractors of America. Members may be selected from other organizations.

Program Support

Contributions to the program should be made payable to The Ohio State University Development Fund and designated to the Overholt Drainage Education and Research Program. Contributions are tax deductible. Recognition of contributors is as follows:

Overholt Club Member - $10,000 or more
Gold Sponsor - $5,000 to 9,999; Silver Sponsor - $500 to 4,999; Bronze Sponsor - $100 to 499

Contributors

(Updated listing will be released Fall of 2005)
The Program Proudly Recognizes and Thanks Its Supporters

For more information about the program, email, write or phone:

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Overholt Drainage Education and Research Program
International Program for Water Management in Agriculture
Department of Food, Agricultural, and Biological Engineering
The Ohio State University
590 Woody Hayes Drive
Columbus, Ohio 43210-1057
Phone: 614.292.3826 FAX: 614.292.9448 brown.59@osu.edu

Tab for laser Surveying

Slide 1

LASER SURVEYING

Ohio **L**and **I**mprovement **C**ontractors **A**ssociation

Ron Cornwell, Paul Demuth,
Fred & Rick Galehouse
Louis McFarland

Slide 2

Objectives

Introduce parts of a Laser Surveying System.

Properly set up and use the system to produce usable information (Elevations).

Slide 3

Got Some Questions?

There is a lot of information in this course and we will be proceeding rather quickly.

If you have questions along the way please ask them.

There are no stupid questions.

Slide 4

LASER Acronym

L - is for Light
A - is for Amplification by
S - is for Stimulated
E - is for Emission of
R - is for Radiation

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Slide 5

Parts of a Laser Surveying System

Laser Transmitter with tripod or mounting.

Level Rod (Conventional or *Lenker Rod*).

Rod Receiver (Laser light receiver on Level Rod).

Field book to record information

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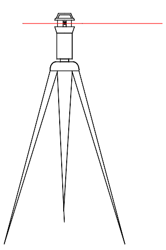
Slide 6

Laser Transmitter

Sometimes called the *Command Post* with tripod or mounting.

May have external battery



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Slide 7

Laser Transmitter

Produces a light beam rotating in a plane.

The light may be visible (red) or invisible (infrared).

The plane may be level (0.00 grade) or at a slope for machine control.

Slide 8

Laser Transmitter

Rotation speed may be adjustable.

Leveling is usually automatic.

Set the base level within the leveling range

Slide 9

Laser Transmitter

Check the legs are snug in the base

Set the legs firmly in the ground

Set the grade to 0.00 or level.

Slide 10

Rod Receiver

Has a battery as a power source with an on/off switch.

Has a pointer at the numbers on the tape.

Slide 11

Rod Receiver

Has lights or display for high, on grade and low.

Has an adjustment for sensitivity.

Has an audible output with a steady tone for on grade.

Slide 12

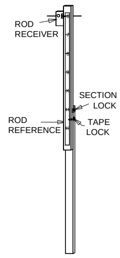
Level Rod (Conventional)

Laser Receiver reads at rod
Range 10', 15' or 20'
Low cost Few working parts
ELEV produced by using height of instrument calculations
Many subtractions in book
Field book needs extra columns
Numbers from bottom up

Slide 13

Level Rod (Lenker Rod)

- Little arithmetic w/Laser reading at rod
- Range 10' 15'
- Direct ELEV reading
- Has working parts & needs reasonable care



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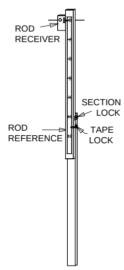
Lenker Rod

- The Lenker rod is a sliding, two-section rod.
- The sections have a friction section lock to keep the parts from sliding.



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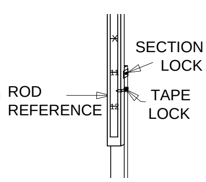
Lenker Rod

- The numbers and graduations are on a loop tape that has eyelets alon one side.
- The tape lock fits in one of the eyelets.



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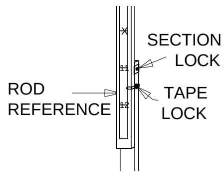
Lenker Rod

The rod has a reference mark a given distance from the bottom of the rod



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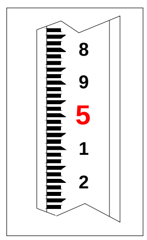
Lenker Rod

The graduations used are:
- Feet, (1.00')
- Tenths of feet (0.10')
- Hundreds of feet (0.01')

Large numbers are feet centered on the foot mark and are usually colored red.



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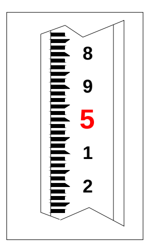
Slide 18

Lenker Rod

Small numbers are tenths of foot (0.1) centered on the tenths of foot mark.

Lines are the same width as the spaces and are 0.01' high.



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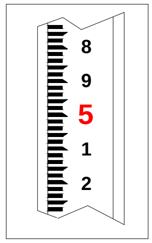
Lenker Rod

The line is pointed on the foot mark, the tenth's of a foot mark and the 5 hundredths of a foot mark.



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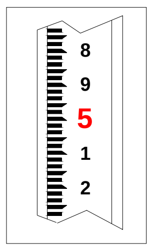
Lenker Rod

Numbering on a Lenker rod is from the top down

The Lenker tape or any rod should always be read when the rod is vertical or plumb



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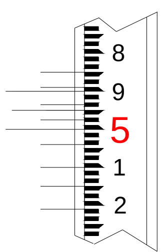
Test

LENKER ROD

NOTE: ROD GRADUATIONS IN FEET , 10ths, AND 100ths

WHEN POINTER IS BETWEEN TWO MARKS THE LOWER MARK IS THE CORRECT READING



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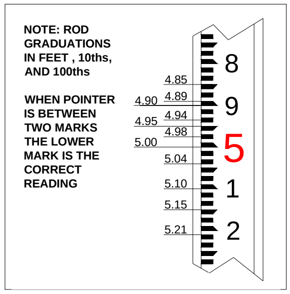
Answer



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Slide 23

Lenker Rod

The tape is a movable continuous loop and any number may be placed at the plane of light or the line of sight.

The tape can be connected to the bottom rod section with the tape lock.

The tape lock often comes loose.

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Slide 24

Using a Lenker Rod

There are only two operations that you need to learn to use a lenker rod.

Setting the Tape - after the transmitter is moved.

Reading the Rod - to produce elevations.

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Slide 25

Setting the Tape

Find the light.

Lock or hold the rod sections together.

Move the tape so the elevation (ft, tenths, hundreds) is at the receiver pointer.

Slide 26

Setting the tape

Use a number that represents a known elevation (BM or TP).

If the elevation is 100.00 set the tape at 0 (also reads 10) and (100 becomes your constant).

Slide 27

Setting the tape

Set the tape lock in one of the holes and tighten the lock screw.

Check the setting and adjust if not correct.

Follow the reference point around the rod and read the tape.

Slide 28

Setting the tape

Record the number in the notes column.

The reference # is a check to see if the tape lock comes loose. If you do not have the reference number and the tape lock comes loose you must go back to a known elevation point and resurvey from there.

Slide 29

Reading the Rod

Move to a point of unknown elevation and find the light by moving the rod sections or the receiver.

Read the tape at the pointer.

Slide 30

Reading the Rod

On turning points and benchmarks read the tape to hundreds of a foot.

When reading ground shots read to tenth of a foot.

Record what you read.

If you read to hundreds record as hundreds.
If you read to tenths only record as tenths.

Slide 31

Using the Rod

Record in book and add constant to produce elevations.

If you read 2.4 (and your constant is 100) the elevation is 102.4

So the elevation difference is (102.4 – 100.00 = 2.4') or just under 30"

Slide 32

Using the Rod

Move to a point of unknown elevation and read the number at the pointer.

If you read .95 (and your constant is 100) the elevation is 100.95

So the difference is (100.95 – 100.00 = .95') or about one foot

Slide 33

Field Book Headings

Date

Location

Kind of Survey

Weather Conditions

Survey Party (1person)

Type of Equipment

Type of Rod

Slide 34

COLUMN HEADINGS

STA Location of reading.
ELEV Elevation of STA.
ROD The numbers from the rod tape.

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COLUMN HEADINGS

CONST The difference between the number from the tape and the Elevation.

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COLUMN HEADINGS

Notes/Ref Additional information about the elevation point.
Notes/Ref A number to check if the tape lock has come loose.

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Jan 7, 2002 | Rod – Fred | Command post
Septic school | Book - Rick | Trans grade 0.00
Differential survey | Observer - Ron | Lenker Rod

STA	CONST	ROD	ELEV	NOTES/REF
BM # 1	100	0.0	100.00	FLOOR/R4.87
TABLE		2.4	102.4	
BOX		0.95	100.95	

Slide 38

Explaining the Loop Tape

The loop tape has some special conditions.

If the loop tape is 10 ft the readings are correct.

There may be a 10 ft adjustment to the constant if you have gone past the 10 ft mark.

Slide 39

Explaining the Loop Tape

If the loop tape is 15 ft there is a choice of tape settings when the units are between 0 and 5 or between 10 and 15.

This may require a 5 ft adjustment to the constant when the readings go past the 15’ mark

Slide 40

A Helpful Rule Reducing the Number of Adjustments Needed

When elevations are below the known elevation, select the higher or 10 to 15 range.

Slide 41

Are there any questions ?

Slide 1

CHECKING THE TRANSMITTER

Ohio Land Improvement Contractors Association

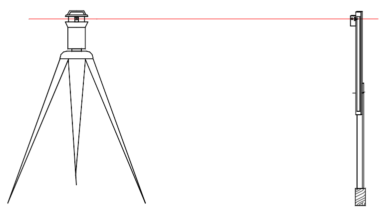
Fred & Rick Galehouse

Ron Cornwell

Paul Demuth

Slide 2

Checking the Transmitter



Slide 3

Checking the Transmitter

Check legs are snug in the base

Set the base very level.

Set the tripod firmly.

Set the grade to 0.00 or level.

Slide 4

Checking the Transmitter

Go to a solid point about two thirds the range of the transmitter.

Aim one of the grade directions at the point.

01/09/04 CHECKING THE TRANSMITTER V1 4

Slide 5

Checking the Transmitter

01/09/04 CHECKING THE TRANSMITTER V1 5

Slide 6

Checking the Transmitter

A precise reading is one with the sensitivity at the finest setting and the rod held very vertical.

You may want to average several readings

01/09/04 CHECKING THE TRANSMITTER V1 6

Slide 7

Checking the Transmitter

Find the plane of light and read a precise reading and record

Return to the transmitter, or have an assistant turn the transmitter 180 degrees.

Slide 8

Checking the Transmitter

Record another precise reading.

A difference in readings is the amount of error in that direction.

Slide 9

Checking the Transmitter

Turn the transmitter 90 degrees.

Record another precise reading.

Turn the transmitter 180 degrees.

Record a precise reading.

Slide 10

Checking the Transmitter

A difference in readings is the amount of error in that direction.

If the amount is small or “0” you will have confidence in the accuracy of the transmitter

Slide 11

Checking the Transmitter

If the readings recorded are different, this indicates an error in the transmitter and the transmitter should be serviced .

A dual slope transmitter could have an error if both grades are not set level.

Slide 12

Are there any questions ?

Station	Constant	Rod Reading	Elevation	Notes

Tab for Laser Manual

Galehouse Laser Surveying Manual

Preface

This manual is a labor of love by Mr. Fred H. Galehouse, Doylestown, Ohio. Fred originally developed this manual for laser surveying educational sessions taught at the Overholt Drainage School, as part of the Virgil Overholt Drainage Education and Research Program at The Ohio State University. The development of this manual was guided by Fred, and since 1989 it has evolved through his continued contributions and dedication, and from suggestions, recommendations, refinements by many people, the least of which is Fred's son Rick (co-author, illustrator, etc.). The current version is a portion of the original written by Fred in 1989. The following is the verbatim 1989 Preface.

This manual was prepared for the laser surveying school of the Virgil Overholt Drainage Education and Research Program, at The Ohio State University.

Most of the manuals I have seen treat laser surveying as a new method and do not interface with basic surveying procedures. In this manual I have tried to provide this connection and in the process show the advantage of advances in use of the lenker rod, laser surveying and machine control. The rod usage illustrated in this manual is a lenker rod.

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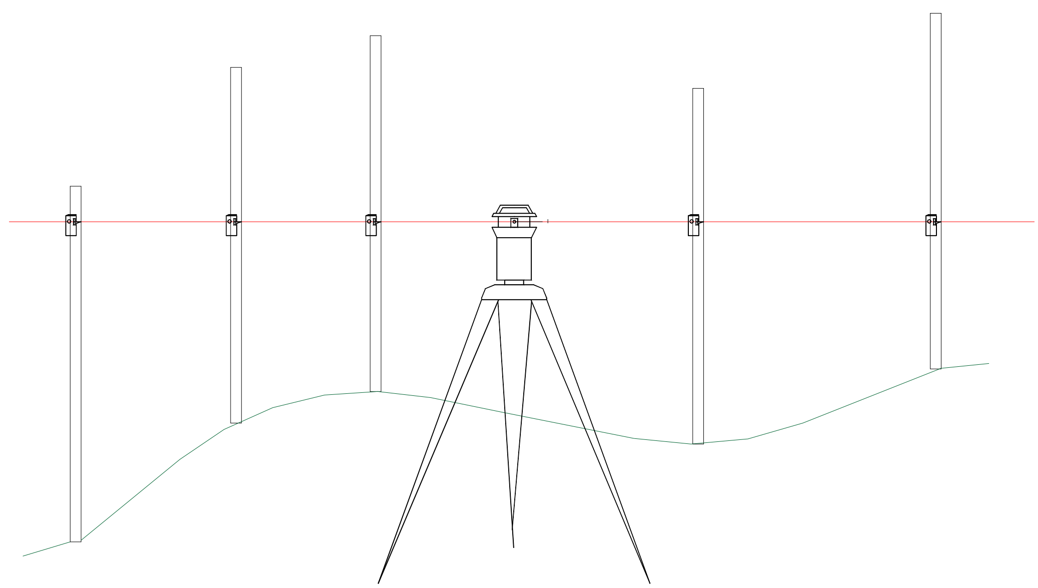
I would be the first one to say that it is not complete and will probably never be completely up to date as there are new advances and changes, constantly. I just recently realized there are no references to lenker rod usage in Soil Conservation Service Field manuals. I would appreciate any comments on omissions and improvements that would enable an update. The manual is written for subsurface drainage only, due to time constraints. Some other manuals are excellent in their coverage of land grading.

Thanks to all of you who have helped.

Fred Galehouse, March 1989

Fred has continued to provide this material for the Drainage School since 1989, and each year presents revisions and enhancements, with the help of his son Rick. The Overholt Drainage School instructors, including Fred, have used the various revisions of this manual in 13 Drainage Schools since 1989 (1989-1992; 1994; 1996-1998; 2000-2001; 2003-2005), helping to educate over 550 land improvement contractors, farmers, consultants, and others. Fred, the first and only land improvement contractor voted to the International Drainage Hall of Fame continues to donate the use of his manual to the Overholt Drainage Education and Research Program to help advance the knowledge and skills of land improvement contractors worldwide. We thank Fred Galehouse for his continued contributions to the profession of land improvement. Dr. Larry C. Brown, The Ohio State University; brown.59@osu.edu

LASER MANUAL



BY
FRED GALEHOUSE
1989

PREFACE

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Most of the laser manuals I have seen treat laser surveying as a new method and do not interface with basic surveying procedures. In this manual I have tried to provide this connection and in the process show the advantage of advances in use of a Lenker rod, laser surveying and machine control. The rod usage illustrated in this manual is a Lenker rod.

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Fred Galehouse
March 1989

Laser Manual Table of Contents

LASER MANUAL

The purpose of this manual is to provide a better understanding of the use of Laser Systems and the Lenker Rod in differential leveling, profile leveling, grade setting and machine control. The information presented in this manual should be considered as basic information and thoroughly understood before using it as a basis for construction.

The contractor should have a basic knowledge of drainage design, how to draw a plan, machine operation, etc. The manual will cover reading the surveying rod, checking the Laser Transmitter, keeping field notes, drawing a profile and figuring information for machine control. In surveying measurement in a vertical direction is involved. This manual will use feet, tenths and hundreds of a foot. This is a common practice in surveying due to the number of subtractions involved.

A Laser grade control system allows one setup to grade a number of drains or large area with a high degree of accuracy if the system is used properly. There are numerous makes of Laser grade control systems that operate on the same principle. The operation of any one may be slightly different than described in this manual.

LASER SYSTEM PARTS

The basic parts of any Laser system are as follows.

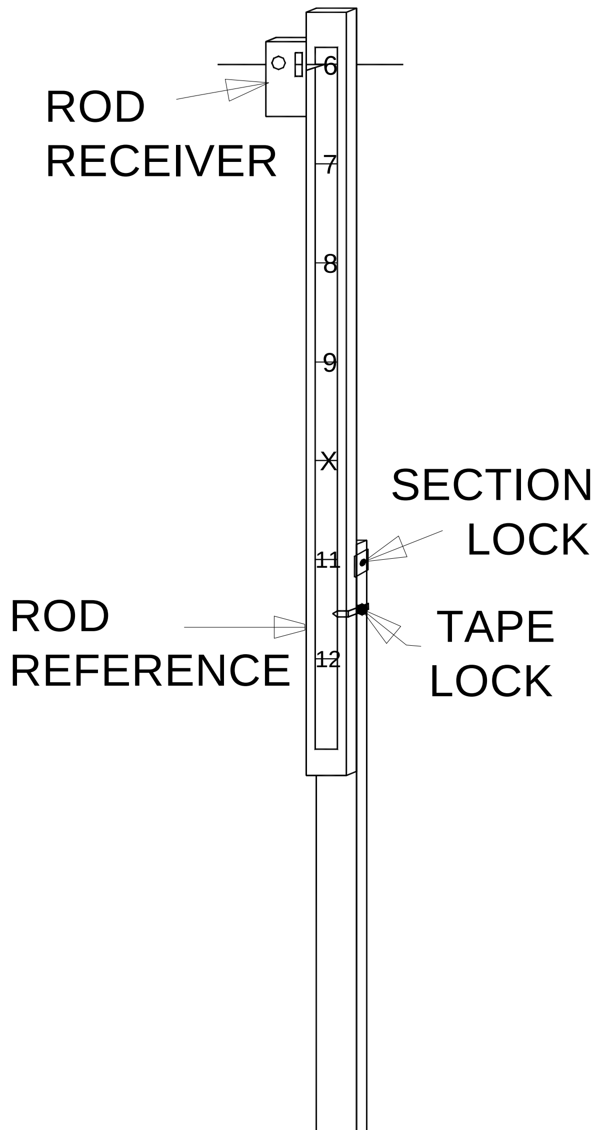
LASER TRANSMITTER (command post) with tripod or mounting
LEVEL ROD (LENKER ROD or conventional)
ROD RECEIVER (Laser light receiver on Level Rod)
LASER RECEIVER (on machine or mast)
MAST (to hold laser receiver)
CONTROL BOX and connecting wires
GRADE BREAKER with control panel, may be in control panel

Only the Laser Transmitter, Level Rod and Rod Receiver are needed for surveying. The other equipment is used for machine control.

Laser is an acronym for - Light – Amplification – Stimulation – Emission – Radiation. Sunlight has the same wave lengths as the laser so the rotation of the beam makes a blinking lightt which the receivers can identify,

The Laser Transmitter contains a Laser light generator and columinator to generate a narrow beam of light. The narrow beam of light is rotated to produce a plane of Laser light. The plane of light may be level and parallel to a datum or it may have grade by setting the Laser Transmitter as desired. The Laser Transmitter is usually set on a tripod or other solid base. In drainage work it is usually set on a high tripod so the beam of light is not obstructed by parts of the machine or other machines working in the area.

LENKER ROD & ROD RECEIVER



The Rod Receiver is a small Laser Receiver, which slides on the top section of the rod and has a pointer at the numbers on the tape where the Laser light beam would hit. The Rod Receiver has lights for high, on grade and low. It also may have a buzzer, which beeps on and off when high or low, but is continuous when centered on the plane of light or “on grade”. It has a battery as a power source, with an on/off switch and an adjustment for sensitivity.

USING THE LENKER ROD AND ROD RECEIVER.

The Lenker Rod is most often used in Laser surveying and machine control

1. Because elevations are higher and rod readings are lower as the land rises, the numbering on a Lenker rod is from the top down.
2. The tape is a continuous movable loop and any number may be placed at the line of sight or light.
3. The tape is marked off in units (1.), tenths (0.1), and hundredths (0.01). Often the units are marked in red and the tenths numbers are in black and the hundredths are the top and bottom of the lines with the spaces between the lines the same height as the lines. The readings are taken counting down. Tape may be in meters or feet, for this manual, feet will be used.
4. The tape can be locked to the bottom rod section with the Tape Lock, which has a little pin that fits in a grommet in the tape. The bottom section also has a Section Lock and Rod Reference Point (a marked distance from the bottom of the rod). The Rod Reference points to the numbers on the front of the Lenker Rod. When the tape is locked, sliding the rod sections will not change the Rod Reference Point reading.

To measure the vertical distance from the plane of light to some point is the first use. The easiest way to get readings with the Lenker Rod is to use method "A" or "B" as described on the following pages. These methods will allow readings to be taken from the maximum to the Rod Reference Point by sliding the sections of the rod to bring the Rod Receiver into the plane of light. If the plane of light is below the top of the rod, when closed, the Rod Receiver will have to be moved to the plane of light and the tape moved to the Rod Receiver Pointer. Whenever readings are taken only vertical measurements are desired, so the rod needs to be held vertical. Any angle on the rod will result in a reading that is larger than the correct reading.

A conventional Level Rod has numbers from the bottom up and readings are counted from the bottom up. The numbers are reversed from elevations so subtraction is needed to find elevations.

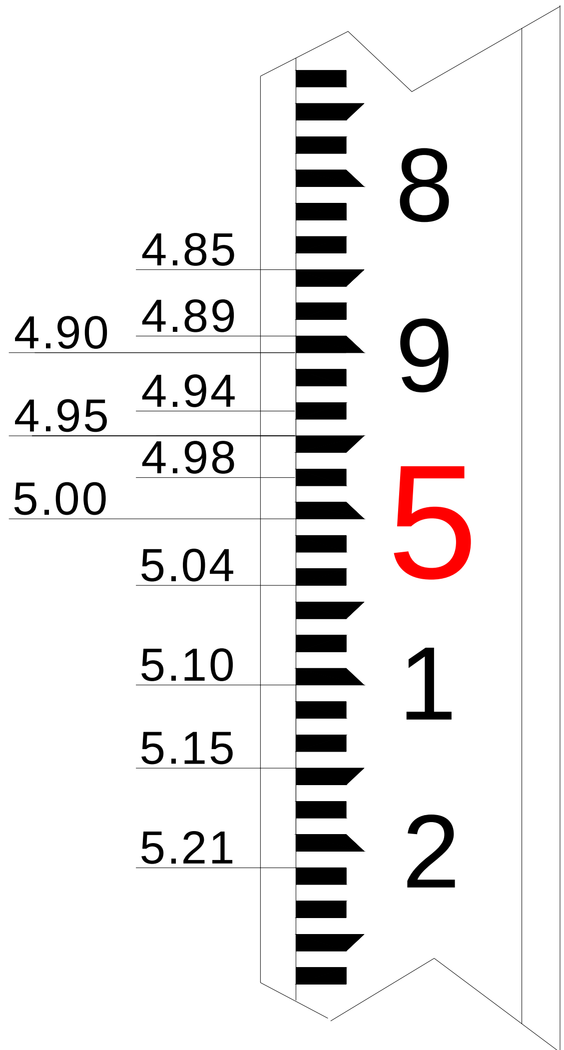
PRECISE READINGS

When very precise readings need to be made. First adjust the sensitivity for the smallest "on grade" signal (dead band). Set the rod vertical and lean the rod slowly from side to side about 10 degrees, reading the smallest number. Do the same thing in the foreword and back direction. Repeat at least three times, and then use the average of the three readings. A rod level may be helpful in keeping the rod vertical.

LENKER ROD

NOTE: ROD GRADUATIONS IN FEET , 10ths, AND 100ths

WHEN POINTER IS BETWEEN TWO MARKS THE LOWER MARK IS THE CORRECT READING

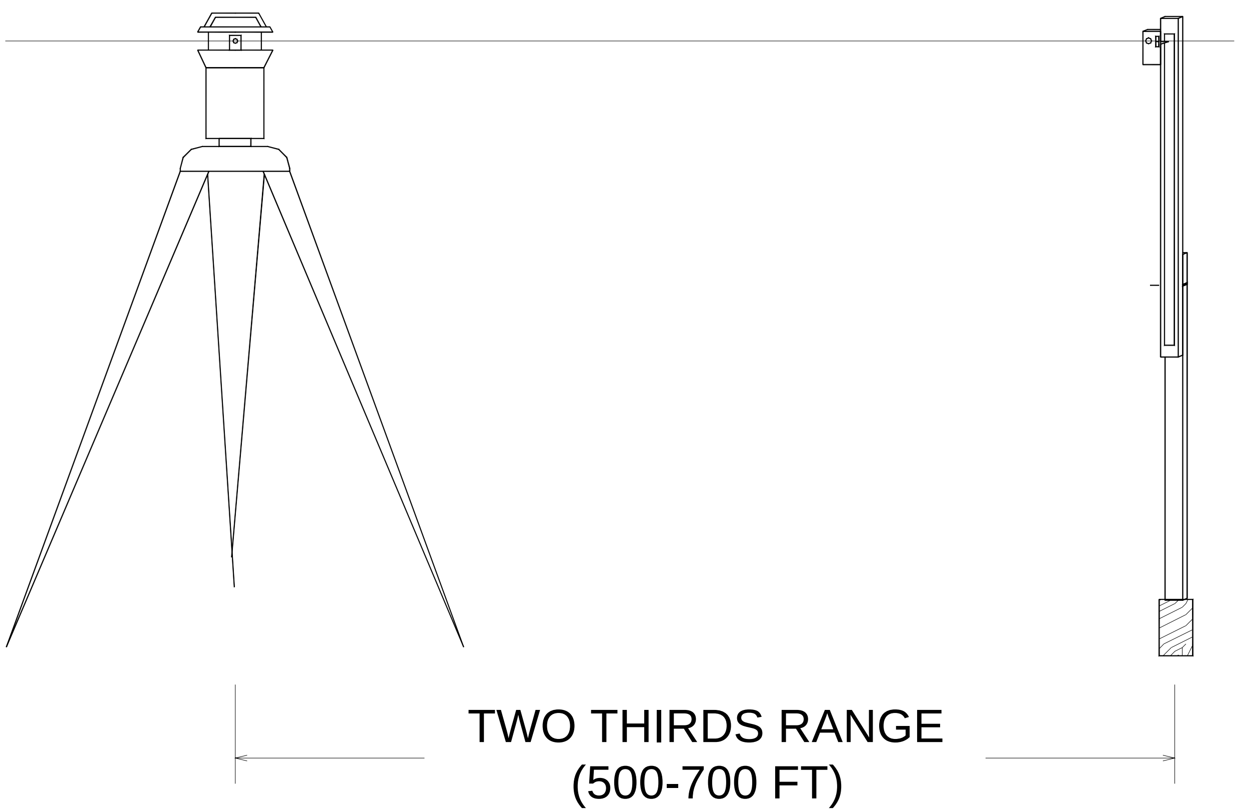


CHECKING THE LASER

Just like a level or transit, a Laser Transmitter needs to be checked for accuracy. This check should be done about monthly, depending on use and should probably be checked before a critical job. It should also be checked if it is bumped or in some way subjected to severe handling.

To check the Laser Transmitter set it up firmly with the light plane level or zero grade. It helps to set the tripod base close to level. Point the "Up grade" of the Laser Transmitter toward a stake or solid point approximately 500 to 750 ft. away or two thirds to three-fourths the range of the Laser Transmitter. Allow the Laser Transmitter to adjust and become stable. Take the survey rod to the point, find the light and take precise rod readings. Rotate the Laser Transmitter 180 degrees and after the Laser Transmitter adjusts and becomes stable take precise rod readings at the same point. If the rod readings are not the same some adjustments need to be made. The Laser Transmitter should also be turned with the cross grade pointing at the stake and the procedure followed again to check the cross grade for accuracy.

On some Lasers it is possible to make the adjustment in the field, while on others it must be returned to a repair facility. Check the manual supplied with your system to see which is right for your system.

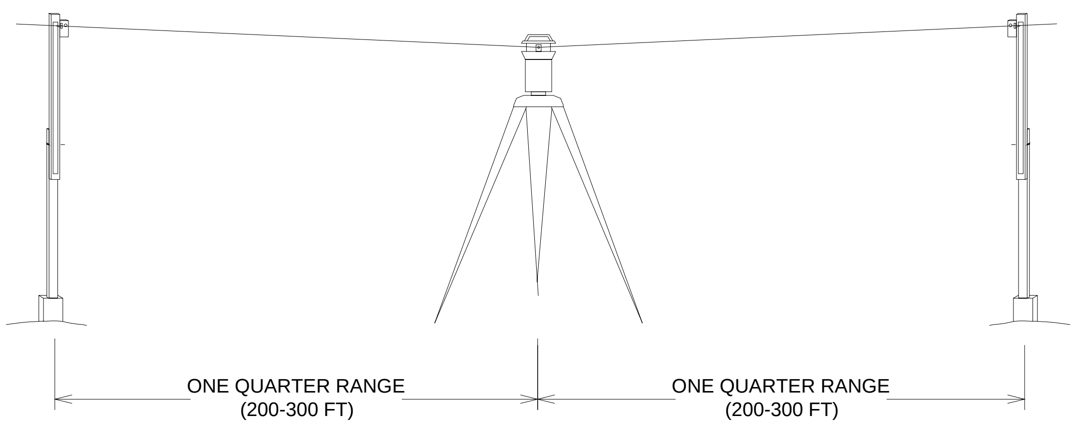


CONE ERROR CHECK

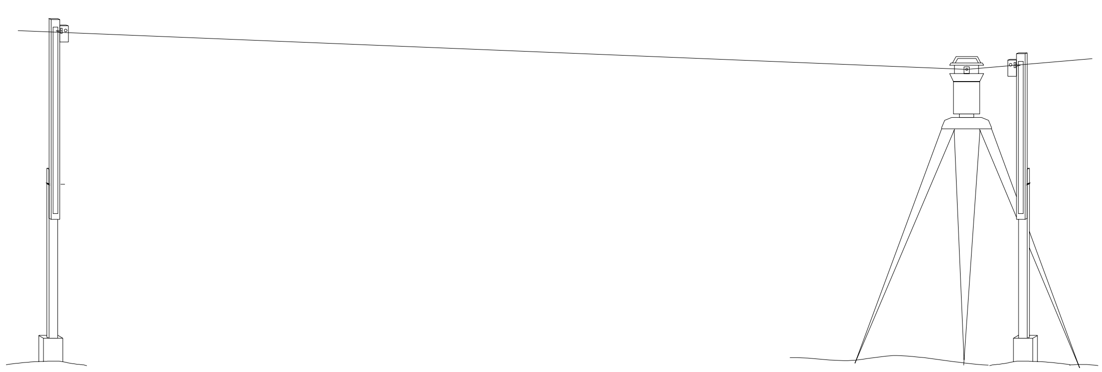
This check is used to determine whether the plane of light is flat or funnel shaped. If a prism is used in the rotating head this error cannot occur. To check for a flat plane the Laser Transmitter should be set up between two points about 500 ft. apart or half range. Set the Laser Transmitter grade level or to 0.00 with the upgrade in the direction of one of the points and allow the transmitter to become stable. Record precise rod readings at each point; the difference is the true elevation difference between the two points. Turn the Laser Transmitter to the cross grade and again record precise readings at each point. Again find the true elevation difference. Move the Laser Transmitter close to one of the stakes and in line with the stakes. Record precise rod readings at each point and compare the elevation difference with the first set of readings. The Laser Transmitter should be sent to a repair facility if there is more than 0.02 ft. Elevation difference between the readings.

This test may be done at night between buildings or posts. Set the rotation slow so the position of the passing beam may be marked on the posts or buildings. For the second set up move the Laser Transmitter near one of the buildings and with some elevation distance (0.5 ft.) between the marks. The second marks should be the same vertical distance from the first marks at each point.

CHECKING CONE ERROR



POSITION 1 -- TRUE ELEVATION DIFFERENCE



POSITION 2 -- CHECK FOR SAME DIFFERENCE

ELEVATION SURVEYING - CONVENTIONAL

Elevation surveying is used to determine the elevation of points in a field or area. Elevations can then be used to produce topographic maps, profiles, and determine differences in elevation. Elevations are the basic information used in planning most types of construction. Let us start by recording rod readings and calculating elevations. The format below becomes an official record when recorded in a field book.

Locations are recorded in the field book in the “Station” column and the convention is to use letters and/or numbers. Stations are also frequently described as distance from some starting point, and written as (2+40) meaning a distance of 240ft. Bench Marks are usually the starting point and marked (BM# __) in the “station” column, they should also be described in the “DESC” or “NOTE” column so the Bench Mark can be found at another time and used to complete work. Turning Points are a point where the elevation is maintained while the transmitter is moved and are marked in the “station” column (TP#_), a station can be a turning point (TP 5+11)

FIELD BOOK HEADINGS

Record the date, location, weather, kind of survey, the survey party, type of equipment, (Laser Transmitter grade, height, direction and Lenker rod).

STA	BS (+)	HI	FS (-)	ELEV	NOTES

SETTING UP AND RECORDING READINGS

1. Select the Laser Transmitter location so the height when set up is no more than the maximum rod length (15') above the lowest point to be surveyed. Selecting this height will become easier with experience in the field.
2. Set up the Laser Transmitter following the procedure for the system. Use a firm base and set the tripod solidly.
3. Set the Laser Transmitter grade to 0.00%
4. Use either method "A" or "B" to read the rod
5. Record the reading at the appropriate place in the field book (see definitions for "BS+" back sight or "FS-" front sight and Height of instrument “HI”).
6. Move to the next station and repeat steps 4, 5 and 6.

This method produces rod readings the same as with a conventional Level Rod. For large areas or areas with more than the rod height elevation difference, select a turning point (TP) and move the Laser Transmitter as appropriate. To calculate the elevations (note reduction) start from a known (or assumed) elevation recorded in the (ELEV) column, add the back sight (BS +) rod reading, to find the Height of instrument (HI), enter it in HI column in the field book. From the HI subtract the Front sight (FS -) rod reading for each point, to find the elevation.

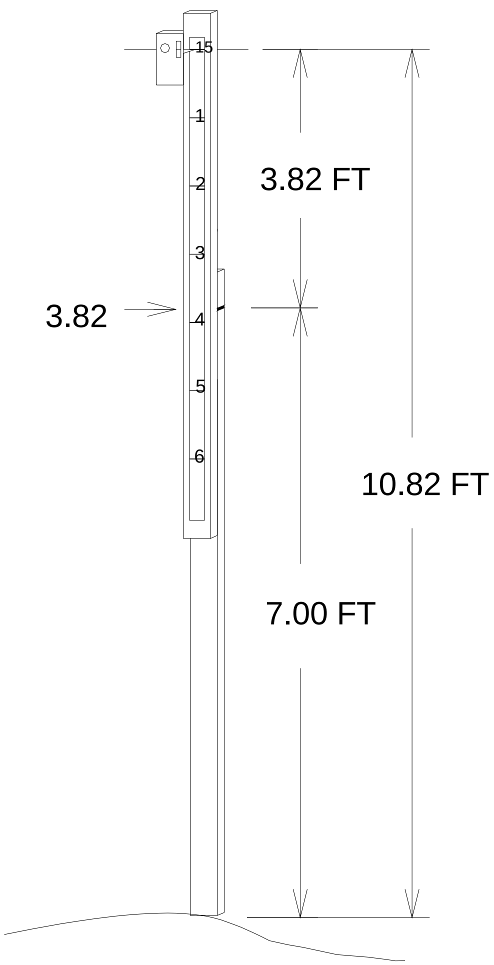
Some of this note reduction should be done in the field to close the circuit and check for errors before leaving the field.

USING THE LENKER ROD AND RECEIVER FOR ROD READINGS

Method "A" - Rod Reading with Addition

Conventional Rod Readings

To read the distance from the plane of light to the ground, using addition.



Step 1	Move the Rod Receiver near the top of the rod so the pointer will be over the tape.
Step 2.	Advance the tape to set the 0.00 or 15.00 at the pointer on the Rod Receiver. Do not lock the tape.
Step 3.	Set the rod vertical on the point you wish to read.
Step 4.	Move the top section until the Rod Receiver is centered on the plane of light.
Step 5.	Read the tape at the Rod Reference Pointer.
Step 6.	Add the tape reading to the rod reference.

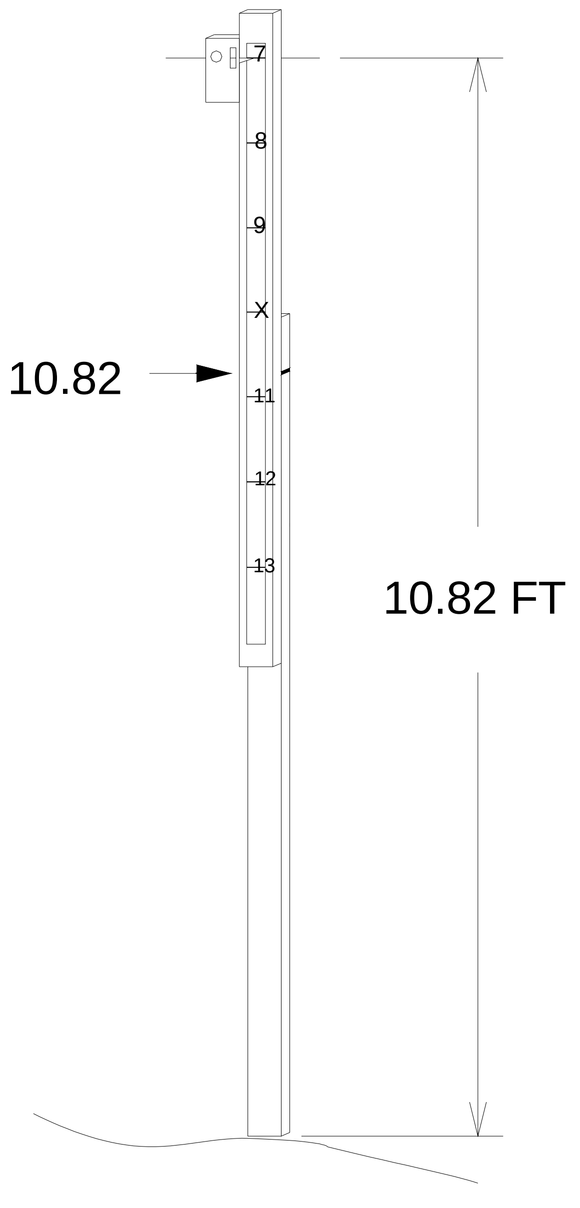
3.82	= tape reading
7.00	= rod reference
10.82	= distance from plane of light to the ground or conventional rod reading.

USING THE LENKER ROD AND RECEIVER FOR ROD READINGS

Method "B" - Rod Reading without Addition

Conventional Rod Readings

To read the distance from the plane of light to the ground, without addition



Step 1 Move the Rod Receiver near the top of the rod so the pointer will be over the tape.

Step 2 Advance the tape to set the rod reference number (7' or 8'), at the Rod Receiver Pointer. Do not lock the tape.

Step 3 Set the rod vertical on the point you wish to read.

Step 4 Move the top section until the Rod Receiver is centered on the plane of light.

Step 5 Read the tape at the Rod Reference Pointer. The reading is the distance from the plane of light to the bottom of the rod without addition

ELEVATION SURVEYING - DIRECT

The Laser surveying system with a Lenker rod may be used to read elevations directly and avoid some of the note reduction (subtraction and calculations)

FIELD BOOK HEADINGS

Column headings would be as shown below:

Record the date, location, kind of survey, weather, people and their job, equipment, laser grade, and use of a Lenker rod.					
STATION		**CONST.**		**ELEV.**	**NOTES/REF**
BM# 1	.			742.56	

SETTING UP AND RECORDING ELEVATIONS

1. Select the transmitter location so the plane of light is above the Benchmark and at a height to cover the largest number of points in the transmitter range.
2. Set up the transmitter following the procedure for the system. Set the tripod solidly to provide a firm base. If the transmitter has grade capabilities set the grade level (0.00%)
3. Take the Lenker rod to the benchmark and find the plane of light with the rod receiver. Hold or clamp the rod sections together.

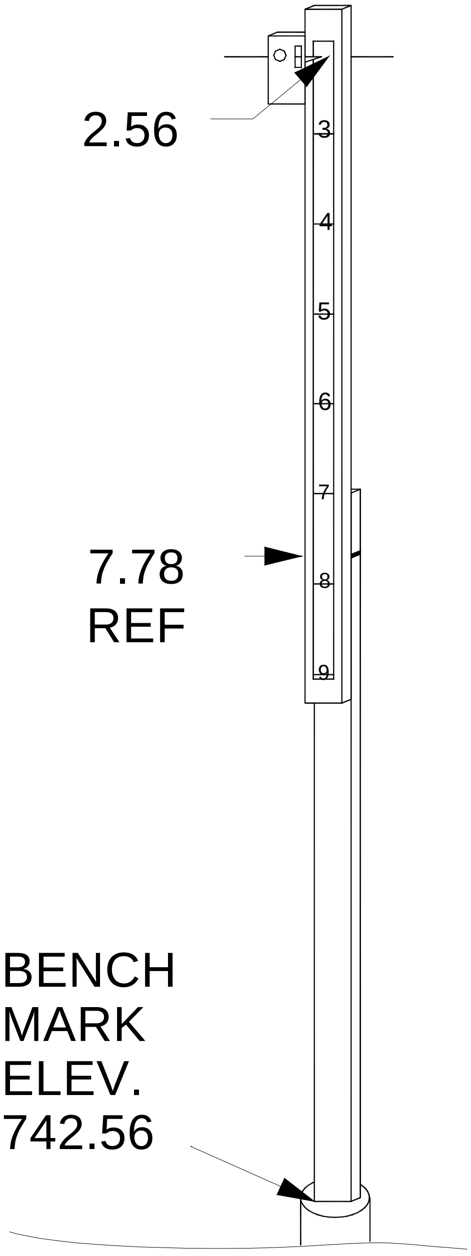
Note - Some Lenker rods have 10 ft. Loops, while others have 15 ft loops. The larger loops have a greater elevation range, When using a Lenker rod with a 15 ft tape there will be times that a choice or rod readings is available when setting the tape. When the units (feet) are between 5 and 10 there is no choice, but when the units are between 0 and 5 or between 10 and 15 there is a choice. You have to be careful if your reading is past the 15 ft mark, as the readings will have to be adjusted by 5 ft. The following rule will be helpful in reducing the times that will require adjustment.

RULE: When elevations are below the known elevation select the higher or 10 to 15 ft. range.

4. Move the Lenker tape until the unit's digit, tenths, and hundreds of feet of the benchmark are in line with the rod receiver pointer and lock the tape. Check the setting, as any error will be reflected in the readings that follow. The Constant is the Elevation minus the tape setting. Record the constant. Loosen the clamp on the rod sections but leave the tape locked.
5. Go to a new location and read at the pointer and add the constant to get the elevation.

USING THE LENKER ROD AND RECEIVER FOR DIRECT ELEVATIONS

Method "C" - Direct Elevations



Direct Elevation Surveying

Step 1	At Bench Mark, known elevation or assumed elevation (742.56). Select the feet, tenths and hundreds from the elevation to find the Rod Reading. (2.56)
Step 2	Find the plane of light with the Rod Receiver and lock the rod sections together.
Step 3	Move the tape so the Rod Reading from Step 1 is at the Rod Receiver. Lock the tape and check the accuracy of the setting. Any error in setting the tape is included into all the following elevations
Step 4	Record the constant as the difference between the elevation and the Rod Reading. (742.56 – 2.56 = 740 the constant to record or remember.)
Step 5	Read the number at the Rod Reference and record as a note. Unlock the rod sections.
Step 6	Go to the next location; find the plane of light by moving the rod sections or the Rod Receiver.
Step 7	Read the tape at the Rod Receiver. Add the constant to the tape reading and record the elevation. (740 + 4.38 = 744.38) and station
Notes:	The Rod Receiver may move and the rod sections may move as long as the tape is locked to the bottom section of the rod.
	Turning Point - (TP) when you wish to extend your survey. Complete Step 7 to find the elevation and move the transmitter to new location. Then go to Step 1, use the elevation from Step 7.

EXAMPLE SURVEY

To illustrate let us go through an example.

As the ground is lower than the benchmark

Set up the transmitter as low as possible as all of the elevation readings will be lower.

Take the Lenker rod to the benchmark find the plane of light. Lock the sections together.

With a BM # 1 elevation of 742.56 the tape can be set at 2.56 or 12.56. Since the elevations are lower than the benchmark, select 12.56 and lock the tape, and unlock the sections. The constant is the Elevation (742.56) minus the tape setting (12.56), which equals 730, (742.56 - 12.56 = 730) which is recorded in the field notes.

Each time the tape is locked it is good practice to double check the setting and adjust the tape if necessary. Then record the reference number.

Moving to the next point (TP # 1) and reading the tape at 3.72. The Constant (730) plus the rod reading (3.72) equal the Elevation (730 + 3.72 = 733.72).

Move the transmitter. The following elevations are lower, so the higher range of numbers needs to be selected. (3.72 or 13.72) Select 13.72.

Find the light and set 13.72 at the receiver pointer. Lock the tape. Check the setting and figure the constant (733.72 - 13.72 = 720). Record (720) the constant. Read and record a new reference number.

Set or select a BM # 2 and determine the elevation. With a rod reading of 6.18, the elevation of BM # 2 is 726.18. (720 + 6.18 = 726.18).

When this is part of a bench level survey we need to survey back to the starting point to close the circuit to check for accuracy.

To close the circuit, move the transmitter to a new location. Adjust the rod receiver to the light and set the tape at 6.18 at the receiver pointer and lock the tape. (As this number is between 5 and 10 there is no choice.) Check the setting. Record the reference number and the constant.

Select a turning point, find the light and read the tape as 14.21. This means that the elevation is 734.21 (720 + 14.21 = 734.21).

After moving the transmitter and reading back at TP # 2, (elevation 734.21). The closing benchmark is higher so the tape should be set at the lower number (4.21 or 14.21), select 4.21. Find the light and lock the tape. Check the setting. Record the reference number. Figure the constant (730) and record. (734.21 - 4.21 = 730)

Move to BM # 1. The reading at BM # 1 is 12.55 so the elevation is 742.55 (12.55 + 730 = 742.55)

As this is different than the starting elevation (742.56 - 742.55 = 0.01), you will have to determine if this error is acceptable for your application, or run the survey again.

FIELD NOTES FOR EXAMPLE # 1

STATION		**CONST**.	*ROD*	**ELEV.**	**NOTES/REF**
BM#1		 **730**	 *12.56*	**742.56**	 **5.47**
TP#1		*730* **720**	*3.72* *13.72*	**733.72**	 **3.56**
BM#2		*720* *720*	*6.18* *6.18*	**726.18**	 **7.63**
TP#2		*720* **730**	*14.21* *4.21*	**734.21**	 **7.98**
BM#1		*730*	*12.55*	**742.55**	

ONLY BOLD NUMBERS NEED TO BE ENTERED IN THE FIELD BOOK,

NUMBERS IN ITALICS ARE TO MAKE THE EXAMPLE CLEARER.

This example seems complicated but there are only two operations to do when using a Lenker rod for direct elevation surveying.

Setting the rod to match a known elevation

Reading the rod to find an unknown elevation

ALLOWABLE ERROR

The generally accepted allowable error is $- 0.007 \sqrt{\text{length}/100}$

SOURCES OF ERROR

Not reading the rod correctly.
Not holding the rod plumb.
Not centering on the light beam.

TOPOGRAPHIC SURVEYING

Topographic surveying is done to show the relief features or surface configuration of an area. Not every field needs a topographic survey, but if the field is large and the slope is complex a topographic survey can give you a better view of the area. The topographic survey can let you design a better and more complete system. There are a number of ways of producing a topographic survey but the one most commonly used with Laser Systems is the grid system.

LAYING OUT A GRID FOR TOPOGRAPHIC SURVEYING

Set up a grid of stakes at corners of 100' or 200' squares. The grid is marked with stakes or flags. Use field edge, road or crop rows as a base line to measure stake locations. The edge of the field is often not as important as several feet in from the edge, so start about 10 feet from the field boundary or fence. The square is easy to produce in the field. The right angle (90 degrees) may be produced by several methods. A 3 - 4 - 5 triangle or a double right angle prism may be used.

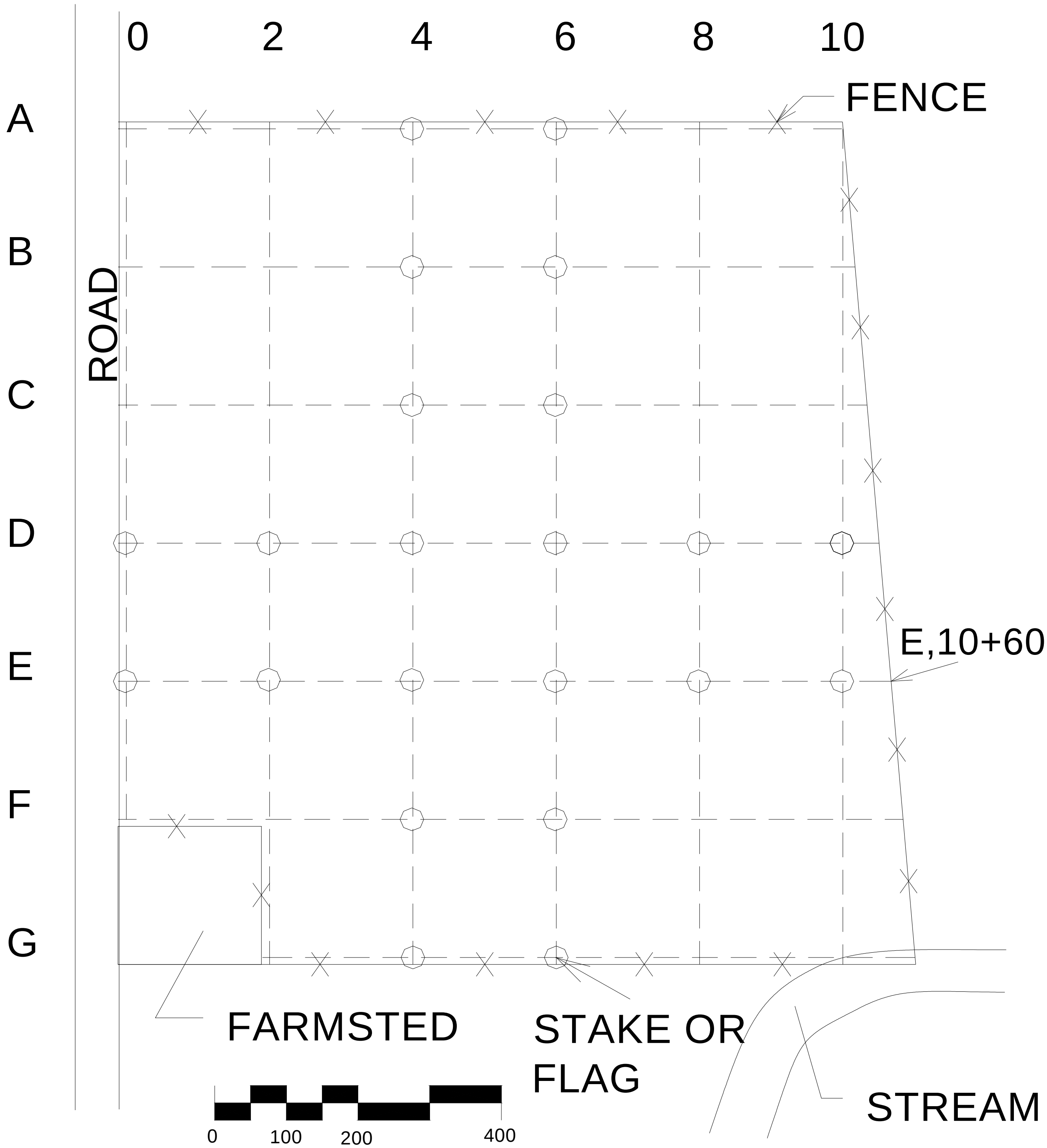
Most of the time a tape or some measuring device should be used in setting out the stakes. Fewer stakes are used if some rows are not staked and the locations only sighted in from other staked rows. To sight in locations, two rows of stakes in each direction will be needed. If the field is large, more than two sets will be needed. If the sight distance is interrupted, additional stakes will be needed. If a vehicle is going to be used to drive over the grid, the stakes will need to be set along the sides or ends only.

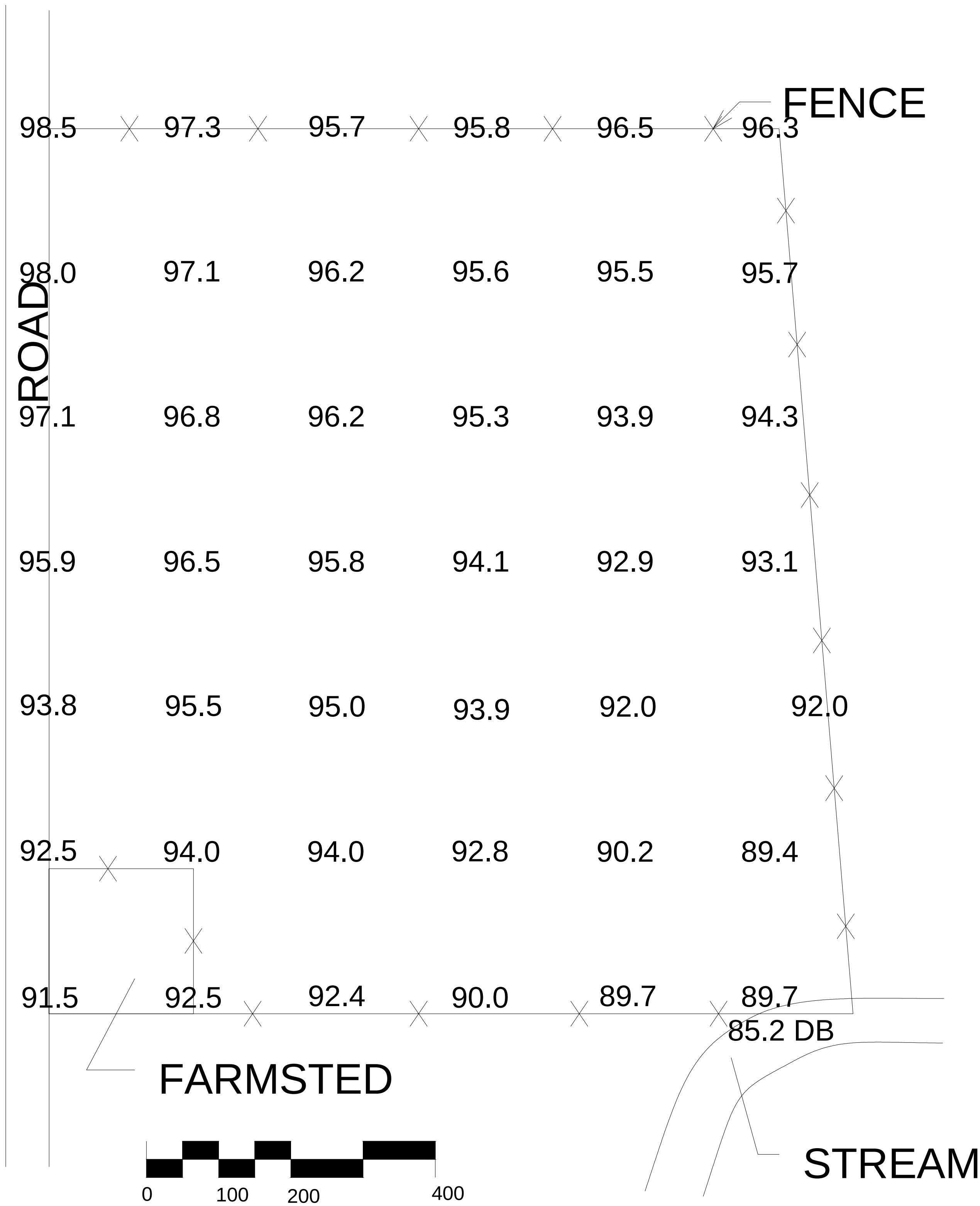
Letter the rows and number the columns. The corner stake would be A,1 the next stake in the A row would be A,2 and the next A,3. Important points between squares may be described by giving the station and a + distance to the point (C+10,2). Write the location in the Sta. column.

Using this stationing, any location in the field can be found from the notes. You may wish to use other descriptions if you desire, just so you can plot the point from the field on the plan. If field boundaries are marked in the notes, a plan of the field will be produced. Care must be taken that the notes describe the point where you are taking the reading. Irregular shaped fields may be surveyed by setting up a base line and recording the edge as a distance from the base line at regular stations. The accuracy of the points is not of critical importance most of the time, but reasonable care needs to be exercised. Some times it may be advisable to plot the points directly on an aerial picture or graph paper while in the field. If you do use this idea, make the period in the reading at the point where the rod is setting.

Make a scale plan of the field to show the grid locations, then the elevations and then the contours.

EXAMPLE GRID LAYOUT





EXAMPLE WITH ELEVATIONS

CONTOUR LINES

A Contour line is a line connecting points on the same elevation. There are some rules that will be helpful in drawing and working with contour lines.

1. Contour lines never cross (except in an overhanging cliff).
2. Contours are always one continuous line without an end. (This may not happen on an individual map).

To convert the grid map with elevations marked upon it there are some assumptions which will help in understanding and drawing contours. Assume the slope of the land is constant between the readings. If this is not true additional points should be recorded until it is nearly true.

The contour interval must be selected, (1 foot, 2 foot, 5 foot, 20 foot, etc.). The closer the contour interval the more lines on the map and the more detail shown, also the more work to produce the map. The use and the slope of the land will determine the interval. Level ground will have fewer contours than hilly land. For subsurface drainage work 1-foot contours are about right.

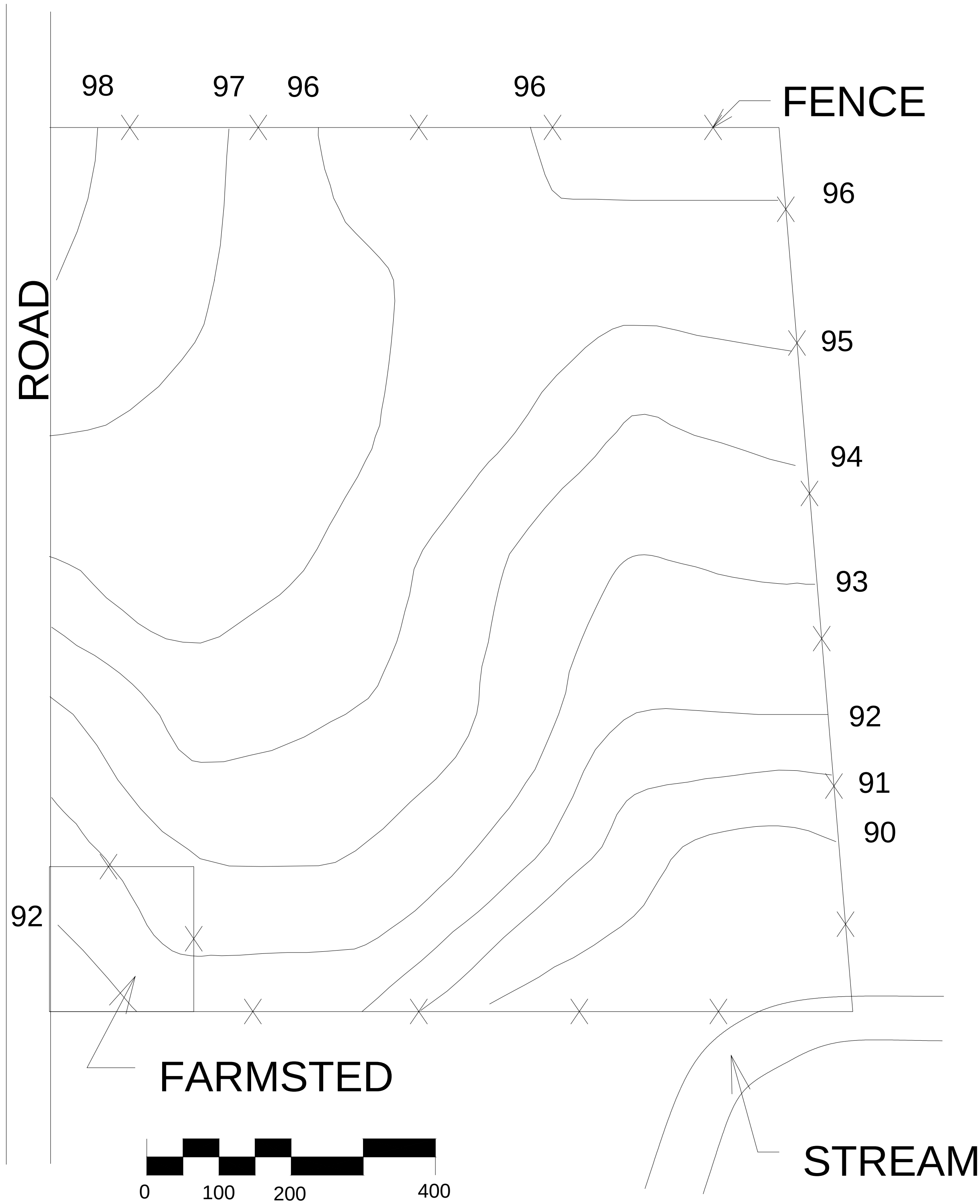
Do not change contour intervals without marking it well as the appearance of the slope will be misleading.

There are many ways and programs to draw contours, but the following is an easy way to teach drawing contours that is straight foreword.

Start at any point to draw a contour. Between two points determine the elevation difference and the number of contours between those elevations. Using points 93.8 and 95.9 there are two 1-foot contours (94 and 95) between them. To find the location of the contours between the points, the distance is divided into (95.9 - 93.8 = 2.1) 2.1 tenths of a foot or 21 spaces. The first contour above the 93.8 point is 94, this is (94 - 93.8 = 2) 2/21 or 0.095% of the distance. Place a dot at the point. The second contour line is 95, this is 12/21 or 0.57% up from the 93.8 point. Place a dot at the point. It could also be determined down from the 95.9 point as (95.9 - 95 = .9) 9/21 or 0.428% down from 95.9 toward 93.8. The 94 contour would be (95.9 - 94 = 1.9) 19/21 or 0.904% down from 95.9. Select another set of points and do the same procedure until several points are plotted, then connect the dots of the same elevation in a smooth line.

The contour line may be straight if the slope of the land is even, however it is most often curved. It is helpful to extend the line outside of the map a short distance and label it with the contour elevation. On some maps heavier lines are labeled and the others left unlabeled which can reduce clutter.

When a knob or depression is shown by a closed loop, it will be difficult to determine which is shown. An elevation point inside the loop will be helpful or the depression may have short lines in the direction of the low area.



EXAMPLE CONTOURS

PROFILE SURVEYING

Profile surveying is done to show a vertical section through the proposed ditch location. A profile will show the ground surface and then a flow line can be drawn for the construction and see what the cuts will be and where grade changes will be needed. Profiles will not be needed on all ditches but will be very helpful on long mains that are not straight or on some laterals that need to end up at a certain depth or point.

LAYING OUT FOR PROFILE SURVEYING

To layout for a profile survey for subsurface drainage, you need to station the ditch starting at the outlet. For surface drainage, the stations should start at the point that needs drainage and proceed as far as necessary to get an outlet. If the ditch is not straight, extra stations should be set at the turns or points where a sub main will enter. Extra stations may be needed at low points or high points. Cross sections (profiles at right angles to the main profile) may also be needed.

SETTING UP AND RECORDING READINGS

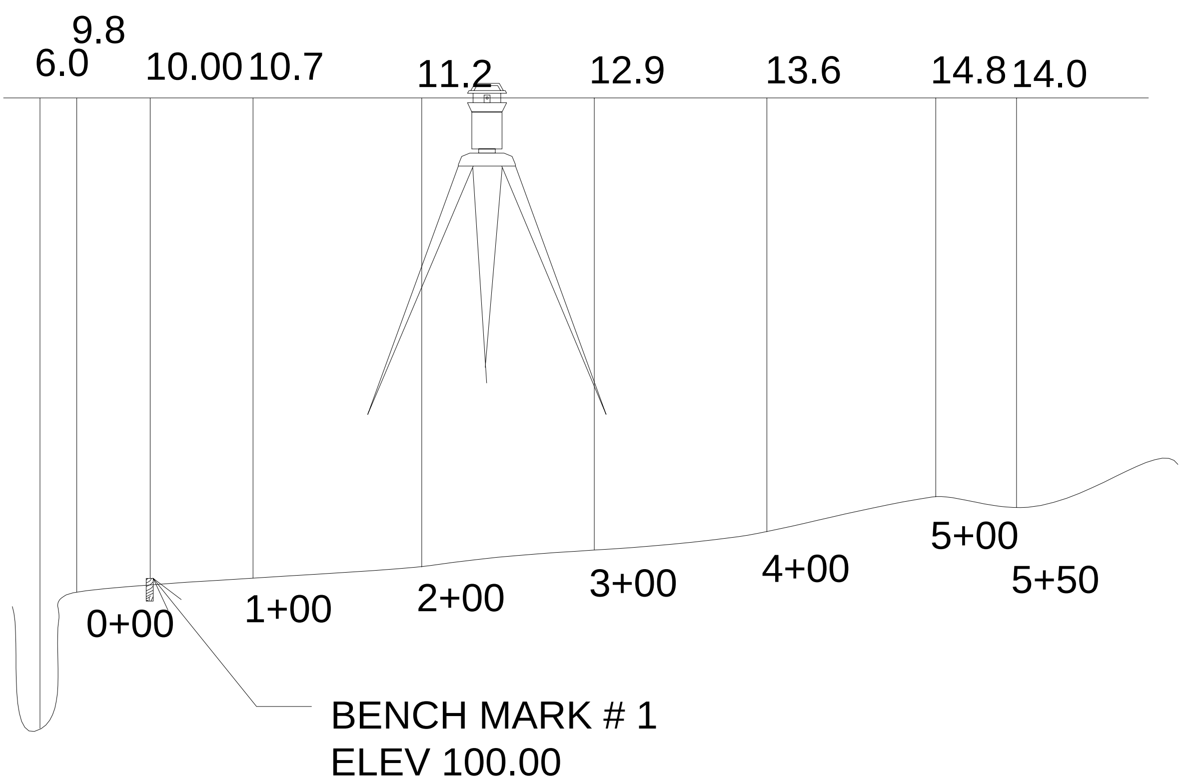
Using direct elevations the Lenker rod would be set as in method “C” and the Field book would use these headings.

STA		CONST	ROD	ELEV	NOTES/REF

Record the date, location, kind of survey, weather, the survey party, type of equipment, (Laser Transmitter grade, and Lenker rod). Also identify the main or lateral.

1. Select the Laser Transmitter location. Selecting this location will become easier with experience.
2. Set up the Laser Transmitter following the procedure for the system. Use a firm base and set the tripod solidly.
3. Set the Laser Transmitter grade to 0.00%.
4. Go to a station and find the light and read.
5. Record the station (STA) and reading at the appropriate place in the field book for the type of readings taken.
6. Move to the next location or station and repeat steps 4 and 5.

For large areas or areas with more than the rod height elevation difference, select a turning point and move the Laser Transmitter as required. Use the same procedure as used in differential leveling.



EXAMPLE OF A PROFILE SURVEY

FIELD BOOK NOTES

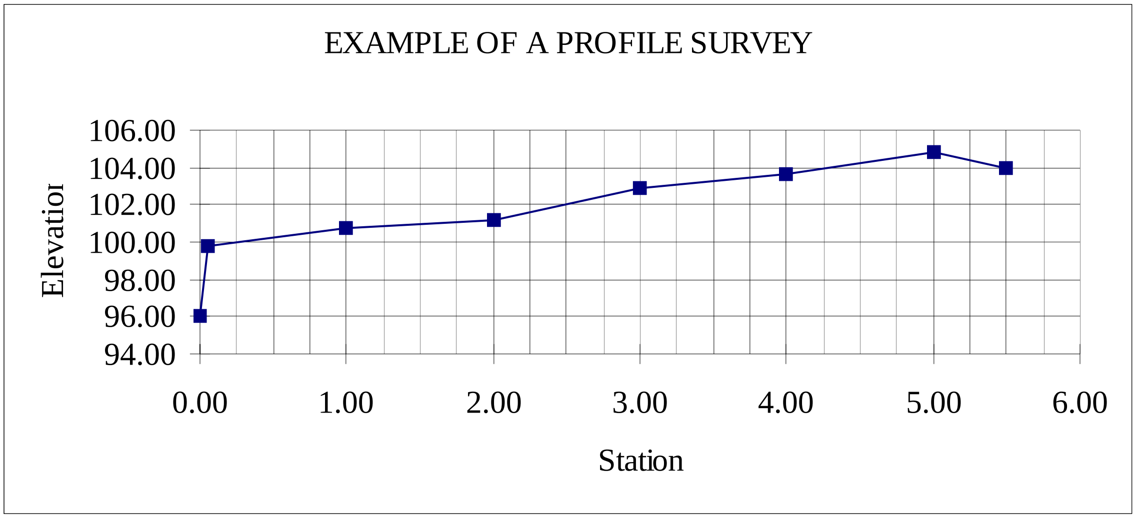
STA		CONST	ROD	ELEV	NOTES/REF
BM#1		90	*10.00*	100.0	BM# 1 TOP OF HUB
0+00			*6.0*	96.0	DITCH BOTTOM
0+05			*9.8*	99.8	
1+00			*10.7*	100.7	
2+00			*11.2*	101.2	
3+00			*12.9*	102.9	
4+00			*13.6*	103.6	
5+00			*14.8*	104.8	
5+50			*14.0*	104.0	

DRAWING A PROFILE

Use profile graph paper (4 lines to the inch horizontal and 20 lines to the inch vertical). On the horizontal scale start about one half inch from the edge of the paper. You need this room for the vertical scale labels. Layout the stations using a scale of either (2 in = 100') or (1 in = 100').

Select a vertical scale that will enable you to plot the highest and lowest elevation. A common vertical scale is 1 in. equals 4 ft. Using the “Example of a Profile Survey” on the previous page, and starting at the 0+00 station, mark the elevation on the vertical scale with a small “x” or period (DB 96.0). Next plot the 0+05 station (99.8), at the intersection of the elevation and the station line. Continue until all elevations are plotted. Connect the plotted points and you have a profile of the ground surface. This will give you a picture of how a slice through the field would appear. See the example. Slope may be calculated by dividing the elevation difference by the distance. By laying a ruler on the plan, a grade slope may be selected and the grade elevations figured in the field book. The cuts may be checked on the profile and then calculated in the field book.

To draw a profile from a contour map. Start by drawing a line on the contour map at the location you wish to draw a profile. Scale the station distances along the proposed line to each contour line. It is less confusing to put the distances and elevations in a table and then plot the elevations on the profile paper. Connecting the plots will give a ground line, and a flow line may be planned and drawn. The accuracy of the contour lines will determine the accuracy of the profile. A final profile survey should be made in the field to produce the actual cut sheet.



DRAWING A PROFILE FROM A SLOPED PLANE

When drawing from a sloping plane of light survey. The grade of the plane of light in the direction of the profile must be used as a base line. If the profile has a turn then the plane of light base line must be changed to match the plane of light grade for that section. The Angle Slope section later in this manual will help in figuring the plane of light grade.

Select the Station scale and label along the bottom of the profile. Select the vertical scale and label along the left edge of the profile. Plot the Ditch Bottom (DB) and then measure vertically up from this point the survey gauge height (SGH) distance and plot. Next draw the grade of the plane of light. This is done by multiplying the grade of the plane of light by the distance of the profile in hundreds of feet, to find the amount of elevation change. Count or scale the stations across and up the elevation to plot the point. Connecting the two plotted points with a straight line will represent the plane of light base line. The other points (SGH's) at the correct stations are then plotted down from the plane of light base line. Be careful to measure vertically on the station lines. Connecting the plots will give a profile of the ground. Drawing a line parallel with the plane of light base line from the DB or starting point will show the proposed grade line. Cuts can be measured from the ground line to the grade line.

ANGLE SLOPE CORRECTION

When using a sloping plane of light and operating the machine parallel to the direction of the transmitter grade, the drain will be installed as designed. If operation is in a direction other than transmitter grade you will have less grade than set in the transmitter. The amount of loss is a Cosine function of the angle involved and is not a set amount per degree.

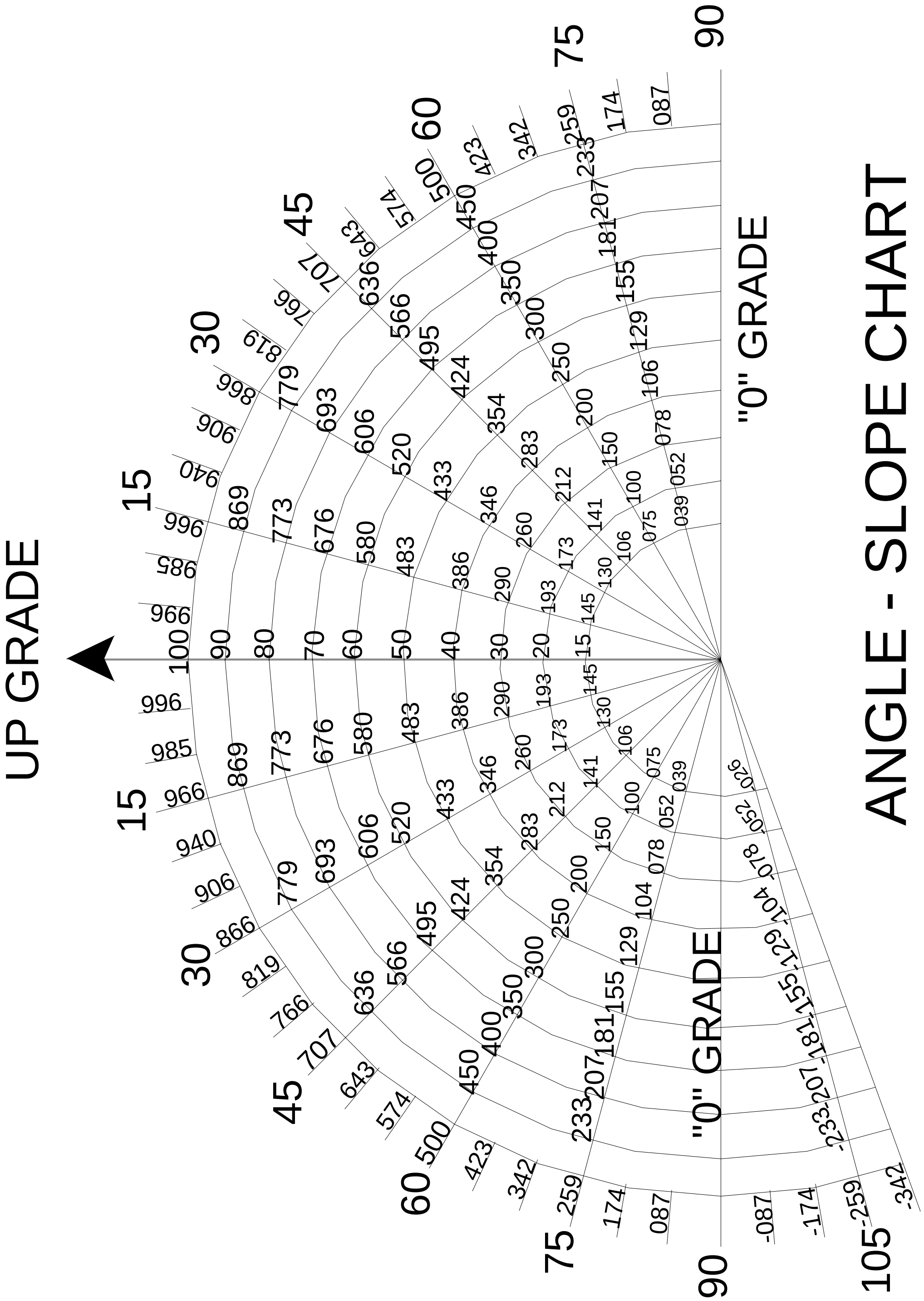
Angle Slope Correction Table lists the amount of loss in percent for various angles. Use it to multiply times the transmitter grade to find the loss of grade. Table 1 also lists the % grade left. Use it to multiply times the transmitter grade to find the grade left.

ANGLE SLOPE CORRECTION TABLE

DEGREE OF TURN	% LOSS OF GRADE	% OF GRADE LEFT
5	0.4	99.6
10	1.5	98.5
20	6.0	94.0
30	13.4	86.6
40	23.4	76.6
50	35.8	64.2
60	50.0	50.0
70	63.8	34.2
80	82.6	17.4
90	100.0	0.0

For example with the transmitter grade at 0.30 and the angle of ditch from the transmitter grade ("UP GRADE") 45 degrees, 70.7% X 0.30 = 0.212 is the grade followed. This means grade must be added to maintain the 0.30 grade. (0.30 - 0.212 = 0.088) ADD 0.09 with the grade breaker to maintain 0.30 on the ditch. Using the loss of grade column you get the same answer 0.30 X 29.3% = 0.088. The angles of 45 & 60 degrees are some values to remember. At 45 degrees two equal grades can be obtained by setting the transmitter at 1.414 times the grade desired. 60 degrees has one half the grade of the transmitter.

ANGLE SLOPE CHART



READING THE ANGLE SLOPE CHART

The "Angle Slope Chart" shows the same information in a chart form. The "Up grade" points in the direction of the transmitter grade and the arcs show a series of transmitter grades for angles. Using the same example as above go up the "up grade" arrow to .30 then follow around the arc to the 45-degree line and read .212. This chart could be used in the field by pointing the up arrow in the direction the laser transmitter is pointing ("UP GRADE") and then sighting across the chart in the ditch direction to find the angle of the ditch from the transmitter grade. Then look in the chart to find the grade actually followed.

Note the "0" grade line is at right angles to the "UP" grade line and the loss of grade is much greater for angles near the "0" grade line.

COMPOUND SLOPE - DEFINITION AND RULES

The laser system can be set to have a specified grade in two, right angle directions. This may be used where the main and the lateral's are at right angles. One transmitter grade setting can be used to provide control for both main and laterals If the main has a constant grade then the laterals will all start at the same gauge height.

Compound slope is defined as the maximum slope between two right angle slopes. There are a number of ways the compound slope may be calculated. Here is a list of some of the methods: scale drawing, azimuth ring on some transmitters, table, chart, calculator with polar radian function, or by use of trigonometric functions. There are several important things to remember:

a) Always point the transmitter in the "UP GRADE" direction of the larger slope and turn it toward the direction of the smaller slope.

b) Your final grade setting in the transmitter will be larger than either the larger or smaller initial slopes.

c). The maximum grade when using a dual slope transmitter is always between the two upgrade directions, and greater than either set grade.

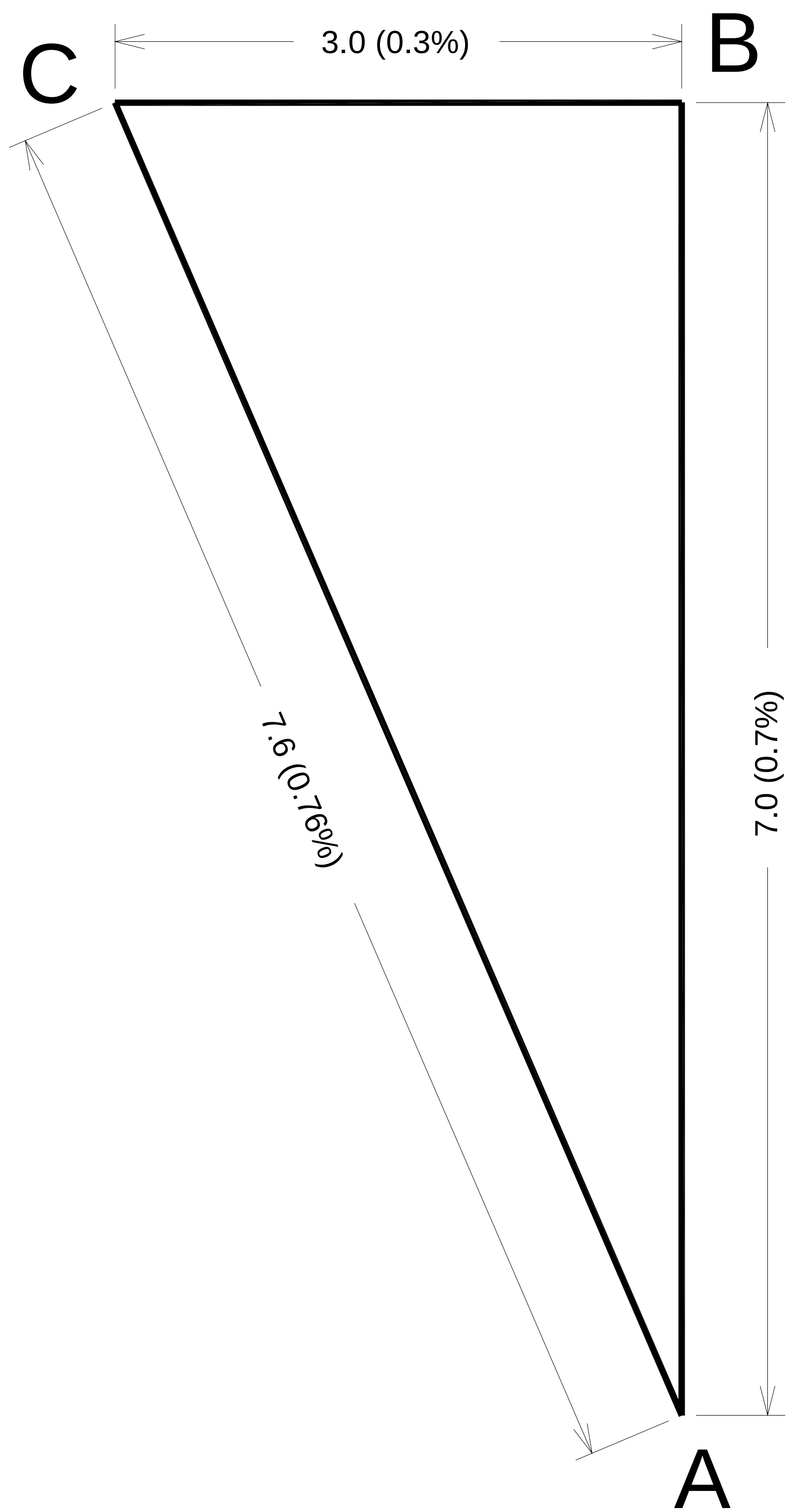
d). CAUTION - A ratio of 3 to 1 or more between larger slope and smaller slope is to be used with caution, be very careful, not because the method is inaccurate but because the direction of travel is critical. A small error in direction can produce travel in the "0 GRADE" or reverse grade direction.

The following is an example and instructions for calculation of COMPOUND SLOPE

.

A SCALE DRAWING

1. Choose a suitable scale, the larger the better. Use graph paper or even draw it on the ground. A good scale for paper is 1 in. = 0.1 % grade. A good scale for the ground is 1 ft. = 0.1% grade.
2. Draw a line AB to scale the length of the larger slope and in the direction of the slope. (7 in. representing 0.7% grade)
3. Starting at B the upgrade end of the larger slope and at right angles to line AB, and in the direction of the smaller slope, draw a line BC the length of the smaller slope. (3 in. representing 0.3% grade).
4. Draw line AC from point A to point C, forming a triangle.
5. The angle between line AB and line AC is the angle to turn the transmitter from the larger toward the smaller slope. The direction of line AC is the direction to point the transmitter. (23 degrees)
6. The scale length of line AC is the slope to set in the transmitter (7.6 in = 0.76%).



MACHINE CONTROL

LASER RECEIVER

The laser receiver contains photocells that are sensitive to laser light. The photocells are arranged in groups to receive the laser light and send the high, on grade or low signal to the control box. Some Laser Receivers must be aimed at the Laser Transmitter, some track the laser light by photocells on the side of the Laser Receiver and others receive the laser light from any direction.

MAST

The mast is mounted on the machine and carries the Laser Receiver. It can move the Laser Receiver in a vertical direction, within the limits of travel, and record the movement in the control box. This movement will change the Machine Constant or Gauge Height.

CONTROL BOX OR PANEL

The Control box or control panel contains all the indicators and controls necessary to receive signals from and control the Laser Receiver, Mast, Grade Breaker and Hydraulic System. It indicates the Laser Receiver height (Machine Constant or Gauge Height) on a counter. Panel lights also indicate "high", "low" or "on grade". An "auto/manual" switch can be selected to send a control signal to adjust the hydraulics of the machine so the Laser Receiver follows the plane of light. There are switches on the Control panel to set the Counter and adjust the Laser Receiver Gauge Height.

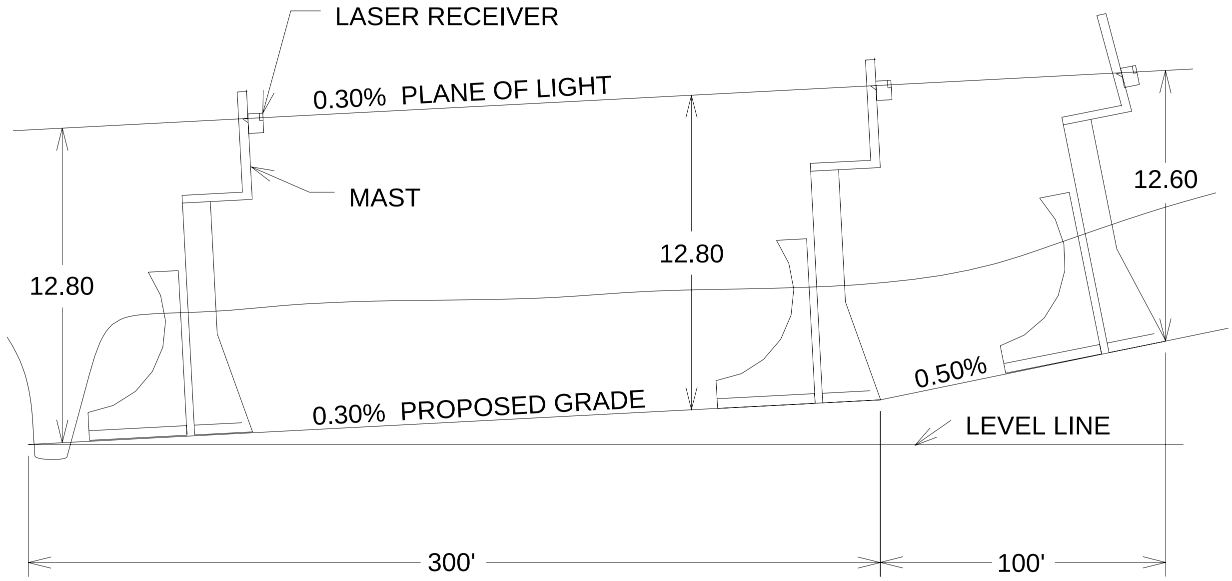
GRADE BREAKER

The grade breaker is an accessory that measures distance and allows the machine to cut a grade different than the plane of light grade. The grade breaker can add grade, use the plane of light grade or subtract grade. It changes the grade by adding or subtracting Mast Gauge Height in relation to distance in steps of 0.01 ft. This Gauge Height change will adjust the grade in relation to distance while following the plane of light grade.

Lengthening the mast causes the Laser Receiver to rise above the light plane. The machine automatically will respond by lowering the cutting edge until the Laser Receiver is on the plane of light grade. As a result the cut is increased and the grade is flattened. Refer to this operation as subtracting grade (SUB -).

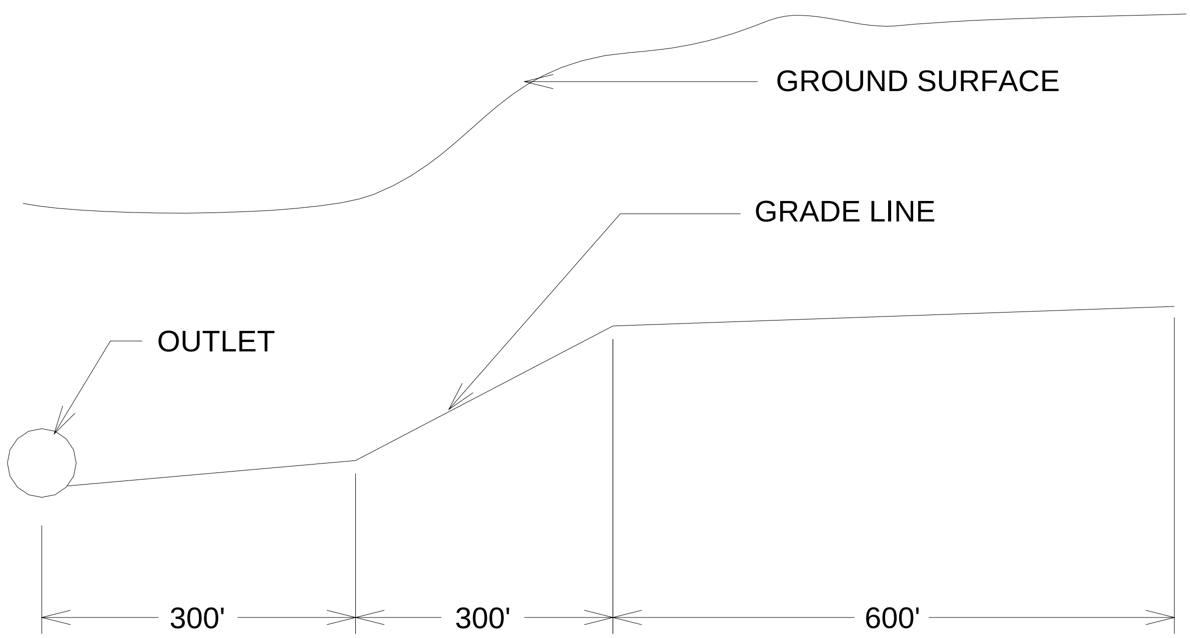
Shortening the mast moves the Laser Receiver below the light plane. The machine automatically will respond by raising the cutting edge until the Laser Receiver obtains the on grade signal. As a result the cut is decreased and the grade is increased. Refer to this operation as adding grade (ADD +) or sucking mast.

GRADE BREAKER ILLISTRATION



The grade breaker illustration shows the proposed grade follows the plane of light for the first 300 ft. The mast height does not change.

However when the 300 ft. station (3+00) is reached, the proposed grade increases to 0.50% while the light plane does not change. Subtract the plane of light grade from the proposed grade, the difference is set into the grade breaker control (0.50% - 0.30% = 0.20%). and place the add/sub switch in the "ADD +" position. The grade breaker will then automatically adjust the mast in 0.01' steps (which in this example is every 5 ft). This will reduce the mast length by 0.20 ft. in 100 ft. (12.80 - .20 = 12.60) resulting in a



grade of 0.50%.

EXAMPLE PROBLEM

Using the above problem this is how you would use the grade breaker to construct the drain.

Total fall in the drain :
3.00 X 0.30% = 0.90
3.00 X 1.00% = 3.00
6.00 X 0.015%= 0.90
Total fall = 4.80

Using a level Laser Plane of light with the grade breaker the mast would be shortened 0.90 ft. in the first 300 ft., then 3.00 ft. in the next 300 ft. and 0.90 ft. in the last 600 ft. This shortening of 4.80 ft. is more than the maximum mast travel. Therefore some grade must be set in the Laser Transmitter or the Transmitter moved

The average grade would be a good place to start. Remember Grade is the feet of fall divided by the number of hundreds of feet of length. (total fall) / (total length / 100) (4.80/12.00 = 0.40%) This would be the average grade set into the Laser Transmitter and the desired grade would be achieved by using the grade breaker as follows.

Station	Specified grade -	Light plane grade =	Grade breaker setting
1 to 3	0.30%	0.40%	- 0.10% (SUB -)
3 to 6	1.00%	0.40%	+0.60% (ADD +)
6 to 12	0.15%	0.40%	- 0.25% (SUB -)

CALIBRATING THE MACHINE GAUGE HEIGHT

When grade is added or subtracted with the Grade Breaker, the Laser Receiver is moved up or down by the Mast. This movement is limited by the mechanics of the Mast. The high and low limits are referred to as the Gauge Height limits. These limits will be different for each mast and machine. The full extent of the limits should not be used as the Mast has an interlock that might not release on the last tenth of a foot. The limits remain the same until the cutting edge wears The Gauge Height should be checked at least once a month.

Once calibrated, the counter reading in the control box indicates the distance the Laser Receiver is above the installation bottom. With a conventional machine, using a sight bar, this would be the Machine Constant and remain fixed. With Laser equipment using Grade Breaking this counter reading may vary within the traveling limits of the Mast and is called the Gauge Height.

The procedure to find the Gauge Height & Gauge Height Limits is to dig until the machine is following the light plane and then measure the vertical distance from the light plane to the installation bottom.

1. Set the machine in the ground and use the machine grade control and/or the Mast travel to run the Laser Receiver to the light plane until an "on grade" light is received.
2. Switch the "auto/manual" switch to "auto". Turn the grade breaker off and dig about 25 ft.
3. Measure a vertical reading from the installation bottom to the plane of light. (If the survey rod is not long enough to read directly, measure from the installation bottom to some point on the machine and then from that point to the plane of light adding the two readings together.)
4. Dig another 25 ft. and repeat step 3. This checks that the machine is following the grade.
5. Average the readings (If they are nearly the same) (If the first one is different from the others the machine did not get fully on grade before taking the readings and should not be used.)
7. Set this number in the Mast Counter in the Control Box, use the set and add or subtract switches.
8. Switch the control box to "Manual" and "Operate" then lower the Laser Receiver to the bottom of the travel. The Mast Counter is the Minimum Gauge Height Limit. Record this number in a permanent location as it can be used to reset the counter if the counter gets out of calibration.
9. Raise the Laser Receiver until it stops. The number in the control box counter is the Maximum Gauge Height Limit.

CALIBRATION OF MACHINE (PAN, DOZER, GRADER)

To calibrate the machine with a movable mast

1. Set up the laser transmitter in a location that will cover the work area. If grade is to be level, set the laser level. If grade is to have slope, set slope and direction into laser.
2. Survey to find the correct elevation for the work to be done.
3. Calibrate the machine Gauge Height (GH):
   - A. Adjust the mast receiver to the plane of light
   - B. Measure the vertical distance between the plane of light and the cutting edge of the machine.
   - C. Adjust the counter reading to the vertical measurement by using the set switches on the control panel.
   - D. Lower the mast to the lower limit and record the counter number for reference.

4. Raise the mast till the survey gauge height number is in the control panel on the machine and cut to grade from the plane of light.

To calibrate the machine with a non-adjustable mast

1. Set up the laser transmitter in a location that will cover the work area. If grade is to be level, set the laser level. If grade is to have slope, set slope and direction into laser.
2. Survey to find the correct elevation for the work to be done.
3. Find a place at the desired grade elevation or some known elevation from the desired grade.
4. Set the cutting edge on the location you found in step 3.
5. Adjust receiver to the plane of light.
6. If the location in step 3 is not at the desired grade then adjust the receiver for the desired cut or fill and mark the mast.
7. Cut to grade from the plane of light.

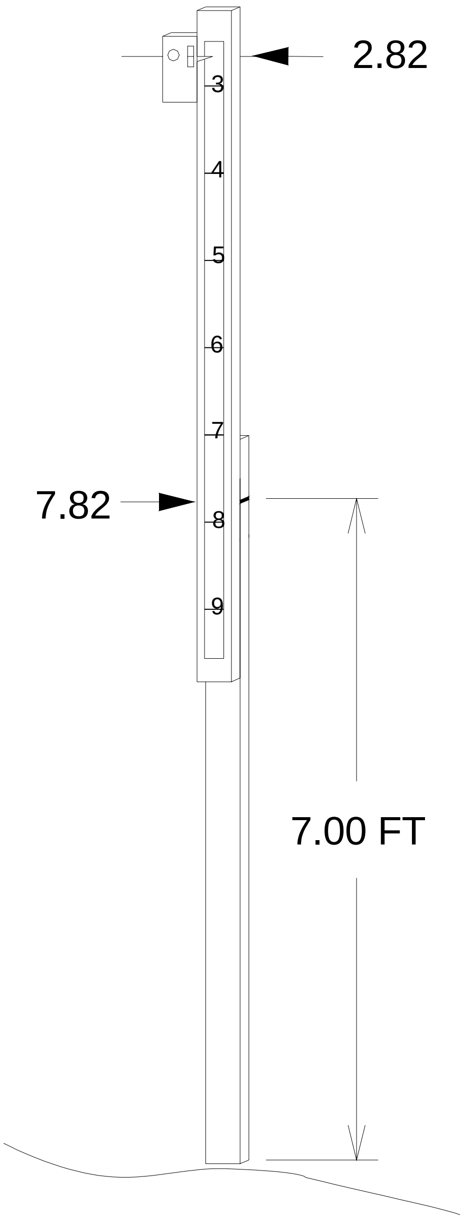
Note - Dual slope or compound slope may be used when properly oriented in step

THE LENKER ROD FOR MACHINE INFORMATION

There are a number of ways to use the Lenker rod to get desired information. Up to now it has been used like a conventional surveying system to get either rod readings or elevations. Now when information to control the machine is desired, the Lenker Rod may be used to get machine control information. The next illustrations show ways the Lenker Rod may be used depending on the type of information desired.

USING THE LENKER ROD AND RECEIVER FOR MACHINE INFORMATION

Method "D" - Gauge Height Through Desired Cuts

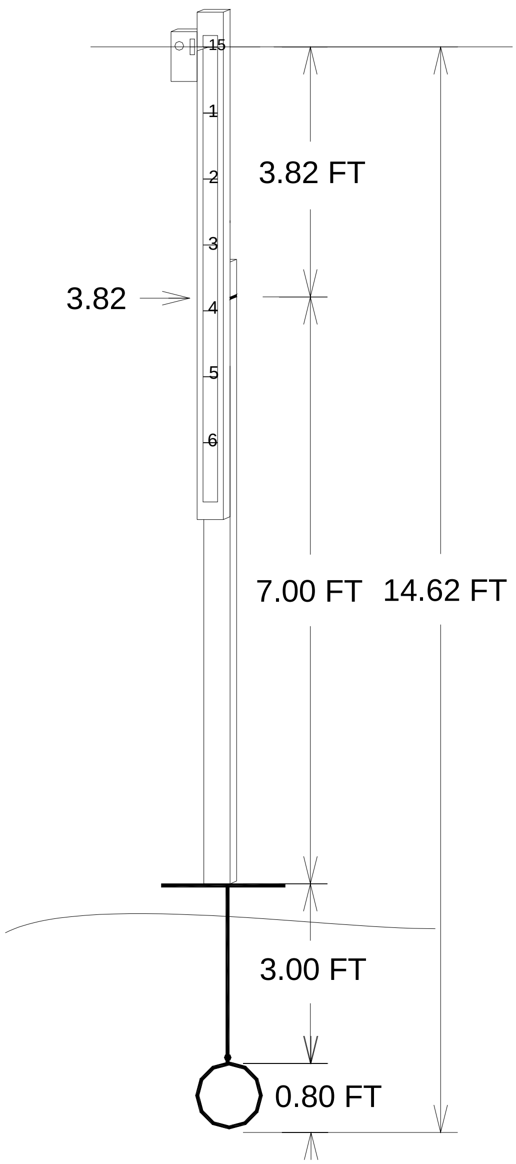


Step 1	Move the tape until the desired cut (2.82) is at the Rod Receiver Pointer. Do not lock the tape.
Step 2	Set the rod vertical and move the top section of the rod until the Rod Receiver is centered on the plane of light.
Step 3	Read the tape at the Rod Reference (7.82).
Step 4	Add the tape reading and the Rod Reference to get the Gauge Height for the desired cut (2.82) at that location.

7.82	= Tape reading
7.00	= Rod Reference
14.82	= Gauge Height to produce a 2.82 cut.

USING THE LENKER ROD AND RECEIVER

Method "E" - Gauge Height from Pipe or Tile Probe



Gauge Height through addition

Step 1	Move the tape to set the 0.00 or 15.00 near the top of the rod, at the pointer on the Rod Receiver. Do not lock the tape.
Step 2	Set the rod vertical on the tile probe and move the top rod section up until the Rod Receiver is centered on the plane of light.
Step 3	Read the tape at the Rod Reference Pointer.
Step 4	Add the tape reading at the Rod Reference Pointer, the Rod Reference, length of the tile probe and the tile outside diameter (O.D.) size in feet.

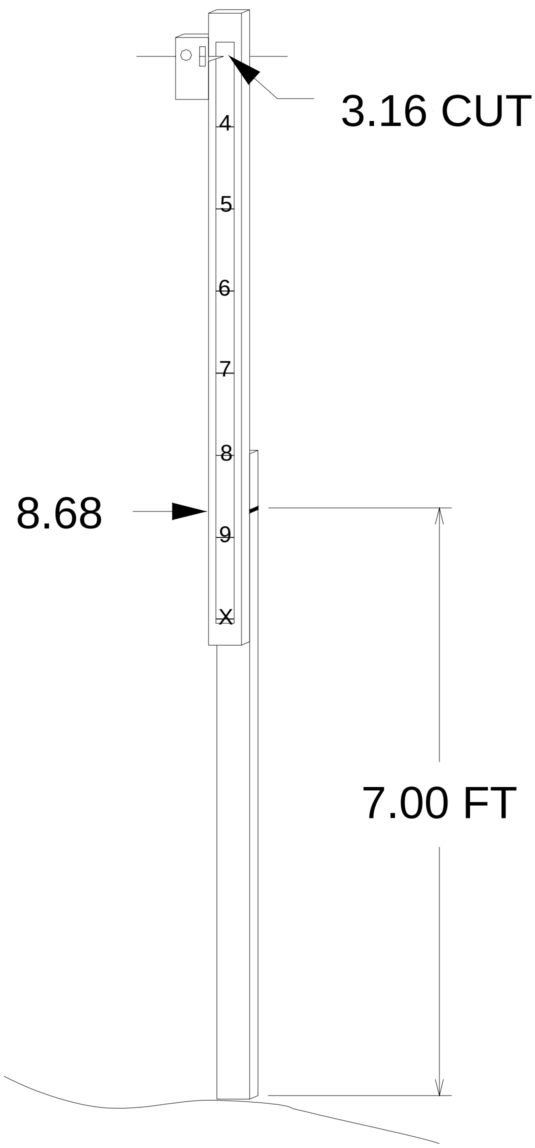
3.82	Tape Reading
7.00	Rod Reference
3.00	Length of tile probe
0.80	O.D. in feet, of 8" tile
14.62	Gauge height

USING THE LENKER ROD AND RECEIVER

Method "F" - For Cut Readings

Surveying for cut readings

Once the Gauge Height is known the cut at any location along the proposed ditch may be found through the following steps.



Step 1 From the Gauge Height subtract the Rod Reference.

15.68	Gauge Height
-7.00	Rod Reference
8.68	Difference

Step 2 Move the tape until the number from Step 1 lines up with the Rod Reference Pointer (8.68).

Step 3 Lock the tape.

Step 4 Set the rod vertical and center on the plane of light and read the cut at the Rod Receiver Pointer (3.16).

DEFINITIONS OF TERMS USED IN SURVEYING

AZIMUTH RING - A ring located on the command post used to figure compound grades.

BACK SIGHT (BS) (+) - A level rod reading taken at a point of known elevation It is the first reading taken on a bench mark or turning point immediately after the initial or new setup. The BACK SIGHT is added to the elevation to obtain the Height of Instrument (H.I.).

BEEPER - see ROD RECEIVER

BENCHMARK (BM) - A benchmark is a point of known elevation of a permanent nature. It may be elevation above Sea Level or assumed at some convenient number (usually 100.00). A permanent bench mark will be a brass pin or cap set in concrete, a long metal stake driven in the ground or a certain point on a concrete bridge or other solid object. A temporary benchmark, (TBM) needed for only a few weeks until a job is completed could be a wood stake or a nail in a tree or post. Benchmark locations should be accurately described in the field book and plans, so a person who had never been in the area could locate them.

COMPOUND SLOPE - Is the maximum slope between two right angle slopes.

CONTOUR INTERVAL - The difference in elevation represented by each contour line on a map.

CONTOUR LINE - A line drawn on a map that connects points of the same elevation.

CONTOUR MAP - A map on which irregularities of land surface are shown by contour lines, the relative spacing of the lines indicating the relative slope of the surface

CONTROL BOX - An interface on a machine to receive signals from a receiver, mast, grade breaker or slope meter and indicate to the operator various information also to send signals to control points on the machine if desired.

CROSS ARM - A short horizontal bar attached to a stake a known distance from the bottom of the proposed ditch.

CROSS SECTION - A profile taken at right angles from the station line.

CUT - The distance from the ground surface to the bottom of the trench or grade elevation

CUT CARD - A pocket size card with heading and columns , which has column to record rod readings, survey gauge height and figure cuts and grade breaker settings

DATUM - A level surface with respect to which elevations are established This may be sea level or an imaginary line under or on the ground surface.

DETECTOR - see ROD RECEIVER

DETECTOR POINTER - see ROD RECEIVER POINTER

DIFFERENTIAL LEVELING - A method of leveling used to find the difference in elevation between points.

DITCH BOTTOM (DB) - The lowest point in the ditch or the normal low water level.

ELEVATION (ELEV) - The height of a point in relation to Datum whether sea level or assumed.

FIELD BOOK - A book used as a permanent record of surveying.

FIELD NOTES - Notes taken in the field and recorded in the field book as the survey is carried out. They are a record of the survey and as such should be complete, identifying the survey by title, including location and purpose, identification of party members and duties, type of equipment used, date and weather conditions.

FORESIGHT (FS) (-) - A rod reading taken at a point of unknown elevation The foresight is subtracted from the height of instrument (H.I.) to find the elevation. (HI - FS = ELEV)

GAUGE HEIGHT - The vertical distance from the sight bar or receiver to the bottom of the finished cut

GRADE - SLOPE - The rate of rise or fall along a specified line. Grade is the same as slope and is usually expressed in percent (feet of rise or fall in 100 feet of horizontal distance).

GRADE BREAKER - A distance measuring mechanism attached to a machine that can change gauge height in relation to distance.

GRADE ELEVATION - The desired elevation of a trench, ditch or surface.

GUARD STAKE - A stake or marker placed beside a hub stake to locate, protect and identify the hub stake.

HEIGHT OF INSTRUMENT (HI) - The elevation of the line of sight of a surveying instrument or a level plane of light. It is found by adding the BACK SIGHT (+) to the elevation of the bench mark or turning point. (ELEV + BS = HI)

HUB STAKE - A short stake driven almost flush with the ground to mark elevations at stations

LASER DETECTOR - see ROD RECEIVER.

LASER RECEIVER - An instrument that indicates the location of a laser light, usually attached to a machine to indicate or control the grading of the machine.

LASER TRANSMITTER - TRANSMITTER - A source of laser light that rotates to generate a plane of light, used as a reference to determine elevations or cuts or control a machine.

LASER TRANSMITTER SLOPE - The amount of slope on the plane of light

LATERAL IDENTIFICATION CARD - see CUT CARD

LENKER ROD - A level rod used in surveying that has a graduated movable tape or ribbon. The Lenker rod can be used to read elevations directly. Use of this rod reduces the amount of calculations needed in entering notes or elevations.

LEVEL - An instrument used to establish a true horizontal line of sight.

LEVEL ROD - A rod used in surveying to determine the distance from a line of sight or laser light to a point. Usually graduated in feet, tenths and hundreds.

MACHINE CONSTANT - see GAUGE HEIGHT

MAST - An adjustable support for a Laser Receiver, controlled or monitored through the control box.

PROFILE - A vertical section of the ground surface along the line of survey.

PROFILE LEVELING - A method of finding the elevations of a series of points at measured horizontal distances along a specified line.

RANGE POLE - A long pole with feet painted alternating red - white, used to mark points that must be seen from a distance.

RIBBON LOCK - see TAPE LOCK.

ROD RECEIVER - DETECTOR - LASER DETECTOR - SENTRY - BEEPER - A laser receiver of small size that may be attached to a level rod

ROD RECEIVER POINTER - The pointer on the ROD RECEIVER where the plane of light would intersect and rod readings are taken.

ROD REFERENCE POINT - The marker for the distance from the bottom of the Lenker rod usually even feet. This is the point where rod readings will sometimes be taken and added to the reference amount for that rod. Also used as a reference mark to determine if the tape lock has loosened allowing the tape to move

SENTRY - see ROD RECEIVER

SLOPE - see GRADE

STATION (STA.) - Points along a line of survey, usually 100 ft. intervals The first station is zero. Stations are usually marked with a hub stake and guard stake, paint or flag. Rod readings are taken at stations.

SURVEY CUT - Is the difference between the survey gauge height (SGH) at the beginning of the ditch, and the (SGH) of the station.

SURVEY GAUGE HEIGHT (SGH.) -Vertical distance from a tilted plane of light to the ground

TAPE LOCK - RIBBON LOCK - Clamp that locks the ribbon or tape on a Lenker rod, so that it does not move in relation to the bottom section of the rod - The: Reference point reading remains constant.

TILTED PLANE - When the Laser Transmitter has slope on the light plane.

TRIPOD - A three-leg support for a Level or Laser Transmitter

TURNING POINT (TP) - A turning point is a firm object such as a hub stake, stone, fence post or axe head so that the elevation will not change while the instrument or transmitter is being moved. A point on which a foresight (-) rod reading is taken to obtain the elevation and on which a BACK SIGHT (+) rod reading is taken after the instrument is moved to a new location.

Tab for Topographic Mapping

Slide 1

TOPOGRAPHIC INFORMATION

Ohio **L**and **I**mprovement **C**ontractors **A**ssociation

Fred & Rick Galehouse

Ron Cornwell, Mark Seger, NRCS

Slide 2

Surveying for topo information

- If you have questions along the way please ask them.
- There are no stupid questions.

Slide 3

Surveying for topo information

In order to do some planning before the machine is ready to go and waiting in the field, we need to make some kind of a map or plan.

The most common plan starts with a topographic or contour map.

Slide 4

Surveying for topo information

To draw a contour map we need to make some assumptions.

We assume that the slope between the points we use is constant, and can be represented as a straight line.

Slide 5

Surveying for topo information

If the field is relatively smooth then using a grid to get the elevations works well.

The changes between grid points is nearly a straight line.

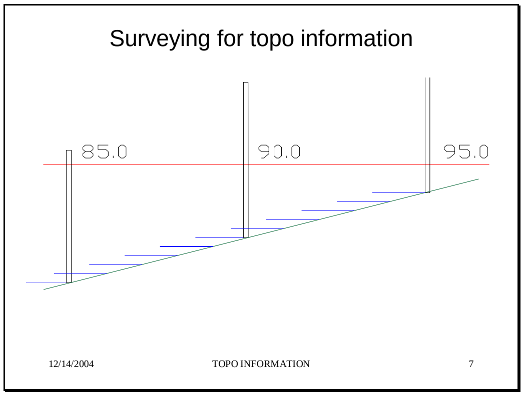
The resulting map will be a good representation of the field.

Slide 6

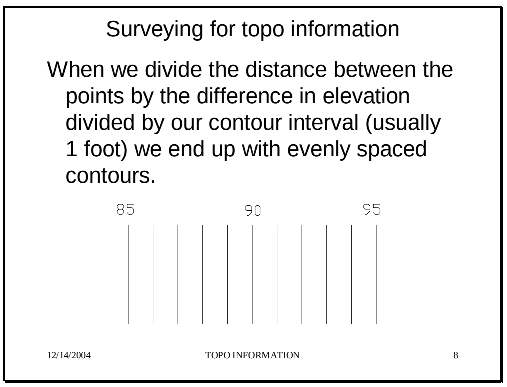
Surveying for topo information

If the field has a lot of slope, BUT the ground surface between the points is relatively smooth and can still be represented as a straight line then the resulting map will be a good representation of the field.

Slide 7



Slide 8



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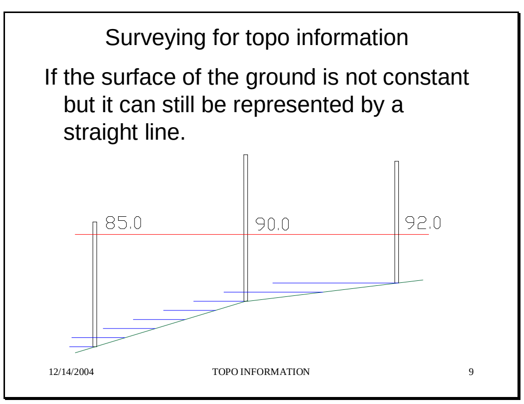
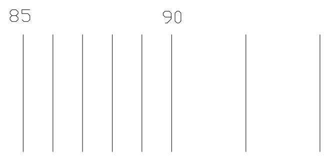


Slide 10

Surveying for topo information

This changes the contours to

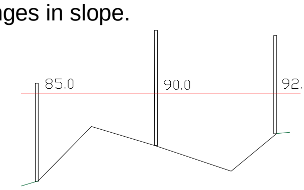


12/14/2004 TOPO INFORMATION 10

Slide 11

Surveying for topo information

When we use a grid to get the elevations. The grid points may not fall at the changes in slope.

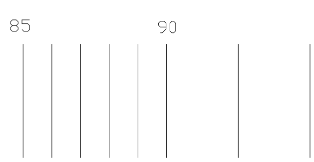


12/14/2004 TOPO INFORMATION 11

Slide 12

Surveying for topo information

If we use the elevations only at the grid points the contours would look like this.

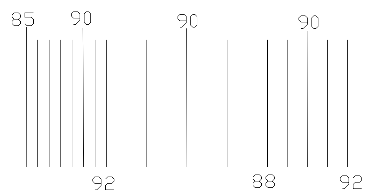


12/14/2004 TOPO INFORMATION 12

Slide 13

Surveying for topo information

But they should look like this.

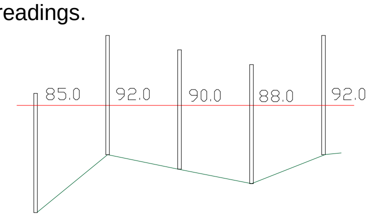


12/14/2004 TOPO INFORMATION 13

Slide 14

Surveying for topo information

To get a more accurate contour map. You need to either take more elevation readings.

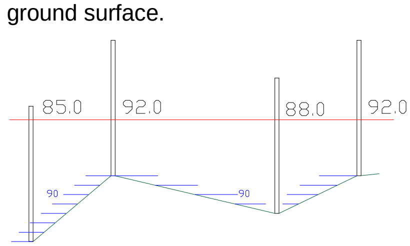


12/14/2004 TOPO INFORMATION 14

Slide 15

Surveying for topo information

Or take readings at the changes in the ground surface.



12/14/2004 TOPO INFORMATION 15

Slide 16

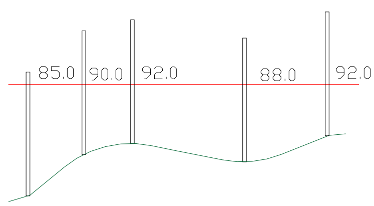
Surveying for topo information

If the surface is not straight (it usually isn't), then the rod man needs to do some estimating, and take shots that come as close as practical to what would be represented by a straight line

Slide 17

Surveying for topo information

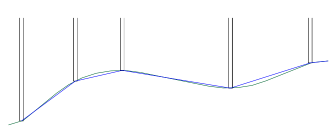
Curved surface



Slide 18

Surveying for topo information

Curved surface as represented by straight lines.



Slide 19

Surveying for topo information

If you are using a grid you need to remember that what is between the grid points also needs to be represented by a straight line.

12/14/2004 TOPO INFORMATION 19

Slide 20

Surveying for topo information

If the field is rolling, another method of data collection may be more efficient than using a grid.

A total station can collect the data at any point, within line of sight.

GPS based methods can also be used.

12/14/2004 TOPO INFORMATION 20

Slide 21

Surveying for topo information

Regardless of what you use to collect the data, if the points that are selected can not represent the surface as a bunch of straight lines or flat planes, then the contour map that can be generated will not be accurate.

12/14/2004 TOPO INFORMATION 21

Slide 22

Surveying for topo information

GIGO – Stands for Garbage In, Garbage Out

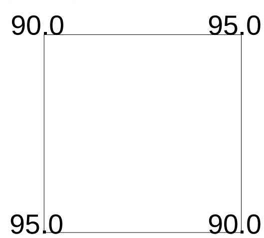
It is a computer term but it describes what you get if you don't have accurate field data.

Slide 23

Surveying for topo information

If you get readings on a grid that looks like this.

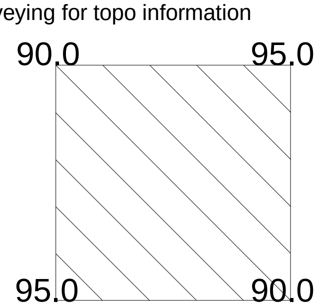
How do you draw the contours?



Slide 24

Surveying for topo information

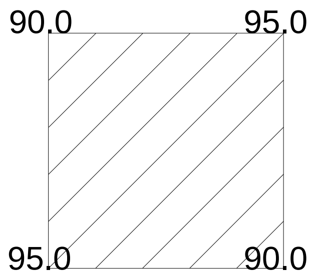
Like this?



Slide 25

Surveying for topo information

Or this?



Slide 26

Surveying for topo information

If you have been to the field you may have some idea which way it should be drawn.

But if you have never seen the field, you really don't know.

The truth is you don't have enough elevation data to really know which way it should be.

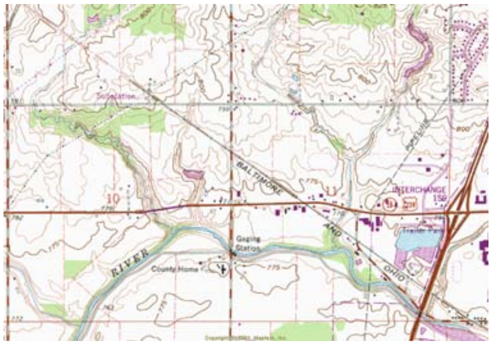
You should go back to the field and add some more elevation shots

Slide 27

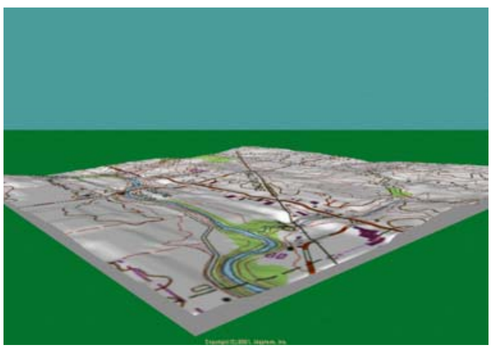
Contours

Complex topographic maps sometimes called contour maps can be drawn from the survey information.

Slide 28



Slide 29



Slide 30

Properties of Contours

Contours are lines connecting points of the same elevation.

They never cross themselves (except in an overhanging cliff).

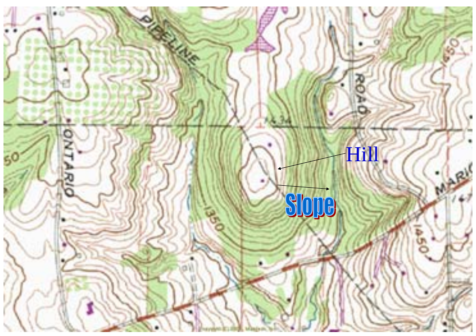
Slide 31

Properties of Contours

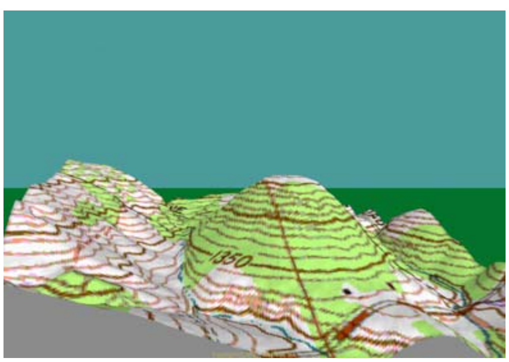
Contours close together indicate steep land.

Contours far apart indicate nearly level land.

Slide 32



Slide 33

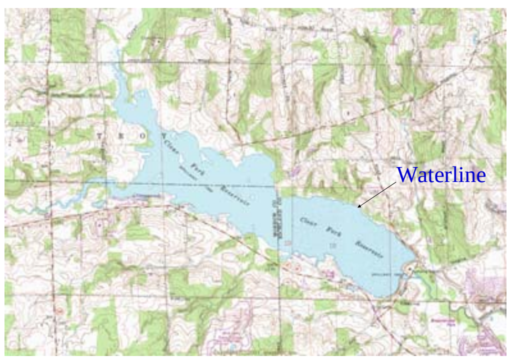


Slide 34

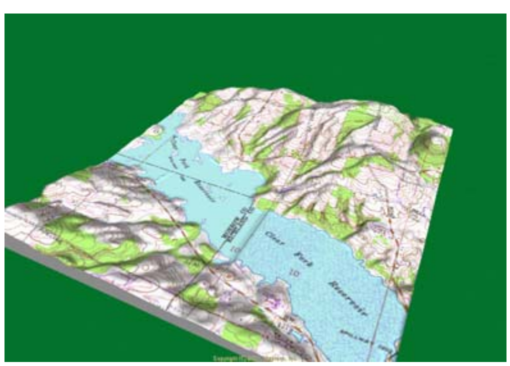
Properties of Contours

They are always one continuous line without end. Like the high water mark in a bath tub or the waters edge in a pond

Slide 35



Slide 36



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Properties of Contours

Ridges are usually U shaped

Low spots may have hash marks on the inside of the contour line

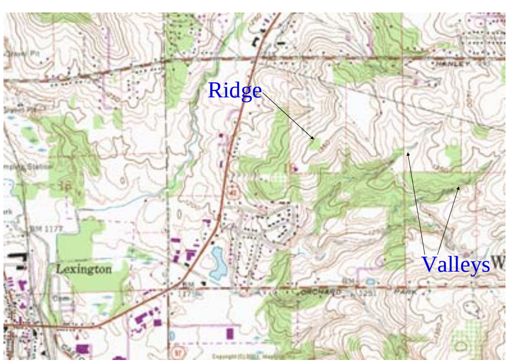
Slide 38

Properties of Contours

The slope is perpendicular to the contour

The contours crossing a stream or valley point upstream

Slide 39



Slide 40

Slide 41

Properties of Contours

The entire loop may not be in your plan area.

They can never branch into two contours of the same elevation

Slide 42

Drawing a Contour

Select a contour interval 1, 5, 10 or 20

Try to use only one contour interval on your plan.

Changing the contour interval will change the appearance of the slope.

Slide 43

Drawing a Contour

For most septic or subsurface drainage work, a 1 ft contour interval can give you good information.

Slide 44

Drawing a Contour

The accuracy of the contours is ½ the contour interval.

If someone starts with a contour map that was drawn using a 10 ft contour interval, and add lines to make 1 ft contours, the contours are really 1 ft plus or minus 5 ft.

Slide 45

Drawing a Contour

Are there any questions?

USGS Symbols; 2005 Overholt Drainage School
http://mac.usgs.gov/mac/isb/pubs/booklets/symbols/

Roads, Railroads, and Other Features

ROADS AND RELATED FEATURES

Roads on Provisional edition maps are not classified as primary, secondary, or light duty. They are all symbolized as light duty roads.

Primary highway	
Secondary highway	
Light duty road	
Unimproved road	
Trail	
Dual highway	
Dual highway with median strip	
Road under construction	U. C.
Underpass; overpass	
Bridge	
Drawbridge	
Tunnel	

RAILROADS AND RELATED FEATURES

Standard gauge single track; station	
Standard gauge multiple track	
Abandoned	
Under construction	
Narrow gauge single track	
Narrow gauge multiple track	
Railroad in street	
Juxtaposition	
Roundhouse and turntable	

TRANSMISSION LINES AND PIPELINES

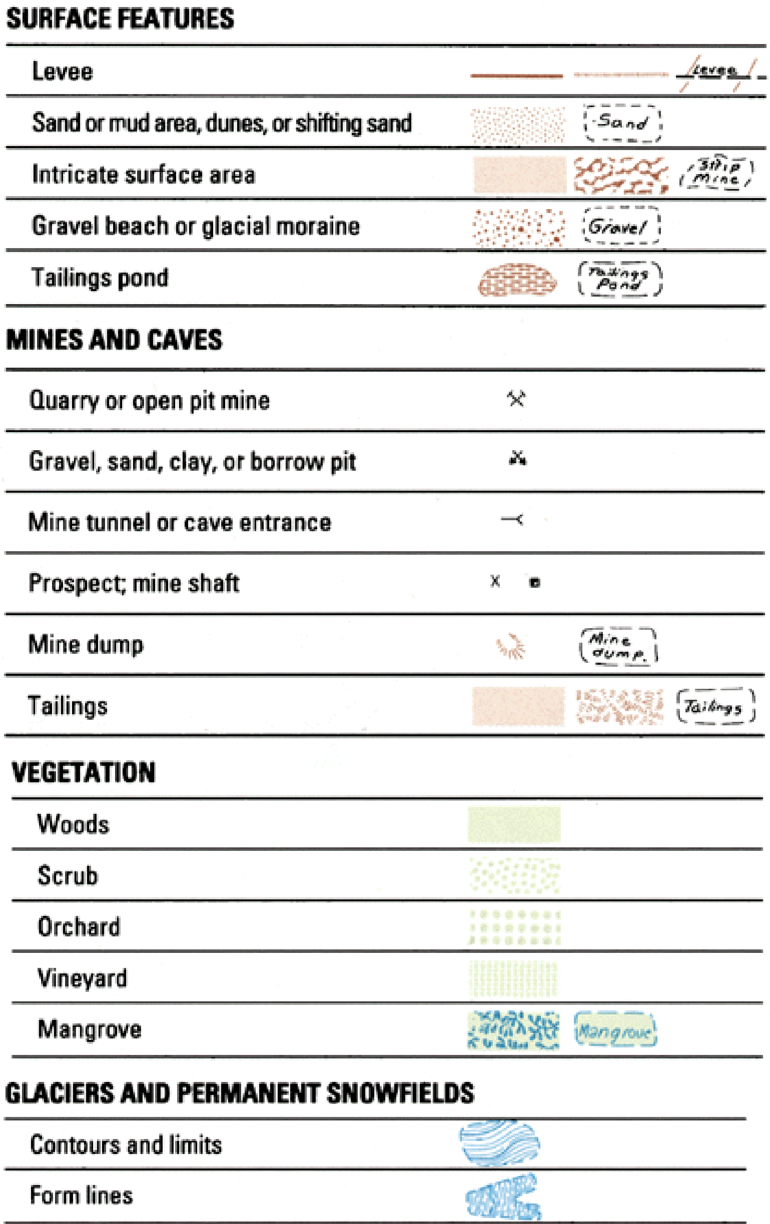
Power transmission line: pole; tower	
Telephone line	Telephone
Aboveground oil or gas pipeline	
Underground oil or gas pipeline	Pipeline

Elevation

CONTROL DATA AND MONUMENTS	
Aerial photograph roll and frame number*	3-20
Horizontal control	
Third order or better, permanent mark	Neace △ Neace
With third order or better elevation	BM △ 45.1 Pike BM 45.1
Checked spot elevation	△ 19.5
Coincident with section corner	Cactus △ Cactus
Unmonumented*	+
Vertical control	
Third order or better, with tablet	BM × 16.3
Third order or better, recoverable mark	× 120.0
Bench mark at found section corner	BM + 18.6
Spot elevation	× 5.3
Boundary monument	
With tablet	BM □ 21.6 BM 71
Without tablet	□ 171.3
With number and elevation	67 □ 301.1
U.S. mineral or location monument	▲

CONTOURS	
Topographic	
Intermediate	
Index	
Supplementary	
Depression	
Cut; fill	
Bathymetric	
Intermediate	
Index	
Primary	
Index Primary	
Supplementary	

Land Surface Features



Boundaries

BOUNDARIES	
National	
State or territorial	
County or equivalent	
Civil township or equivalent	
Incorporated city or equivalent	
Park, reservation, or monument	
Small park	

LAND SURVEY SYSTEMS	
U.S. Public Land Survey System	
Township or range line	
Location doubtful	
Section line	
Location doubtful	
Found section corner; found closing corner	
Witness corner; meander corner	WC MC
Other land surveys	
Township or range line	
Section line	
Land grant or mining claim; monument	
Fence line	

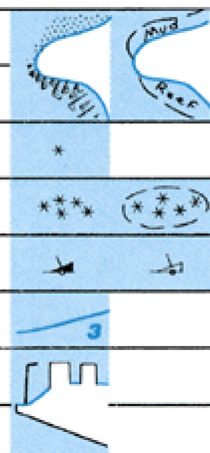
Water Features

MARINE SHORELINE

Topographic maps	
Approximate mean high water	
Indefinite or unsurveyed	
Topographic-bathymetric maps	
Mean high water	
Apparent (edge of vegetation)	

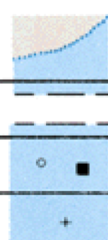
COASTAL FEATURES

Foreshore flat	
Rock or coral reef	
Rock bare or awash	
Group of rocks bare or awash	
Exposed wreck	
Depth curve; sounding	
Breakwater, pier, jetty, or wharf	
Seawall	



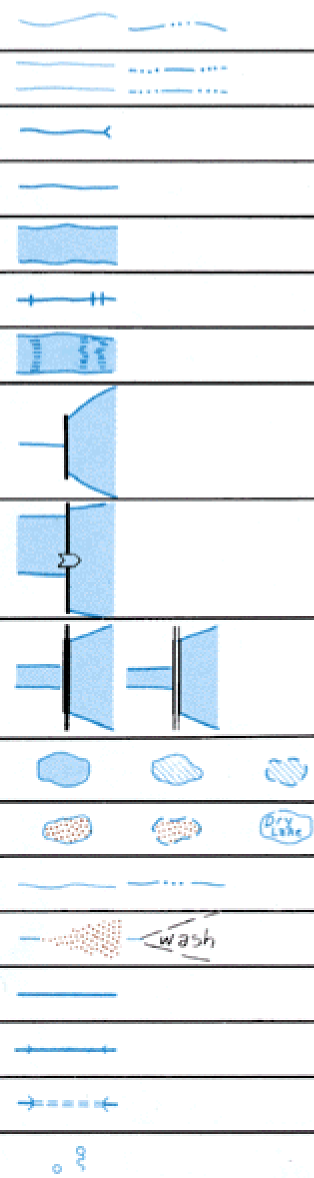
BATHYMETRIC FEATURES

Area exposed at mean low tide; sounding datum	
Channel	
Offshore oil or gas: well; platform	
Sunken rock	



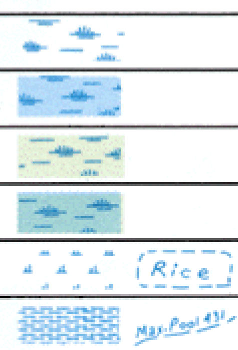
RIVERS, LAKES, AND CANALS

- Intermittent stream
- Intermittent river
- Disappearing stream
- Perennial stream
- Perennial river
- Small falls; small rapids
- Large falls; large rapids
- Masonry dam
- Dam with lock
- Dam carrying road
- Perennial lake; Intermittent lake or pond
- Dry lake
- Narrow wash
- Wide wash
- Canal, flume, or aqueduct with lock
- Elevated aqueduct, flume, or conduit
- Aqueduct tunnel
- Well or spring; spring or seep

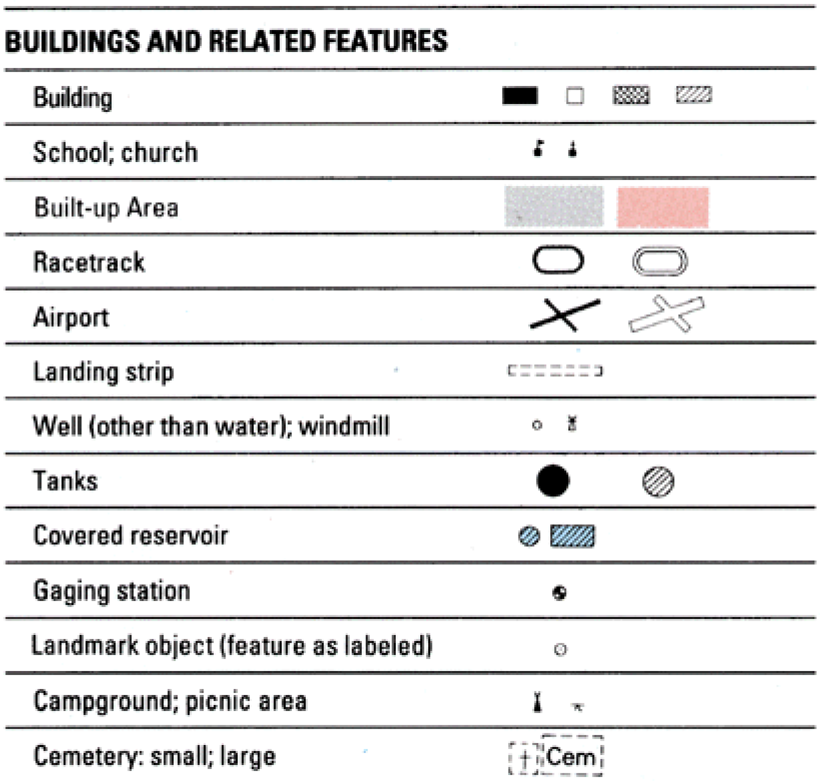


SUBMERGED AREAS AND BOGS

- Marsh or swamp
- Submerged marsh or swamp
- Wooded marsh or swamp
- Submerged wooded marsh or swamp
- Rice field
- Land subject to inundation



Buildings and Related Features



BUILDINGS AND RELATED FEATURES
Building
School; church
Built-up Area
Racetrack
Airport
Landing strip
Well (other than water); windmill
Tanks
Covered reservoir
Gaging station
Landmark object (feature as labeled)
Campground; picnic area
Cemetery: small; large

Tab for Drawing Contours

Slide 1

CONTOUR EXERCISE

Ohio **L**and **I**mprovement **C**ontractors **A**ssociation

Fred & Rick Galehouse

Ron Cornwell

Mark Seger, NRCS

Slide 2

Drawing a Contour

The basic way to get a contour map is to draw a grid of the area and then using the elevations on the grid to draw the contours

Slide 3

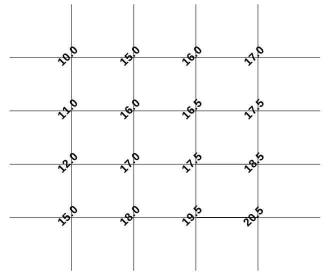
Drawing a Contour

There are a number of ways to draw contours from elevation numbers.

We will divide the space between elevation points and place dots where contour lines cross

Slide 4

Contour Exercise



12/14/20004 CONTOUR EXERCISE 4

Slide 5

Contour Exercise

Starting at the upper left corner of the sheet and going across the sheet

The first elevation is 10.0 The next elevation is 15.0

That means there are 5 contour lines between the points

12/14/20004 CONTOUR EXERCISE 5

Slide 6

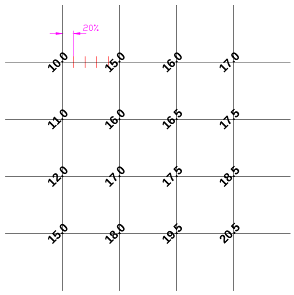
Contour Exercise

Divide the distance into 5 spaces (20%) each and place 4 dots on the line

12/14/20004 CONTOUR EXERCISE 6

Slide 7

Contour Exercise



12/14/20004 CONTOUR EXERCISE 7

Slide 8

Contour Exercise

The next point across is 16.0

That means there are no contours between the points as the contours are at the points.

12/14/20004 CONTOUR EXERCISE 8

Slide 9

Contour Exercise

The next point is 17.0 again the contours are at the points

12/14/20004 CONTOUR EXERCISE 9

Slide 10

Contour Exercise

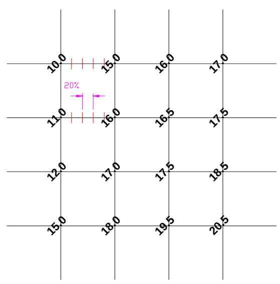
Now going across the second line

The numbers are 11.0 & 16.0 (5 contours) so place 4 dots at (20%)

12/14/20004 CONTOUR EXERCISE 10

Slide 11

Contour Exercise



12/14/20004 CONTOUR EXERCISE 11

Slide 12

Contour Exercise

Between 16.0 and 16.5 there is no contour so go to the next space

Between 16.5 and 17.5 there is a contour (17) half way between so place a dot at the midpoint.

12/14/20004 CONTOUR EXERCISE 12

Slide 13

Contour Exercise

Going across the third line
12.0 & 17.0 (5 spaces) place the 4 dots
17.0 & 17.5 (no contours)
17.5 & 18.5 (1 contour half way)

Slide 14

Contour Exercise

Going across the bottom line
15.0 & 18.0 three spaces 2 dots
18.0 & 19.5 one dot 2/3 from 18.0
19.5 & 20.5 one dot halfway

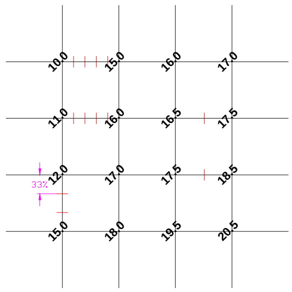
Slide 15

Contour Exercise

Going down the left side of the sheet
10.0 & 11.0 contours at the points
11.0 & 12.0 contours at the points
12.0 & 15.0 three spaces 2 dots

Slide 16

Contour Exercise



Slide 17

Contour Exercise

Going down the second vertical line
All the contours are at the points

Slide 18

Contour Exercise

Going down the third vertical line
16.0 & 16.5 no contours
16.5 & 17.5 one contour halfway

Slide 19

Contour Exercise

Between 17.5 and 19.5 there are two contours and therefore 3 spaces, but they are not equal.

One way to locate the points is to figure out how many units (tenths) there are between 17.5 and 19.5. (19.5 – 17.5 = 2.0 or 20 tenths)

Slide 20

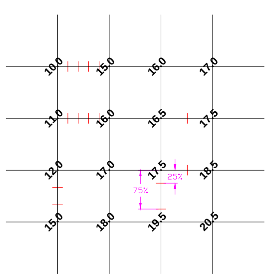
Contour Exercise

The 18 contour is 5 tenths from 17.5, so 5/20 = 0.25 or 25% (1/4) of the distance

The 19 contour is 15 tenths from 17.5, so 15/20 = 0.75 or 75% (3/4) of the distance

Slide 21

Contour Exercise



Slide 22

Contour Exercise

Going down the fourth vertical line
17.0 & 17.5 no contours
17.5 & 18.5 one contour halfway
18.5 & 20.5 two contours
one at ¼, one at ¾

Slide 23

Contour Exercise

All that is left to do is connect the dots.
The first dot on the top line (11) connects the the 11.0 point on the second line.

Slide 24

Contour Exercise

The 2nd dot on the top line (12) connects the the 1st dot on the second line (12) AND to the 12.0 point on the third line.

Slide 25

Contour Exercise

The 3^{rd} dot on the top line (13) connects to the 2^{nd} dot on the second line (13) AND to the 1^{st} dot on the third line (13) AND to the 13 dot on the 1^{st} vertical line between 12.0 and 15.0.

12/14/20004 CONTOUR EXERCISE 25

Slide 26

Contour Exercise

The 4th dot on the top line (14) connects to the 3rd dot on the second line (14) AND to the 2nd dot on the third line (14) AND to the 14 dot on the 1st vertical line between 12.0 and 15.0.

12/14/20004 CONTOUR EXERCISE 26

Slide 27

Contour Exercise

The 15.0 point on the top line connects to the 4th dot on the second line (15) AND to the 3rd dot on the third line (15) AND to the 15.0 point on the bottom line.

12/14/20004 CONTOUR EXERCISE 27

Slide 28

Contour Exercise

The 16.0 point on the top line connects to the 16.0 point on the second line AND to the 4th dot on the third line (16) AND to the 16 dot on the bottom line between 15.0 and 18.0.

Slide 29

Contour Exercise

The 17.0 point on the top line connects to the 17 dot on the second line between 16.5 and 17.5 AND to the 17 dot on the third vertical line between 16.5 and 17.5 AND to the 17.0 point on the third line and to the 17 dot between 15.0 and 18.0 on the bottom line.

Slide 30

Contour Exercise

The 18 dot on the fourth vertical line connects to the 18 dot on the third line between 17.5 and 18.5 AND to the 18 dot on the third vertical line between 17.5 and 19.5 AND to the 18.0 point on the bottom line.

Slide 31

Contour Exercise

The 19 dot on the fourth vertical line connects to the 19 dot on the third vertical line between 17.5 and 19.5 AND to the 19 dot on the bottom line between 18.0 and 19.5.

12/14/20004 CONTOUR EXERCISE 31

Slide 32

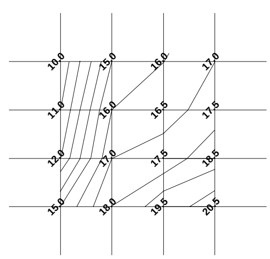
Contour Exercise

The 20 dot on the fourth vertical line between 18.5 and 20.5 connects to the 20 dot on the bottom line between 19.5 and 20.5

12/14/20004 CONTOUR EXERCISE 32

Slide 33

Contour Exercise



12/14/20004 CONTOUR EXERCISE 33

Slide 34

Contour Exercise

Looking at the contour map the left 100’ has about 5 ft per 100’ (5%)

The right side has about 1’ per 100’ (1%)

Remember slope is perpendicular to the contour lines.

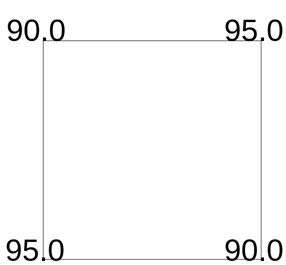
Slide 35

Contour Exercise

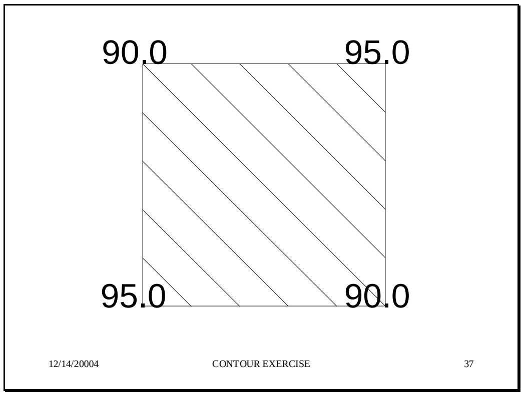
Are there any questions?

Slide 36

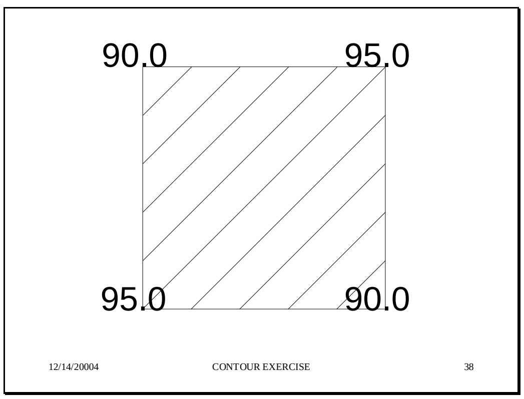
CONTOUR TEST



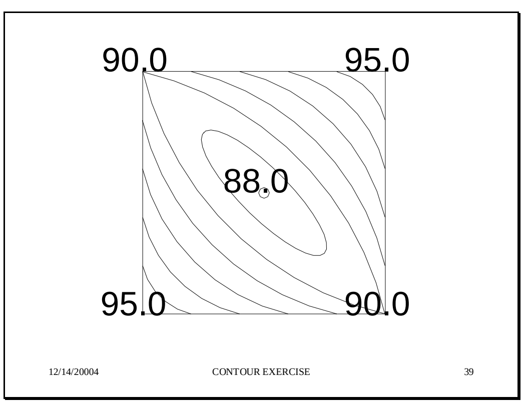
Slide 37



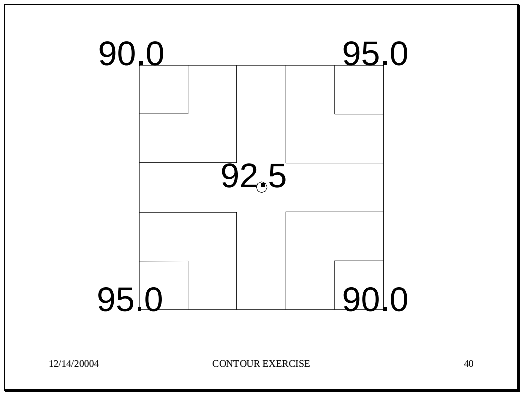
Slide 38



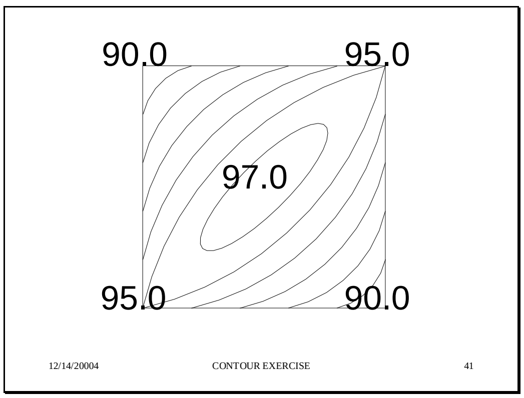
Slide 39



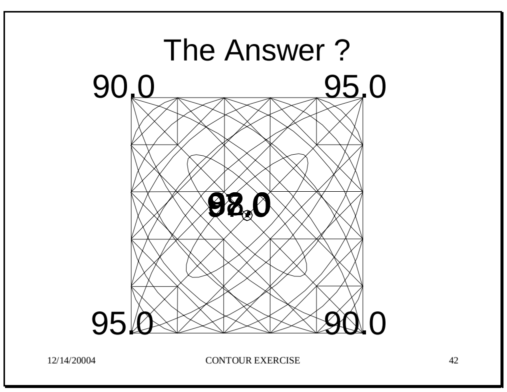
Slide 40



Slide 41



Slide 42



Slide 43

The Right Answer

Any one of the previous answers could be correct.

If you have seen the site you may be able to visualize what it should look like.

Otherwise you need additional readings.

Tab for Profiles and Earthwork Info

Slide 1

PROFILES
from a Topographic Map

Ohio **L**and **I**mprovement
Contractors **A**ssociation
Ron Cornwell Paul Demuth
Fred & Rick Galehouse

01/12/03 PROFILES from Topo V2 1

Slide 2

OBJECTIVE

To use Elevations and Locations to display a Vertical Section
To display any problems
To help design a construction plan

01/12/03 PROFILES from Topo V2 2

Slide 3

QUESTIONS

If you have questions along the way please ask them
There is a lot of information in this course and we will be proceeding rather quickly
There are no stupid questions

01/12/03 PROFILES from Topo V2 3

Slide 4

PROFILES

A profile is a vertical section through a proposed location.

A profile can be used to show the ground surface and also a proposed design

Slide 5

Profiles

Stations (STA) are a way of showing distance or locations on a plan or profile. Stations are commonly labeled something like 1+25 which would indicate 1 hundred and 25 feet

Slide 6

Profiles

Open ditches and septic systems are usually stationed from the top down

Sub surface drains are usually stationed from the outlet up

Slide 7

Profiles

A profile may be drawn from the information that you get when you go out in the field, set stakes and survey the actual location.

A profile may be drawn from a Topographic map.

Slide 8

Drawing a Profile from a Topographic Map

By drawing a line anywhere on the topographic map you can create a profile along that line

The proposed line may change directions

Slide 9

Drawing a Profile from a Topographic Map

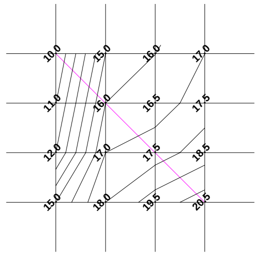
Using the topographic map we produced in the Contour Exercise

Draw a diagonal line from the top left to the bottom right as a proposed location.

Slide 10

Contour Exercise

PROFILE #1



01/12/03 PROFILES from Topo V2 10

Slide 11

Drawing a Profile from a Topographic Map

At the starting end of the line, find the elevation for station 0+00

It is easier to put this information into a table and then transfer it to Profile paper

01/12/03 PROFILES from Topo V2 11

Slide 12

Drawing a Profile from a Topographic Map

Using the scale of the topographic map (in this case 1”=100’ or the 10 scale on an engineer ruler).

Measure along the proposed profile line (starting at the 10.0 point) to the first contour line to get a distance.

01/12/03 PROFILES from Topo V2 12

Slide 13

Drawing a Profile from a Topographic Map

Enter the distance into the table as the Station (STA)

Record the contour into the table as the elevation (ELEV)

Continue along the proposed profile line recording stations and elevations for all the contour lines and readings

Slide 14

Table #1 page 1

STA	ELEV
0+00	10
0+24	11
0+46	12
0+69	13
0+94	14
1+18	15
1+41	16

Slide 15

Table #1 page 2

STA	ELEV
2+35	17
2+83	17.5
3+06	18
3+54	19
4+01	20
4+25	20.5

Slide 16

Drawing a Profile from a Topographic Map

Using profile graph paper with 20 horizontal lines to the inch with every 5th line darker

Select a vertical scale to label as elevation that will enable a plot of the highest and lowest elevations, including proposed locations.

Slide 17

Drawing a Profile on paper

Common scales are

1”=2’ where each horizontal line is 0.1’ of elevation or

1”=4’ where each horizontal line is 0.2’ of elevation

Slide 18

Drawing a Profile on paper

Using profile graph paper with 4 vertical lines to the inch

Select a scale along the bottom of the profile paper for the vertical lines that will enable a plot of the stations

A common scale is 1 inch = 100 feet (Vertical lines = 25’ distance)

Slide 19

Drawing a Profile on paper

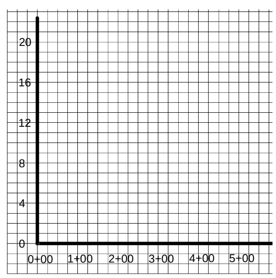
Label the elevations along the left edge of the profile paper

Label the stations along the bottom of the sheet

Slide 20

Drawing a Profile on paper

Something like this



Slide 21

Drawing a Profile from a Topographic Map

Plot the points from the table you just made, using the scaled distance (STA) and the contour elevation (ELEV)

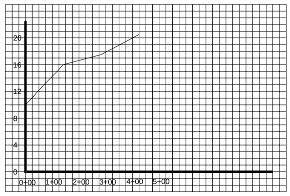
Continue plotting the points along the proposed line

Connect the dots using a straight edge

Slide 22

Drawing a Profile from a Topographic Map

Here is a completed profile (CAD)

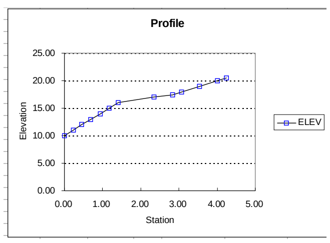


01/12/03 PROFILES from Topo V2 22

Slide 23

Drawing a Profile from a Topographic Map

Here is a completed profile (Spreadsheet)



01/12/03 PROFILES from Topo V2 23

Slide 24

Drawing a Profile from a Topographic Map

If the starting point or other critical point is not at a contour line you need to interpolate between contour lines to find the elevation

Assume the slope between the contour lines is constant

01/12/03 PROFILES from Topo V2 24

Slide 25

Profile Exercise #2

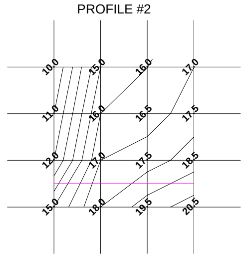
Draw a line across the middle of the bottom row.

Plot a profile for this location.

Slide 26

Topographic Map
w/ profile location #2

Contour Exercise
PROFILE #2



Slide 27

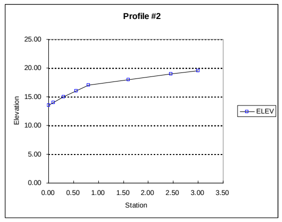
Profile Exercise #2

Starting at the left edge STA 0+00
the Elevation is 13.5
Starting a table

STA	ELEV
0+00	13.5
0+10	14

Slide 28

Profile location #2



01/12/03 PROFILES from Topo V2 28

Slide 29

Uses of a Profile

A Profile produces a visual picture that will help to see any problems along the proposed location

The average slope of the ground can be found

01/12/03 PROFILES from Topo V2 29

Slide 30

Uses of a Profile

An elevation of the outlet can be plotted

A depth of cut at the end of the line can be plotted

Connecting the two points will show a proposed grade line

01/12/03 PROFILES from Topo V2 30

Slide 31

Uses of a Profile

The slope of the proposed line can be calculated

Cuts along the proposed line can be determined

Slide 32

Profiles

A profile may be drawn from a profile survey or a Topographic map

Surveyors with total stations can be hired to produce topographic maps

GPS systems can be used to help produce topographic maps

Slide 33

Uses of a Profile

Each Station can be checked for acceptable cuts.

An adjustment can be plotted and checked again.

Slide 34

Other ways to draw a profile

- Computer spread sheet programs can draw profiles
- Information is entered in the same way as in the field book
- The formulas for figuring the distance and the elevations are entered and saved to be used again and again

Slide 35

Profiles from Topo

Are there any questions?

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March, 1990

UNITS OF MEASUREMENT FOR EARTHWORK

There are a number of basic units of measurement that contractors deal with to make job estimates. These are length, angle, area, and volume. The following is a brief description of these four units of measurement. Common conversion factors are given for each.

Length:

The foot is the common unit. Decimal units (1/10, 1/100) are used when the measurement is less than a whole foot. In some cases, the job description is given in inches. This number should be converted to the decimal system by dividing inches by 12. Overlooking the need for a conversion may lead to a sizable error in a job estimate. In other cases, length may be described in miles. The number in feet can be converted to miles by dividing by 5,280. Miles can be converted to feet by multiplying by 5,280.

Angle:

Angles are usually given in degrees, but may be stated as degrees, minutes (60 minutes per degree), and seconds (60 seconds per minute). Remember that there are 360 degrees in a circle.

Area:

Using the foot as the basic measurement, area is computed as square feet. For example, the area of a 100 ft. by 150 ft. rectangular space is 100 ft. X 150 ft. = 15,000 square feet. This last number could be converted to acres by dividing 15,000 by 43,560 yielding 0.34 acres. There are some custom jobs that require an area measurement in square yards. Taking the first example, 15,000 sq. ft. can be converted to sq. yds. by dividing 15,000 by 9 to equal 1,666.7 sq. yds.

Volume

If the area were given in sq. ft, cubic feet might be the volume unit to use. From a previous example, the area of the job was 15,000 sq. ft. Now, if the average depth was 2 feet, the volume would be 15,000 sq. ft. X 2 ft. to equal 30,000 cubic feet. Normally, to reduce the size of the numerical value, volume may be commonly described by cubic yards. There are 27 cubic feet in a cubic yard. So, in the previous example, 30,000 cubic feet divided by 27 equals 1,111.11 cubic yards (yd_3). We might simply say "yards."

Test Your Knowledge:

What is the volume of soil to be removed from a building site that must be excavated to secure a sound foundation for a building. The excavation area is 300 ft. long, 40 ft. wide, and has an average depth of 8 ft. 4 inches. Show your work here and give your answer in cubic yards.

(Answer: 3,703.7 cubic yards, or simply round off to 3,704 cubic yards)

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CONVERSION FROM INCHES TO FEET

Inches	Fractions of an Inch	Fractions of a Foot
0	0.0	0.000
1/8	0.125	0.010
1/4	0.250	0.021
3/8	0.375	0.031
1/2	0.500	0.042
5/8	0.625	0.052
3/4	0.750	0.062
7/8	0.875	0.073
1	1.0	0.083
1/8	1.125	0.094
1/4	1.250	0.104
3/8	1.375	0.114
1/2	1.500	0.125
5/8	1.625	0.135
3/4	1.750	0.146
7/8	1.875	0.156
2	2.0	0.167
1/8	2.125	0.177
1/4	2.250	0.188
3/8	2.375	0.198
1/2	2.500	0.208
5/8	2.625	0.219
3/4	2.750	0.229
7/8	2.875	0.240
3	3.0	0.250
1/8	3.125	0.260
1/4	3.250	0.271
3/8	3.375	0.281
1/2	3.500	0.292
5/8	3.625	0.302
3/4	3.750	0.312
7/8	3.875	0.323
4	4.0	0.333
1/8	4.125	0.344
1/4	4.250	0.354
3/8	4.375	0.364
1/2	4.500	0.375
5/8	4.625	0.385
3/4	4.750	0.396
7/8	4.875	0.406

Inches	Fractions of an Inch	Fractions of a Foot
5	5.0	0.417
1/8	5.125	0.427
1/4	5.250	0.438
3/8	5.375	0.448
1/2	5.500	0.458
5/8	5.625	0.469
3/4	5.750	0.479
7/8	5.875	0.490
1/8	6.125	0.510
6	6.0	0.5
1/8	6.125	0.510
1/4	6.250	0.521
3/8	6.375	0.531
1/2	6.500	0.542
5/8	6.625	0.552
3/4	6.750	0.562
7/8	6.875	0.573
7	7.0	0.583
1/8	7.125	0.594
1/4	7.250	0.604
3/8	7.375	0.614
1/2	7.500	0.625
5/8	7.625	0.635
3/4	7.750	0.646
7/8	7.875	0.656
8	8.0	0.667
1/8	8.125	0.677
1/4	8.250	0.688
3/8	8.375	0.698
1/2	8.500	0.708
5/8	8.625	0.719
3/4	8.750	0.729
7/8	8.875	0.740
9	9.0	0.750
1/8	9.125	0.760
1/4	9.250	0.771
3/8	9.375	0.781
1/2	9.500	0.792
5/8	9.625	0.802
3/4	9.750	0.812
7/8	9.875	0.823
10	10.0	0.833
1/8	10.125	0.844
1/4	10.250	0.854
3/8	10.375	0.864
1/2	10.500	0.875
5/8	10.625	0.885
3/4	10.750	0.896
7/8	10.875	0.906
11	11.0	0.917
1/8	11.125	0.927
1/4	11.250	0.938
3/8	11.375	0.948
1/2	11.500	0.958
5/8	11.625	0.969
3/4	11.750	0.979
7/8	11.875	0.990
12	12.0	1.000

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MAPPING SCALE CONVERSIONS

	Ratio	ft/in	in/mi	Acres/sq in
	1:48,000	4000	1.32	367.0
	1:24,000	2000	2.64	92.0
	1:20,000	1667	3.17	63.8
*	1:15,840	1320	4.0	40.0
	1:4,800	400	13.2	3.67
	1:2,400	200	26.4	0.918
	1:1,200	100	52.8	0.229
	1:600	50	105.6	0.057

1 foot = 12 inches, 1 mile = 5,280 feet, 1 acre = 43,560 square feet

How To Use These Numbers

For example purposes, use the line with the asterisk (*). Suppose we are looking at a map of a large farm field. If we are using an inch as the basic unit on the map, 1:15,840 means that 1 inch directly on the map is equivalent to 15,840 inches in the field.

Convert the ratio 1:15,840 to ft/in: Dividing 15,840 by 12 inches equals 1320 ft/in. This means that 1 inch on the map is equivalent to 1320 feet in the field.

Convert 1320 ft/in to in/mi: Dividing 5280 by 1320 ft/in equals 4 in/mi. This means that 4 inches on the map is equivalent to 1 mile in the field. This also means that 1 inch on the map is equal to a quarter mile in the field.

EXAMPLE PROBLEM: Convert the ratio 1:15,840 to acres/sq in.

1) First, divide 15,840 by 12 which equals 1320 ft/in.
2) Then, square 1320 ft/in, which equals 1,742,400 sq ft/sq in.
3) Lastly, divide 1,742,400 sq ft/sq in by 43,560 sq ft/acre.

These calculations equal 40 acres/sq in, which means that 1 square inch on the map is equal to 40 acres in the field.

Now, suppose that you have a map that has a scale of 1 inch = 50 feet. How many acres are in 1 square inch on the map?

ANSWER: (50 x 50 = 2500 square feet per square inch. Divide 2500 by 43,560 to get 0.057 acres.)

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FACTORS AFFECTING JOB COST ESTIMATES

In estimating earthwork quantities, the final figure must be tempered with experienced judgement. Overlooking seemingly small items may produce disastrous results. The following is a list of factors that may affect your job cost estimate.[1]

Site Evaluation: Visit the site. Do not rely only on the plans or the information given by developer of property owner. How accurate is the information on the plans?

Accessibility of Site: Special roads or bridges may have to be constructed in order to bear the weight of heavy equipment.

Availability of Facilities: Consider utilities, housing, rest rooms, food, and first aid facilities for employees.

Site Location: Distance of haul of imported or exported material is important. Costs increase greatly with distance and number of costs.

Overall Supervision: An unqualified superintendent or construction company can cost everyone time and money.

Overall Job Difficulty: Consider tight work space, ditches, trees, buildings, steep slopes, utilities, etc. These may hamper production.

Material Compaction: What is the degree of compaction required for fill material? This should be specified. Greater compaction necessitates more passes with heavier compacting equipment. Soil testing can be a costly item.

Special Equipment: Some jobs require equipment that may have to be imported from great distances. A shortage of local rental equipment during busy seasons can produce equipment availability problems.

[1]The major reference for this material was *Estimating Earthwork Quantities* by D. B. Atcheson, Norseman Publishing Co., 781 Lehigh Road, Venice, FL 34293.

FACTORS AFFECTING JOB COST ESTIMATES (Continued)

Material Costs:	Unpredictable fuel and materials costs may drive up job costs, and may be completely unavoidable.
Supply and Demand:	Consider the competition from other local excavating subcontractors, and supply of local labor. Prices tend to rise during boom periods.
Excavation Material:	Consider the earth material to be excavated. Hard, wet soil is more costly to excavate than soft, dry material. Wet materials weigh more.
Fill Material:	Are there special requirements for the fill material? If on-site material is not suitable as fill, suitable material must be imported and unsuitable material may have to be exported.
Surface Conditions:	Poor drainage, sharp rocks, steep slopes, etc., may call for crawler-mounted equipment. These types of equipment are less mobile than rubber-tired vehicles and must be transported to the site by truck.
Subsurface Conditions:	Poor drainage, hidden boulders and bedrock, may require special equipment. Excavating below the local water table necessitates continuous de-watering by pumping. Wet material is more costly to excavate and haul away, and the equipment must be placed on a dry surface above the pit.
Project Size:	Sometimes a small job may take as long to set up and complete as a larger one.
Weather:	Bad weather slows production. After rainfall, the moisture content of the soil may be so great that efforts to sufficiently compact the material may be useless until the material drys out.
Miscellaneous Conditions:	Protection of existing property and trees hampers production. Extreme caution must be exercised when working near power lines. Nearby traffic may require flagmen and barricades.
Underpinning:	Underpinning existing foundations is necessary when excavation is adjacent to an existing structure.

There may be other factors that can have an effect on the final job cost estimate. Practice in making estimates and experience in making on-site evaluations will not make a perfect estimator, but will make one a better estimator. A good evaluation of the job and a systematic method for estimating the earthwork quantity may mean the difference between a successful, profitable job and a failure.

Tab for GPS and Mapping

UK COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY, COLLEGE OF AGRICULTURE

Elements of
PRECISION AGRICULTURE

GPS Simplified

Tim Stombaugh, Scott Shearer, John Fulton, Biosystems and Agricultural Engineering

Precision agriculture is rapidly becoming an important tool for Kentucky farmers. The Global Positioning System (GPS) is one of the key technologies that makes precision agriculture possible. GPS receivers with sufficient accuracy for yield mapping, grid sampling, variable rate application, and other precision activities are available at moderate cost. GPS receivers, which provide accurate, georeferenced position information, are often used with combine yield monitors, scouting equipment, or variable rate application machinery. Unfortunately, the technology behind GPS receivers is still a mystery to many users. This publication gives a simplified explanation of how GPS receivers work.

How GPS Works

The Global Positioning System is a $12 billion system of 24 satellites (plus a few spares) deployed and maintained by the U.S. Department of Defense (DOD). Each satellite passes around the earth twice in a 24-hour period at an altitude of about 12,500 miles. Radio signals from these satellites can be used to determine accurate georeferenced position information. Deployment of the satellites began in 1978, and the system became fully operational (i.e., offering uninterrupted global coverage) in 1995.

GPS receivers use a principle called triangulation, which is a method of determining the position of an object by measuring its distance from other objects with known locations. Each satellite's position is known very accurately. A GPS receiver uses the signals transmitted by a satellite to determine its distance from that satellite. If you know your distance from one satellite, you could be anywhere on a sphere around that satellite. If you add distance information from a second satellite, you narrow your location to the intersection of the two spheres around those satellites, which puts you somewhere on a circle. Addition of a third sphere narrows your position to two points, one of which can be eliminated because it is nowhere near the earth's surface. Because of some clock errors, which are discussed later, GPS receivers need a fourth satellite signal to compute a valid GPS position. Modern GPS receivers are equipped to receive as many as eight extra satellite signals, which are used to increase accuracy.

The information that is broadcast by each satellite includes a timing signal and satellite ephemeris (location). The timing data are generated by highly accurate on-board atomic clocks. The satellite's ephemeris is a set of orbit parameters used to calculate the location and orientation of the satellite.

A GPS receiver uses the timing data transmitted by the satellite to measure the amount of time it took the signal to travel from the satellite to the receiver. Because radio signals travel at the speed of light (186,000 miles per second), the distance between the satellite and receiver is the transmission time multiplied by the speed of light. The total transmission time is less than 0.07 seconds, so this calculation must be very precise to get an accurate position. The locations (ephemeredes) of the transmitting satellites are then used to triangulate the receiver position.

Sources of GPS Errors

Several factors, including the satellite and receiver clock limitations, ephemeris variation, satellite configuration, atmospheric interference, and multipath can cause errors in GPS position information.

Clock Limitations

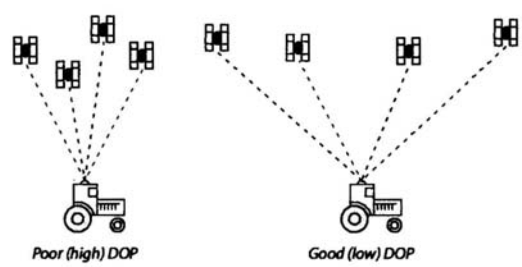
The internal satellite and receiver clocks have limited accuracy, and they are not precisely synchronized. Since position computations are highly dependent on accurate timing information, small clock errors can cause significant errors in position computations. As mentioned earlier, a signal from a fourth satellite is used to correct some of these clock issues.

Ephemeris Variation

Satellite orbits are difficult to predict over time and require periodic adjustment by system maintainers. Because these orbits change, errors can exist in the satellite ephemeris (location) data used in triangulation calculations.

Satellite Configuration

The configuration of the satellites in view to a receiver at any given time can affect the accuracy of position determination. For instance, if all of the visible satellites happen to be bunched close together, the triangulated position will be less accurate than if those same satellites were evenly distributed around the visible sky. The satellite configuration is quantified by the Dilution of Precision (DOP). Many GPS receivers will display DOP values. Lower DOP values indicate better satellite configurations. In general, DOPs less than 4 will give good position determinations.

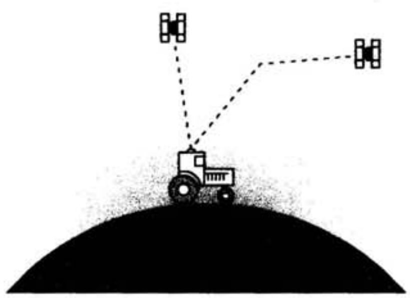


Dilution of Precision

Atmospheric Interference

Moisture and ions in the earth's atmosphere can change the speed at which the satellite radio waves travel. Additionally, the radio waves are bent (refracted) when they enter the earth's atmosphere, which actually changes the length of the path the radio signal takes to get to the receiver.

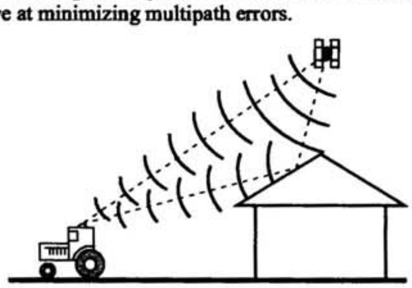
Atmospheric effects are usually greater for satellites low on the horizon; therefore, some GPS receivers allow the user to ignore or mask satellites below a set angle above the horizon.



Atmospheric Effects

Multipath Errors

Multipath means that the same radio signal is received several times through different paths. For instance, a radio wave could leave a satellite and travel directly to the receiver, but it also bounces off a building and arrives at the receiver at a later time. The most common causes of multipath errors in agricultural settings are buildings, ponds, and lakes. With advanced antenna-filtering techniques, most new GPS receivers are very effective at minimizing multipath errors.

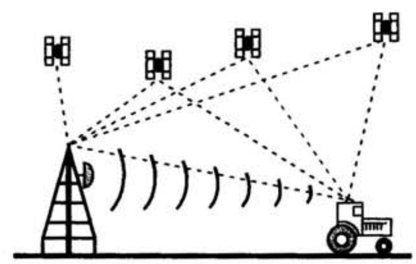


Multipath Errors

Counteracting GPS Errors with Differential GPS (DGPS)

In agricultural applications, the most common way to counteract GPS errors is by using Differential GPS or DGPS. In a DGPS system, a GPS receiver is placed at an accurately known location. This *base station* receiver will calculate GPS errors by comparing its actual location to the location computed from the GPS signals. This error information is sent to the *rover* receiver, which uses it to correct the position information it computes from the GPS signals. Accuracies of DGPS systems can range from 15 feet to 3 feet depending on system configuration.

DGPS corrections can be broadcast by tower-based or satellite-based systems. They can be provided free of charge by government agencies or at an annual fee by commercial providers.



Differential GPS System

U.S. Coast Guard Ground Network

The United States Coast Guard (USCG) has established a network of land-based broadcast towers near major navigable bodies of water. The major advantage of the USCG signal is that it is a free service. One disadvantage is that coverage is limited to areas near the base stations. Also, signal strength will decrease and the correction information itself becomes less accurate as the user moves farther from the base station. In Kentucky, there is good USCG coverage in all but the very eastern portions of the state.

Commercial Correction Services

Several commercial companies have established satellite-based differential correction services. These organizations have installed GPS base stations at various locations in their geographic region of interest. Error corrections computed by these stations are sent to a communication satellite (separate from the GPS satellites) and broadcast back to the user. These satellite-based corrections tend to have a more widespread coverage than the tower-based broadcasts, and system accuracy is not greatly affected by the user's distance from the base station receivers. Most of these service providers, however, require an annual fee for usage.

Wide Area Augmentation System (WAAS)

Recently, the Federal Aviation Administration has established a free satellite-based differential correction service called the Wide Area Augmentation System (WAAS). Although not officially completed, many GPS manufacturers are incorporating WAAS capabilities into newer, lower-cost receivers, which are showing promise for use in agriculture.

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THE OHIO STATE UNIVERSITY EXTENSION

Extension FactSheet

AEX–562-03

Food, Agricultural and Biological Engineering, 590 Woody Hayes Drive, Columbus, OH 43210

GPS Guidance Systems: Tips for Purchasing a System

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Global Positioning System (GPS)-based guidance systems are new advancements in farm equipment. Guidance systems utilizing Differential Global Positioning System (DGPS) can be classified into two general categories, commonly known as lightbar guidance systems and auto-steering guidance systems.

- DGPS lightbar steering guidance systems are driving aids that guide the operator through the field and can be used in place of visual marking systems such as row and foam markers. These systems need an operator steering the vehicle at all times and can be accurate up to 20 inches. A typical system will cost between $3,200 to $12,000.
- The auto-steering guidance systems have the capability to steer a machine across the field. At the end of the field, the driver must steer the machine to the next pass where the auto-steering system will steer itself as directed. The auto-steering guidance systems with a DGPS receiver are accurate to approximately 4 to 10 inches. Using a real-time kenematic (RTK) GPS receiver, the auto-steering guidance system is accurate to 1 inch. The cost for an auto-steering system ranges from $10,000 to $50,000 depending on the type of GPS receiver used in the system.

Currently, at least ten DGPS-based guidance systems are available. The task of choosing a guidance system can be challenging and overwhelming because different brands offer different features. Buyers need to decide what their needs are and then choose a guidance system that matches their farming situation. Knowing the answer to the following questions will help in identifying the appropriate guidance system. The focus of this fact sheet is on DGPS-based guidance systems, steering aid systems, where an operator needs to steer the equipment at all times.

What sources of GPS differential signal are available to use with guidance?

Three main sources of differential signal are available for use with DGPS-based guidance system.

1. The United States Coast Guard Beacon Signal is limited to major bodies of water and rivers. The Coast Guard Beacon Signal is free. As the distance increases from the beacon tower to the mobile antenna, the signal may be degraded or interrupted by weather or structures. The two sources of USCG Beacon for Ohio are Detroit, Michigan and Louisville, Kentucky. The Coast Guard differential source is usually the best option if the GPS receiver is in close proximity (less than 100 miles).
2. The second differential source is fee-based through commercial differential signal service providers. This differential source is a satellite-based correction signal and is available worldwide. To receive this signal, the GPS receiver should be equipped with extra hardware.
3. The newest source of differential signal is Wide-Area Augmentation System (WAAS) from the Federal Aviation Administration. This differential source is also a satellite-based correction signal. Wide-Area Augmentation System is being implemented for air flight travel, but precision agricultural users have the opportunity to use this free source of differential signal.

The ability to receive more than one differential source is important if the guidance system will be used on a regular basis. If the receiver can be switched from one source to another, it provides a good back-up.

How accurate does my GPS receiver/ guidance system need to be?

- If the GPS receiver will be used for mapping rocks, weed patches, or drainage patterns, different levels of accuracy or sensitivity of GPS receivers may be needed. The GPS receiver may need to be configured to come back to the desired point after a period of time.
- If an accuracy of 3 to 9 feet is sufficient, then most DGPS receivers will provide a way to locate the object or navigate back to a specific location.
- For an accuracy of less than 4 inches, consider a real-time kenematic (RTK) GPS receiver. The RTK system requires a base station along with a rover unit. The cost of the RTK equipment may be a limiting factor for agriculture production systems.
- For guidance applications, the pass-to-pass accuracy needs to be as close as possible. The guidance systems will usually have a pass-to-pass accuracy within 20 inches of the desired line. A high quality GPS receiver will provide this accuracy.
- Accuracy of a guidance system can be stated in many different ways, such as static accuracy, dynamic accuracy, relative accuracy, or absolute accuracy. Ask the vendor for information on how the accuracy of the guidance system is determined and make sure you understand these terms.
- For accuracies less than 20 inches, the guidance options to increase accuracy usually require an auto-steering system. The auto-steering systems can use either DGPS or RTK GPS signals for the location information.

What if I already have a GPS receiver?

- When adding a guidance system to the agricultural operation, having a GPS receiver may save a considerable amount of money.
- Make sure the GPS receiver has an update rate that will meet the needs of the guidance system. Most guidance systems need an update rate of 5-Hz to operate efficiently and correctly. Most GPS receivers provide a 1-Hz update rate while some provide 2-, 5-, or 10-Hz update rates. Fast update rates are necessary for guidance performance with increased vehicle speed.
- Low-cost GPS receivers may only have a slow update rate (1 Hz) or less than 1 Hz.
- Check the GPS receiver to see if it is sending the correct data string to the guidance system. Some guidance systems are optimized to use a certain NMEA data string, such as GGA.
- Some guidance displays will only run with certain GPS receivers. The GPS dealer/manufacturer will have this information.

What are the uses of a guidance system?

- A guidance system can be used on a sprayer, fertilizer spreader, tillage equipment, and depending on how accurate guess rows are needed, it may be used to plant soybeans. Guess rows are the outside planter rows that match up to the inside row of the planter pass to pass. The distance of the guess row is not exact, due to driver and row marker error.
- The use of guidance systems to plant row crops such as corn or wheat has not been completely researched and is not recommended at this time.
- A guidance system can be used as a harvest aid to ensure a full swath width of crop on the cutting platform.
- When the GPS receiver is not being used for guidance, it may be used with a data logger for scouting, mapping, or other operations where a record of time and spatial information is needed.

What type of operations and equipment will be used with the guidance system?

- The more applications planned for the GPS guidance system, the easier the cost can be justified. When looking at a guidance system, check to see if the components can be easily transferred from one implement to another.
- The mounting of the guidance display may be a factor in which system suits the operation. Some display units are manufactured for inside the cab only, while others can be used either inside or outside the cab.
- A guidance system can be used to reduce overlap in tillage operations, spraying, spreading fertilizer, planting soybeans, or mapping.

What type of guidance display do I want?

- Guidance displays are either a light bar or visual screen. Light bars come in many versions, but the main premise is a row of lights that indicate where the vehicle is in respect to the desired line of travel. The visual screen may be a computer screen or LCD screen. Both types of visual displays will aid the driver on the desired line of travel effectively. It is up the driver to determine which type of screen is suitable for the equipment.
- Features on the visual display will aid the driver in staying on the desired line of travel, such as heading error (look ahead), swath number, or error from desired line of travel. These features help the driver determine the amount of correction needed for turning and staying on desired line of travel.
- The ground speed of the vehicle or the use of bifocals should be considered when using different types of guidance visual displays. The faster the application speed, the greater the tendency to look at the horizon rather than focus closely on a display unit. If the driver needs to look down at the guidance system through bifocals and then focus on another point in the field of view, careful mounting of the display will be required.

What if I have a computer, yield monitor console, or hand-held computer?

- Many guidance systems have the option (serial port) for a data logger where an application record or field information can be collected. This information can be part of the spray record or planting pattern to overlay future yield data.
- When evaluating guidance systems, make sure the operating system of the home/business computer is compatible with the guidance system software or mobile computer software.
- A card reader may be needed to take the information from the data card to the computer. Make sure that the card reader software is compatible with the latest software updates on the computer.
- A yield monitor console or small computer (personal digital assistant, PDA) may also be used as a data collection system and as a visual display for the guidance system.
- Software is available for the yield monitor console or hand-held computer to aid in the guidance system operation.
- Make sure that the guidance system is compatible with the yield monitor system.

What type of customer support is provided after the purchase of a system?

- How close is the nearest dealer for support?
- Is on-site support more important than phone support?
- What kinds of warranties and extended warranties are available on the system? Evaluate the plans closely to see if it would be beneficial to a farming operation.

What is included in the cost of the guidance system?

- Prices differ when comparing guidance systems. Make sure that the price quoted has all of the necessary components to complete the intended tasks.
- What type of GPS receiver/antenna comes with the guidance system?
- Is guidance system software/firmware included? If so, are the updates free?
- Is a data logger with software included with the system?
- Are hardware upgrades available for the guidance system?
- What aftermarket options are available?

Contact your local Extension office for the most updated information before purchasing a guidance system. Check http://paa.osu.edu for more information on guidance system evaluation and upcoming programs.

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THE OHIO STATE UNIVERSITY EXTENSION

Extension FactSheet

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Food, Agricultural and Biological Engineering, 590 Woody Hayes Drive, Columbus, OH 43210

Understanding GPS Accuracy for Agriculture Applications

Matthew Sullivan and **Dr. Reza Ehsani**
Department of Food, Agricultural and Biological Engineering

Good management decisions are based on good information. Knowing the level of accuracy for GPS/GIS applications is important to perform a specific job. A GPS user needs to understand the limitations of different types of GPS receivers and how those limitations will affect the data collected.

GPS provides several types of information to the user. It primarily provides location information in the X (latitude), Y (longitude), and Z (elevation) planes. It can also be used as a navigation tool to locate objects and determine speed. GPS will provide information for future planning, accurate placement of materials, and give reference to historical points of interest.

Accuracy Classifications

GPS receivers are designed for different purposes and usually correspond to a certain level of accuracy. The level of accuracy needed depends on the user and application. Accuracy can be classified by 2 categories: motion and position. Motion refers to static mode (not moving), or dynamic mode (moving). A GPS receiver's accuracy could be much different statically than when it is moving on a vehicle. Both situations are important for different applications.

The second category concerning accuracy refers to relative position vs. absolute position. Relative GPS position describes a GPS location where a point or line is collected and then is compared to other points collected by the same GPS receiver. Relative positions can also be stated as short-term repeatability. Absolute positioning knows the exact location of points or lines over varying lengths of time and space.

Absolute GPS position is comparing a point or line to a known location such as a USGS reference site. Understanding the difference between relative, absolute, static, and dynamic situations can help the GPS user determine what level of accuracy is needed for a specific application.

Levels of Accuracy

There are 5 main levels of GPS accuracy used in agriculture. The levels are less than 10 feet, less than 3 feet, less than 15 inches, less than 4 inches, and 1 inch accuracy. The first two levels (<10 ft and <3 ft) primarily describe static situations with different classes of GPS. The more accurate levels (<15 inches, 4 inches, and 1 inch) describe applications pertaining to vehicle guidance and surveying.

The application always determines the level of GPS needed. For convenience, we have grouped GPS receivers into four classes, with Class I being the least precise and Class IV being the most precise.

Class I GPS Receivers

A Class I GPS receiver will provide good location information where a high degree of accuracy is not needed. This class of GPS receivers is accurate enough for mapping field boundaries, drainage lines, or other such attributes (see performance and selection guide). The majority of these GPS receivers use the WAAS differential source for GPS correction. Make sure the GPS receiver is WAAS enabled and not WAAS compatible. WAAS enabled means the WAAS signal is operational in the GPS receiver. WAAS compatible means the GPS can receiver the WAAS signal, but is not currently active. These GPS receivers perform better in a dynamic situation than static situation. The relative accuracy usually increases as it is moving. The static accuracy of a Class I GPS receiver is not as good as dynamic accuracy, but will provide good static location positions within a 15 ft. area. Usually the accuracy stated by the manufacturer is a static measurement over a 24-hour period. If a manufacturer's stated accuracy is <2.5 meters (2drms), then usually 95% of its points will fall within about a 2.5 meters (8.2 feet) area.

This class of GPS receivers is not accurate enough for elevation mapping. The error associated with elevation with DGPS receivers is double the X and Y error. For example, if a Class I GPS receiver has an 8 ft. error associated in the X and Y plane, the error in the Z (elevation) could be as much as 16 ft.

Class II & III GPS Receivers

Class II and III GPS receivers obtain a more accurate position location than the Class I. Class II and III are primarily used in vehicle guidance and environmental mapping. The Class

II GPS can use WAAS, Coast Guard, or satellite subscription differential depending on manufacturer model type. The Class II GPS receivers have static accuracies less than 3 feet. These GPS receivers usually have a faster update rate (5 Hz or more) for vehicle guidance. A higher update rate does not mean that the GPS receiver has better accuracy. Class III GPS receivers use dual frequency signals to achieve an accuracy of approximately 4 inches. This degree of accuracy is usually needed for vehicle guidance and planting row crops. There are situations where a Class III would provide better accuracy than a Class II, but in most agricultural applications, a Class II would be sufficient for mapping in the X and Y plane. Both Class II and III are not accurate enough for elevation mapping because their error is similar in the Z-coordinate for Class I.

Class IV GPS Receivers

The highest level of GPS positioning is Real-Time Kinematic (RTK) GPS receivers. This class of GPS will give X, Y, and Z positions within an inch. This accuracy can be used for surveying and highly accurate mapping. It offers the capability of absolute repeatability because it uses a base station collecting GPS location points along with a GPS rover unit. The base station and rover unit communicate via a 900 MHz FM transmitter and receiver. This level of GPS will allow drainage (elevation) maps to be created, but is not accurate enough to install drain lines. This class of GPS receivers are used in agricultural applications such as strip-tilling, row crop cultivation, and harvest.

Overview of GPS

The use of GPS will allow the user to be more accurate in agricultural applications and efficient locating information. The agricultural operation will ultimately determine what type of GPS receivers will be needed to achieve the best location information. Accuracy of location positions are relative to the class of GPS receivers used. A person can benefit from using GPS if the steps are taken to ensure the correct accuracy is needed and used.

Agriculture GPS Performance & Selection Guide

GPS Receiver Classifications

	Class I	Class II	Class III	Class IV
Price (2004)	< $1,000	$1000 to $3,000	$3,000 to $10,000	$40,000 to 50,000
Differential Source Options	WAAS	WAAS, Beacon, L-Band Sat.	Dual Frequency	RTK GPS, Need Base Station
Static Accuracy	5 to 12 feet	< 3 feet	4 to 12 inches	I inch
Static GPS Position Location	Not Stable	Somewhat Stable	Stable	Stable
Advantages	Compact in size, Mobile, CF GPS, Smart Antenna	Higher quality than class I, Faster update rates	Greater accuracy for precise applications	Highly Accurate, Survey Grade, Repeatability
Update Rate	1 Hz	>= 5Hz	>= 5Hz	1 Hz and greater
Uses	Scouting (>15 ft. area), Mapping, VRT applications	Mapping, Guidance, VRT applications	Row crop guidance, Mapping, VRT applications	Elevation and Drainage Mapping, All types of guidance applications, VRT applications

To select the correct GPS make certain that:
- It will provide enough accuracy
- The software/firmware can be upgraded
- It has an external antenna
- It is portable enough for the need

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