CVEN303 CIVIL ENGINEERING MEASUREMENT

Lecture 12 – Differential Leveling
2013
(Sections 2.6-2.9, 2.14-2.17)

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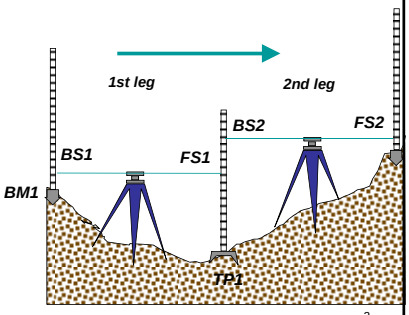
Direct Differential Leveling

- Benchmark (BM) - permanent point of known location and elevation defined by a datum such as NAVD88) and date.
- Backsight (BS) - a level rod reading (vertical distance) on a point of known or calculated elevation.
- Height of Instrument (HI) - elevation of instrument line of sight.
- Foresight (FS) - rod reading on a point for which elevation is to be determined.
- Turning Point (TP) - a stable rod position upon which both a foresight reading and then a backsight reading are taken. Needed when the rod at the end point cannot be seen and thus the level has to be moved.



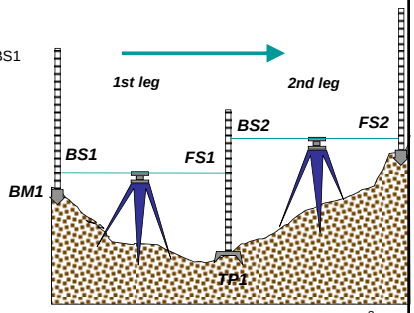
Direct Differential Leveling Computations

Leveling calculations:

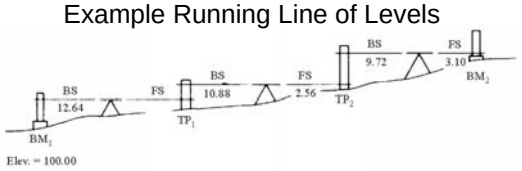
HI1 = Elevation of BM1 + BS1

Elev of TP1 = HI1 – FS1

Check Leveling Calculations:
ΣBS - ΣFS = ΔElv



Example Running Line of Levels



Determine the elevations of TP1, TP2, and BM2. Check your math.
To be solved in class.

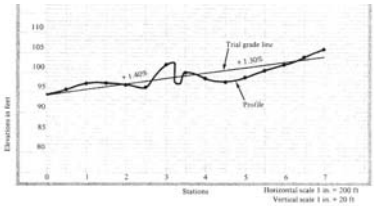
Answers: BM1 Elev=100ft, TP-1 Elev = 109.53ft, TP-2 Elev = 117.85ft, BM2 Elev=124.47ft; Math Check: OK.

Purpose of Profile Leveling

- Determine the elevations of the ground surface along the centerline or edges of a planned route feature (road, sidewalk, channel, railroad, etc.)
- Measure the cross section and the location of route features.

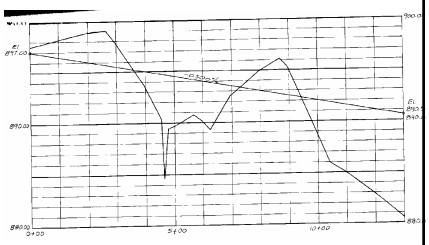
Profile

A graphical representation of the intersection of a series of vertical surfaces with the surface of the earth. Normally, the vertical scale is much larger than the horizontal scale to show the difference of elevation.



Rate of Grade

Rate of Grade (also called Gradient)= Vertical rise (or fall) distance / Horizontal distance
Expressed as %
Falling grade: -%
Rising grade: +%



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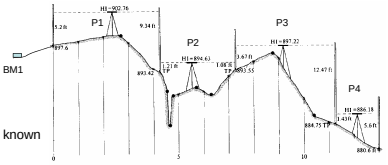
Profile Leveling Procedure



- Start by taking a BS on a BM of known (or assumed) elevation.
- Several intermediate foresight readings (IFS) readings are taken along the centerline of the projects.
  - Intermediate foresights are recorded to define the topography of the route.
  - Intermediate foresights are taken at stations that are not used as benchmarks or turning points.
- When it is no longer possible to continue with IFS, a FS is taken at a TP and the leveling instrument is moved.

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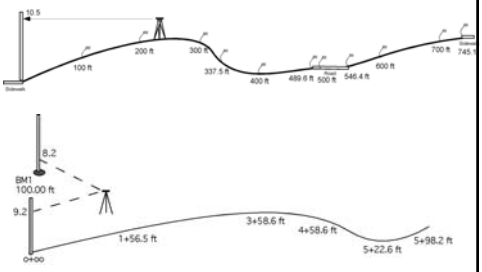
Starting Benchmark



- Along the route benchmark: BS is taken on the first station on the route.
- Side Benchmark: BS is taken on a benchmark not on the route.

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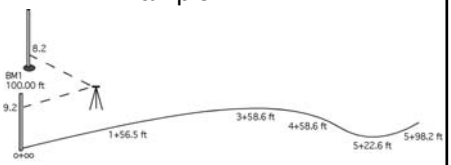
Example

Fill in the yellow cells in the table below. To be solved in class.



STA	BS	HI	FS	IFS	ELEV
BM1					
0+00					

Answers: BM1: BS=8.2ft, HI=108.2ft, Elev=100ft
STA 0+00: IFS=9.2ft, Eelev=99.0ft

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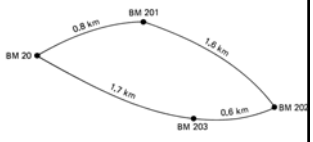
Adapted from Harry Field, Oklahoma State University.

Elevation Errors and Adjustments in Level Loops

- In areas with low-moderate slope, leveling error (closure) is proportional to the distance leveled. Elevation measurements are corrected in proportion to the distance along the leveling path.
- In areas with steep slope, the correction can be made in proportion to the number of instrument setups.



Permissible Error (in mm) = 8 $(K)^{0.5}$, where K is leveling distance in km.

Permissible Error (in ft) = 1 $(M)^{0.5}$, where M is leveling distance in mile.

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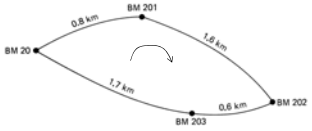
Elevation Error and Adjustments to Level Loop – Example 1



- A surveyor of a highway project started from BM20 and leveled back to BM20 through BM203, BM202, and BM201.
  - BM20 known elevation = 186.273 m
  - BM20 measured elevation = 186.258 m
- Is this leveling error acceptable? If yes, what is the adjusted elevation for BM203, BM202, and BM201?

To be solved in class.

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Answers: Permissible error = 17mm, Error = 15 mm; 15mm < 17mm➔ acceptable. Corrections: see next slide.

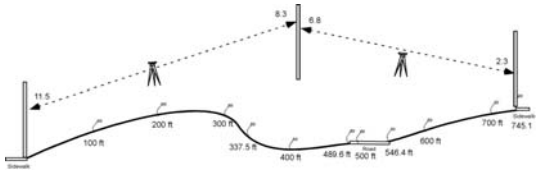
Elevation Error and Adjustments to Level Loop – Example 1 (cont.)

Table 3.4 LEVEL LOOP ADJUSTMENTS

BM	Loop Distance: Cumulative (km)	Field Elevation	Correction: $\frac{\text{cumulative distance}}{\text{total distance}} \times E^*$	Adjusted Elevation
20		186.273 (fixed)		186.273
201	0.8	184.242	$+0.8/4.7 \times 0.015 = +0.003$ =	184.245
202	2.4	182.297	$+2.4/4.7 \times 0.015 = +0.008$ =	182.305
203	3.0	184.227	$+3.0/4.7 \times 0.015 = +0.010$ =	184.237
20	4.7	186.258	$+4.7/4.7 \times 0.015 = +0.015$ =	186.273

*$E = 186.273 - 186.258 = -0.015$ m.

Elevation Error & Adjustments to Level Loop – Example 2



Example adapted from Harry Field, Oklahoma State University.

Elevation Error & Adjustments to Level Loop – Example 2 (cont.)

Is this leveling survey acceptable?

a) Perform math check

b) Perform closure check.

To be solved in class.

STA	BS	HI	FS	IFS	ELEV
0.0	10.5	110.5			100.0
100				6.3	104.2
200				3.9	106.6
300				4.1	106.4
337.5				7.4	103.1
400				9.2	101.3
489.6	6.6	109.1	8.0		102.5
500				6.7	102.5
546.4				6.8	102.2
600				4.9	104.2
700				2.2	106.9
745.1	2.3	109.9	1.5		107.6
TP2	8.3	111.4	6.8		103.1
0.0			11.5		99.9

Answers: Math check: 0.1=0.1 ☺; Permissible error = 0.5ft,
Error = 100-99.9 = 0.1ft < 0.5ft ➔ acceptable.

Good Leveling Practices

- Anchor tripod legs firmly.
- Make sure that the bubble tube is centered before and after staff reading.
- Take as little time as possible between BS and FS readings
- For each set up of the level, use BS and FS distances that are approximately equal.
- Make sure that the level staff is vertical by level tubes or have the staffman wave the staff slowly away and toward the instrument.
- On sloping ground, two of the tripod legs should be placed on the downhill side.
- Always, perform the math check: $\Sigma BS - \Sigma FS = \Delta Elv$