Plane Surveying – Levelling

Introduction:

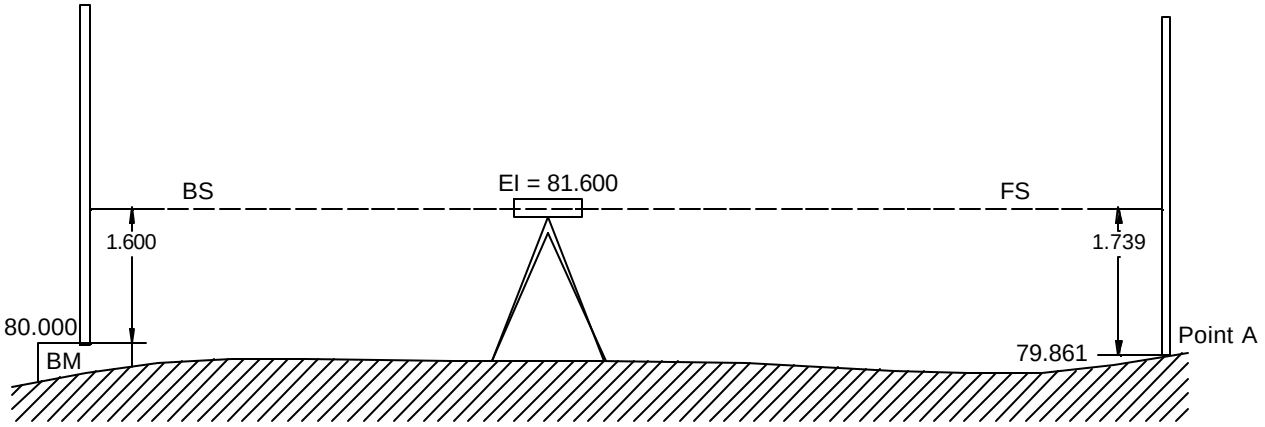
Levelling is a means by which surveyors can determine the elevation of points, using other known points as references. Levelling is perhaps the most basic of surveying operations and forms an important fundamental part of almost every surveying project.

Equipment:

Levelling is carried out by the use of: a Spirit Level, often called an Engineer's Level, and a level rod. The level rod resembles a large fold-up ruler but is not accurately referred to as such.

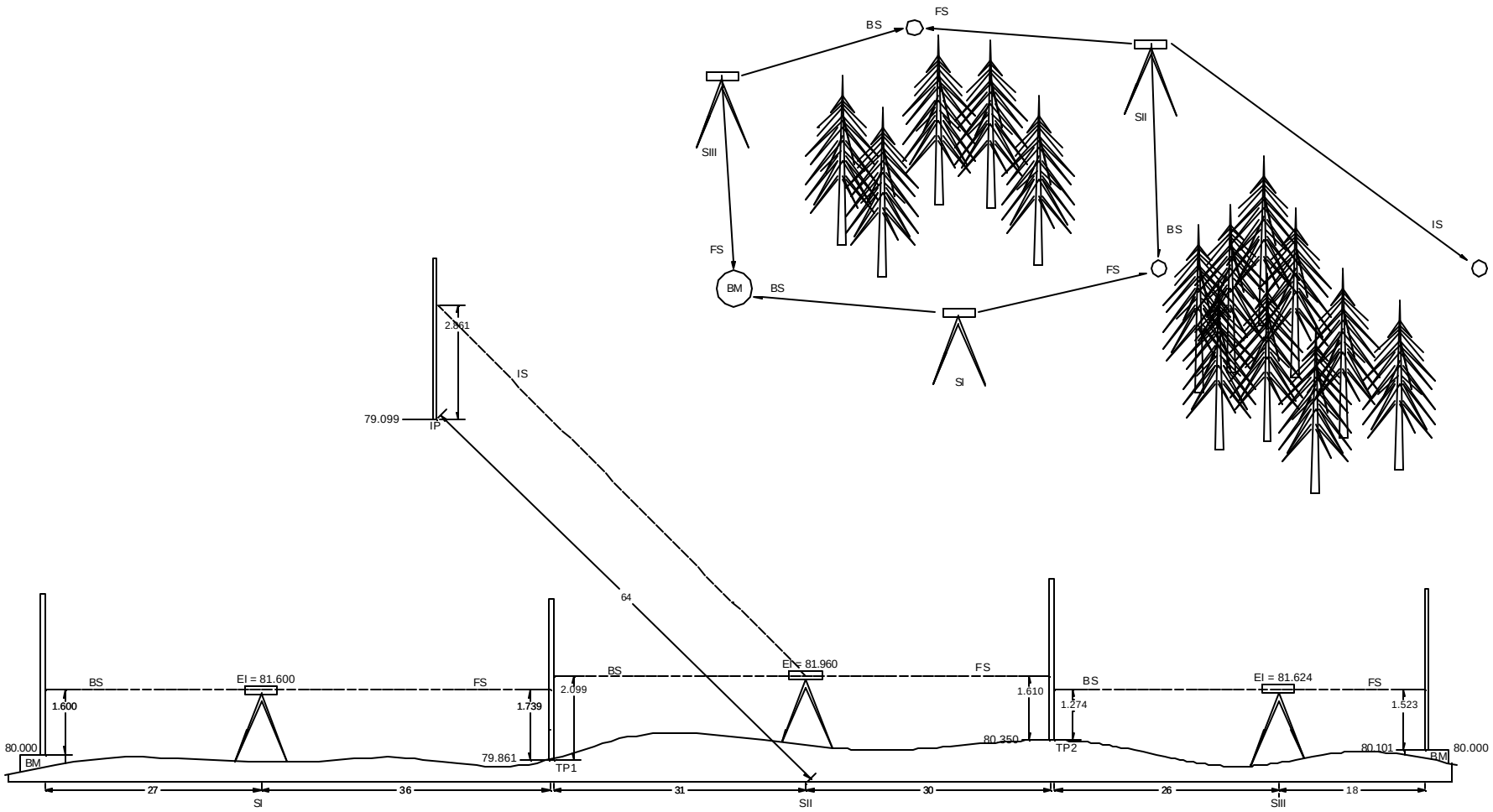
Basics of Levelling:

In levelling, the surveyor looks *back* (BS) to a point of *known* elevation to determine the elevation of his or her instrument (EI). The surveyor then looks *forward* (FS) to a point of *unknown* elevation and determines the elevation of that point using the elevation of his or her instrument (EI) and the value on the level rod read through the level's telescope.



Once the elevation of a point is determined, that point can be used for determining the elevations of other points. In this way, the surveyor may "leap-frog" forward, eventually determining the elevations of points that are impractical from the initial location, and developing greater accuracy by means of a "closed traverse".

A Sample Levelling Traverse:



Sample Traverse Data:

STATION	BS	ELEV. INST.	FS	IS	ELEV.	LENGTH	CORR. EL.
BM					**80.000**		
SI to BM	**1.600**	**81.600**				**27**	
SI to TP1			**1.739**		**79.861**	**36**	**79.823**
SII to TP1	**2.099**	**81.960**				**31**	
SII to IP				**2.861**	**79.099**	**64**	***from peg test***
SII to TP2			**1.610**		**80.350**	**30**	**79.024**
SIII to TP2	**1.274**	**81.624**				**26**	
SIII to BM			**1.523**		**80.101**	**18**	**80.000**

Surveyors accumulate levelling data in a specific fashion. This format ensures that all the relevant data is preserved and none is lost. Calculations are performed as you go, making mistakes easier to detect. This is important in levelling since a turning point may not be marked to revisit in case of error.

Sample Correction Calculations:

Σ(B.S. – F.S.) = 4.973 – 4.872 = 0.101 m This is the closure error.

Adjust on basis of shot lengths. Σ shot lengths = 168 m (exclude IS's from this)

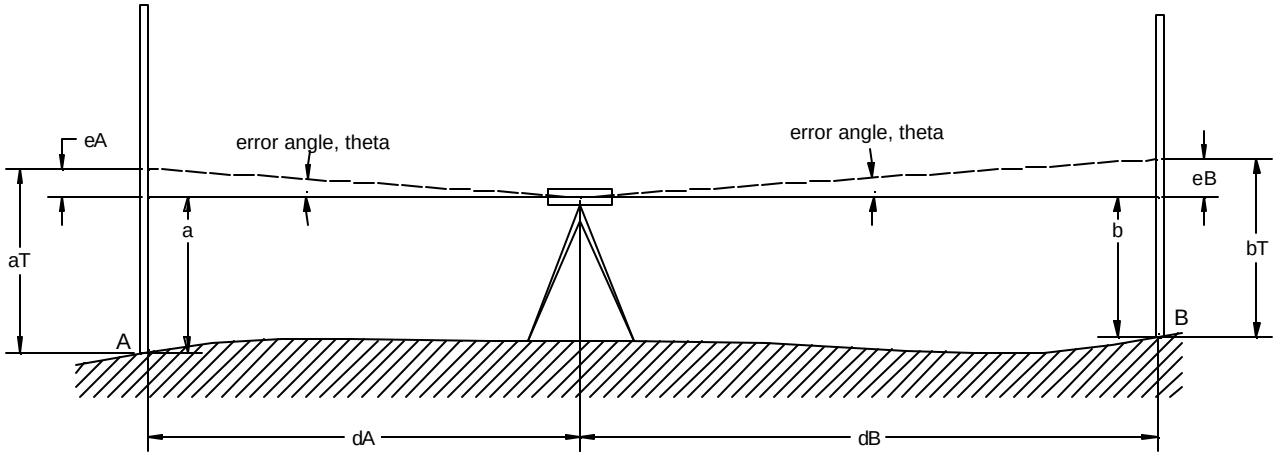
BM to TP1 = 63 m correction (63/168) $\times$ 0.101 = 0.038

BM to TP2 = 63 + 61 correction (124/168) $\times$ 0.101 = 0.075

BM to BM = 63 + 61 + 44 correction (168/168) $\times$ 0.101 = 0.101

Accuracy in Levelling:

In levelling, we want to determine the difference in elevation between A and B. However, a Spirit Level may not be perfectly aligned – that is, the telescope may not be aligned correctly with the level plane described by the level bubble.



Definitions:

d_A = length of shot to A
d_B = length of shot to B
a = actual reading at A
b = actual reading at B
e_A = error component at A due to telescope misalignment
e_B = error component at B due to telescope misalignment
a_T = reading at A seen through telescope
b_T = reading at B seen through telescope

$a = a_T - e_a$ and $b = b_T - e_b$

$e_a = d_A \tan q$ and $e_b = d_B \tan q$

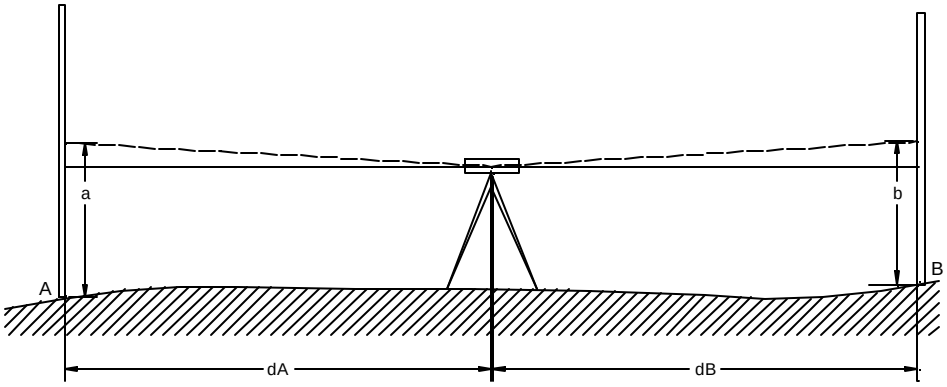
$$a - b = [a_T - d_A \tan q] - [b_T - d_B \tan q]$$

$$a - b = (a_T - b_T) + (d_B - d_A) \tan q$$

therefore :

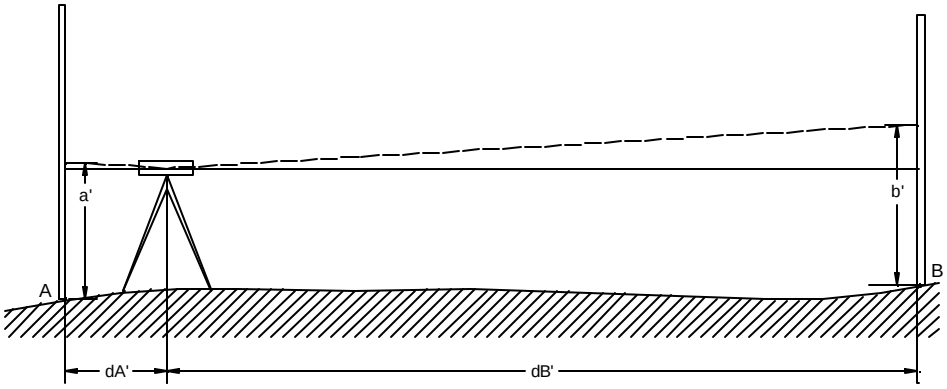
$a - b = a_T - b_T$ only if $[\tan q = 0]$ and/or $[d_B - d_A] = 0$

Levelling – the Peg Test:



Setup 1:
Equal shot lengths to A and B. (ie: dA=dB)

Therefore: (a-b) is "accurate"



Setup 2:
Unequal shot lengths to A and B.

Therefore: (a'-b') is not "accurate"

$$a - b = (a' - b') + (d_{B'} - d_{A'}) \tan q$$

$$\tan q = \frac{(a - b) - (a' - b')}{(d_{B'} - d_{A'})}$$

$$q = \tan^{-1}\left[\frac{(a - b) - (a' - b')}{(d_{B'} - d_{A'})}\right]$$

Peg Test results are reported in degrees and as slopes. A useful way to express peg test results is in the units of "____ mm (high/low) per m length of shot". These results are used to determine how careful you must be balancing FS's and BS's, as well as to correct intermediate shots. (IS's)

Definitions:

Here are definitions for some commonly used terms related to levelling and basic surveying:

Term	Definition
Plumb or Vertical Line	• the line at any point on the earth's surface which follows the gravity vector down towards the centre of the earth
Level Surface	• a surface that is everywhere perpendicular to vertical lines
Horizontal Surface	• a plane perpendicular to a vertical line and perpendicular to a level surface
Elevation	• the vertical distance above or below a given reference level surface
Difference in Elevation of two points	• The vertical distance between the two level surfaces containing the two points
Datum	• An assigned or assumed reference level surface
Benchmark	• A permanent or semi-permanent physical location of known or assigned elevation
Levelling	• A surveying operation carried out to determine the elevation of points or to find the difference in elevation of points
Spirit Level/Engineer's Level	• A surveying instrument used to carry out levelling
Backshot (BS)	• A sighting with a level back to a point of known elevation
Foreshot (FS)	• A sighting with a level to determine the elevation of a point
Turning Point	• A point at which you have establised an elevation with FS and on which you will subsequently take a BS
Intermediate Shot	• A foreshot to a point at which you want to know the elevation but which will not be used as a turning point
Peg Test	• Surveying operation carried out to determine if the levelling bubble and telescope line-of-sight are parallel
Elevation of Instrument (EI)	• Elevation of the telescope cross-hairs
Balancing shots	• Attempt when doing a levelling survey to keep the lengths of FS and BS at any given instrument setup as close as possible.
Closure Error	• Difference in elevation determined from the levelling survey and the known elevation of a benchmark.

LEVELLING FIELD EXERCISE

Instructions:

Each 4 or 5 person party will split up into 2 sub-parties for this exercise. Each sub-party of 2 or 3 people will be required to:

1. Determine the length of your pace and report it. Find how many degrees of arc are represented by each gradation on the level bubble. Report in smallest units.

2. Perform a peg test to check your instrument. Note the error, and if it is large (> 0.5 mm per 1 m), be careful that you balance BS's and FS's. DON'T ADJUST. Each person in the group should record the results of the peg test in their own field book. Report the error as cm's/20m's, mm/m, degrees high or low, fraction of degrees, and as degree's, minutes, seconds.

3. Perform level circuits, one by each member of the group. Each circuit must be closed, and the elevation of the monuments shown on that circuit must be determined. Determine the elevation of individual steps of the designated staircase.

4. Determine the grade of the east sidewalk on Main Mall in the area of your traverse.

Reporting:

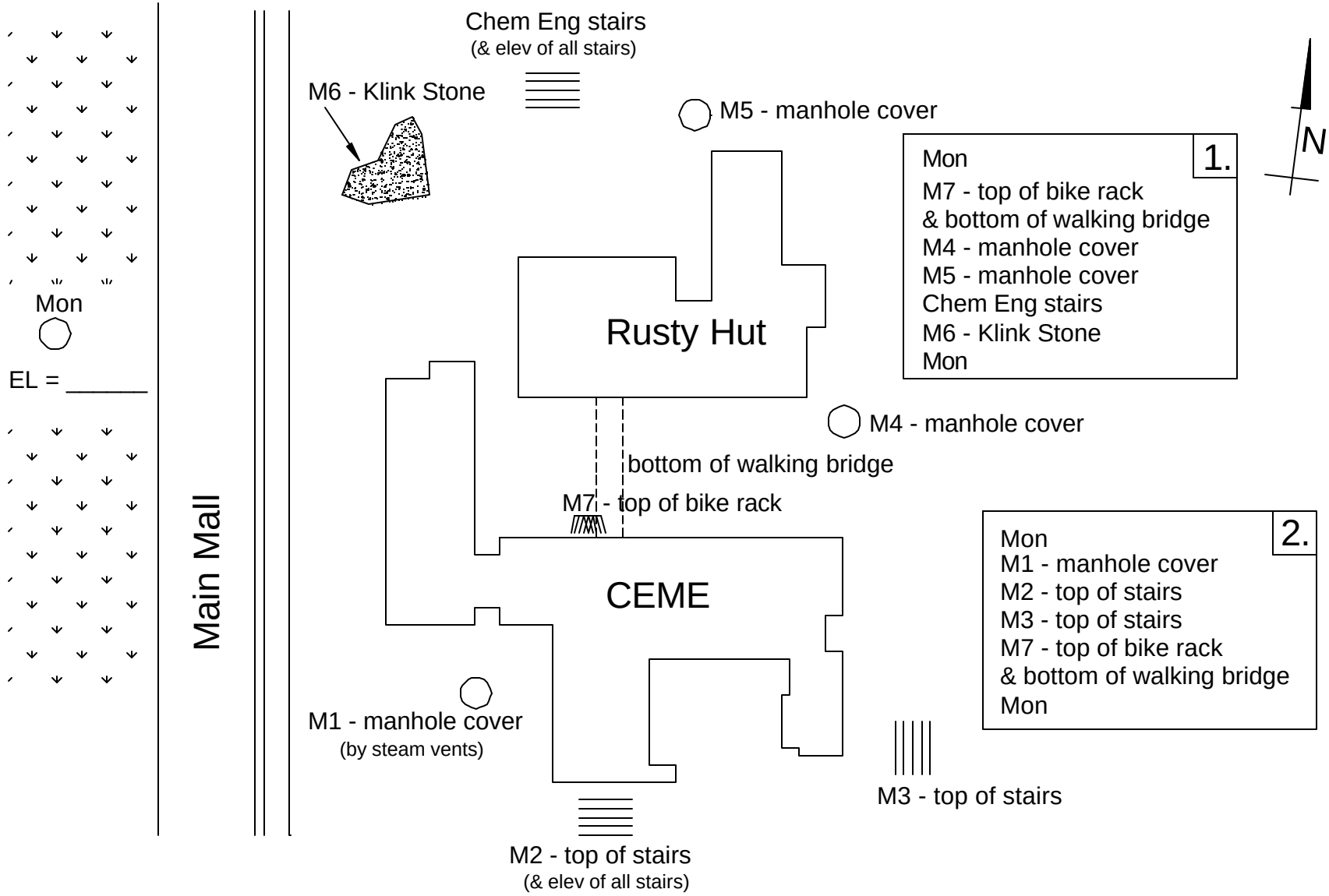
Each individual's field book should contain the results of the peg test. Each should also contain the field notes, error and adjustment calculations for that person's level circuit. During the exercise, once data from at least two monuments has been collected and recorded in your field book, you must have one of the TA's initial it. This is critical. Field books without initials are not acceptable. A brief reminder – please do not record your data anywhere else except into your fieldbook.

Equipment Required for each 2-person sub-party:

- 1 Engineer's Level
- 1 level rod.

Evaluation: Required Elements:

- Your pace length and bubble degrees
- Peg Test: measurements, diagram, calculations, explanation
- Traverse: data table, plan diagram with all information, error calculations, balancing


Chem Eng stairs
(& elev of all stairs)
M6 - Klink Stone
M5 - manhole cover
N
Mon
1.
M7 - top of bike rack
& bottom of walking bridge
M4 - manhole cover
M5 - manhole cover
Chem Eng stairs
M6 - Klink Stone
Mon
Mon
EL = _____
Rusty Hut
M4 - manhole cover
bottom of walking bridge
M7 - top of bike rack
Main Mall
CEME
2.
Mon
M1 - manhole cover
M2 - top of stairs
M3 - top of stairs
M7 - top of bike rack
& bottom of walking bridge
Mon
M1 - manhole cover
(by steam vents)
M3 - top of stairs
M2 - top of stairs
(& elev of all stairs)