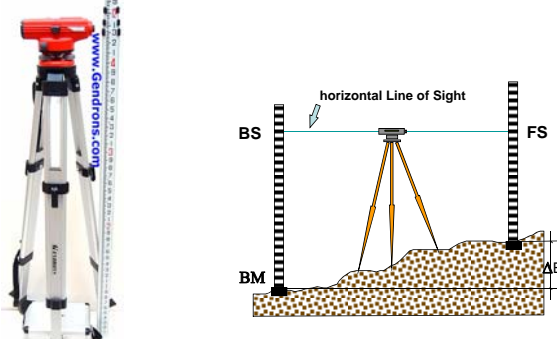


CVEN303 ENGINEERING MEASUREMENT
Lecture 11 – Introduction to Leveling
(Ch. 2) - 2013



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Direct Differential Leveling

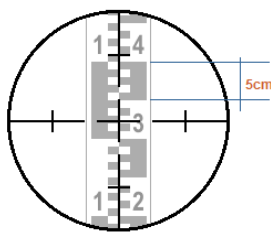


From Univ. of WF 2

Direct Differential Leveling Rod Reading

Read this leveling rod measurement.


Reading A Level Staff



From Joiana Nascarella 3

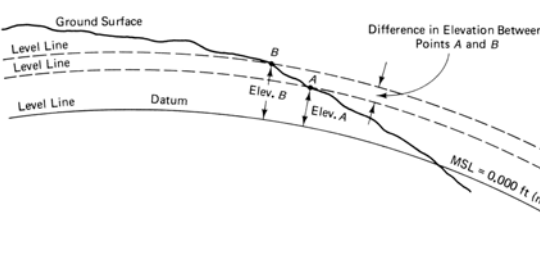
Instruments for Measuring Elevation (Altitude)

- Common Leveling Instruments:
 - Automatic level
 - Laser levels
- Other instruments:
 - Total station
 - GPS



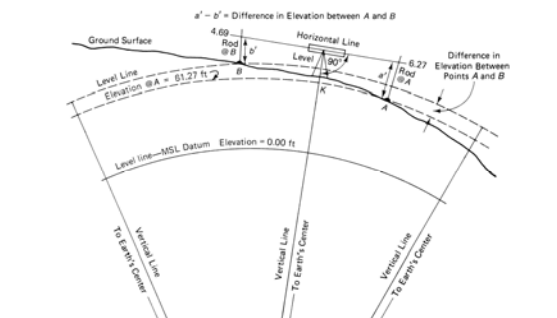
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Leveling Concepts



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Leveling Process



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Leveling Errors

- Curvature error (c): divergence between a level line and horizontal line over a specified distance
- Refraction error (r): all sight lines are refracted downward by the earth's atmosphere.

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Effects of Curvature and Refraction

$$(R + c)^2 = R^2 + K^2$$

$$c = \frac{K^2}{2R + c} \approx \frac{K^2}{2R}$$

For R=6,370 km,
 $c = 0.0000785 K^2$, where K and c in kmEq. 1
 $c = 0.0785 K^2$, where K in km and c in metersEq. 2

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Effects of Curvature and Refraction

It is generally accepted that r is one-seventh of c,
 $\rightarrow r = -0.14c$Eq. 3

By substituting c from Eq. 2 into Eq. 3 and then adding Eq. 2 & 3:

$c+r = 0.0675 K^2$, where (c+r) in meters and K in kilometers

$c+r = 0.574 K^2$, where (c+r) in feet and K in miles

$c+r = 0.0206 M^2$, where (c+r) in feet and M in thousands of feet

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Curvature and Refraction Errors-- Example

Calculate the error due to curvature and refraction for 100 ft, 200 ft, 300 ft, 400ft, 500 ft, 1,000 ft, and 1 mile.

Distance, ft	Distance, 1000ft	(c+r), ft
100	0.1	0.000
200	0.2	0.001
300	0.3	0.002
400	0.4	0.003
500	0.5	0.005
1,000	1	0.021
1 mile	5.28	0.574

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Benchmark (BM)

- Benchmark: Permanently affixed object with recorded elevation (altitude) and/or location. These objects are usually small brass or aluminum disks that are permanently attached to a stable foundation.
- Elevation is almost never written on BM.
 - Why?
- There are some websites that allow you to search for benchmarks:
 - <http://www.geocaching.com/mark/>
 - <http://www.ngs.noaa.gov/cgi-bin/datasheet.pr>

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Reference Surface

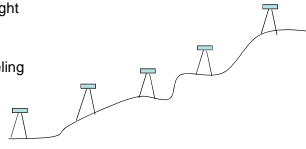
- Mean sea level (MSL), as modeled by:
 - National Geodetic Vertical Datum of 1929 (NGVD)
 - North American Vertical Datum of 1988 (NAVD 88)
- NAVD 88 is a refined version of NGVD
- More than 500,000 benchmarks are included in NAVD 88.

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Types of Leveling

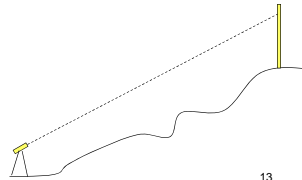
- Direct differential leveling: Line of sight is horizontal, so the difference in elevation is measured directly.

- Advantage: Most accurate leveling method
- Disadvantage: it can be time consuming to move the level many times.



- Trigonometric Leveling: Line of sight is not horizontal, so the difference in elevation is computed from vertical angle and slope distance.

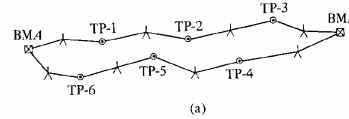
- Advantage: Less time in hilly areas.
- Disadvantage: low to moderate precision



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Closure Error

- Closure error: discrepancy between the known elevation of a benchmark (BM) and its measured elevation at the end of the survey route



(a)

- Legend
- △ Instrument setup
 - Turning point
 - ⊗ Benchmark

Acceptable closure error is computed as a function of the length of the leveling route or as a function of the number of instrument setups.

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1st, 2nd, and 3rd Order Surveys

- First-order surveys
 - Closure error $\leq 3\text{mm} (K)^{0.5}$ to $5\text{mm} (K)^{0.5}$
- Second-order surveys
 - Closure error $\leq 6\text{mm} (K)^{0.5}$ to $8\text{mm} (K)^{0.5}$
- Third-order surveys
 - Closure error $\leq 12\text{mm} (K)^{0.5}$

where K = length of leveling route in km.

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