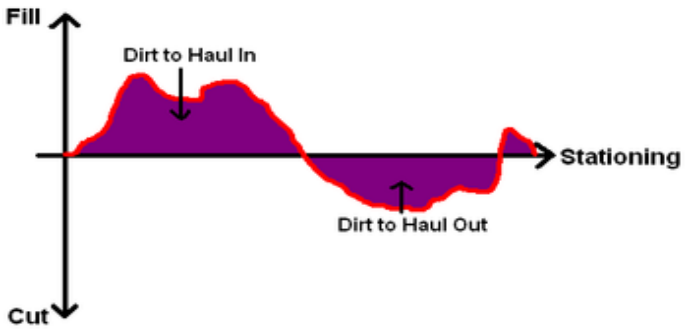
Excavation and embankment (cut and fill)

Excavation = the removal of soil or rock from its natural location.
Embankment = the placement and compaction of layers of earth or rock to form a roadbed of the
planned shape, density, and profile grade.

Various sections of a roadway design will require bringing in earth. Other sections will require earth to be removed. Earth that is brought in is considered **Fill** while earth that is removed is considered **Cut**. Generally, designers generate drawings called Cut and Fill Diagrams, which illustrate the cut or fill present at any given site. This drawing is quite standard, being no more than a graph with site location on the X-axis and fill being the positive range of the Y-axis while cut is the negative range of the Y-axis.



For the PE exam - cut-fill problems are really simple. There are two types of problems that could be asked.

1. What is the volume of the cut/fill area for a road between two stations?
2. What is the volume of the cut/fill area for a road between multiple stations?

In real life, mostly these problems are solved using computer programs. However, you don't have the luxury doing the PE Exam so you need to know a few things,

Excavation and embankment (cut and fill)

The only things you need to know are

1. How to find the Area of the cross section
   - Usually given
   - Use Geometry

Volume cut/fill Formulas Legend required
L=distance between stations
A = Area of cut/fill
A_m = Area of a plane surface midway between the two cross sections

2. How to find the volume using the different techniques

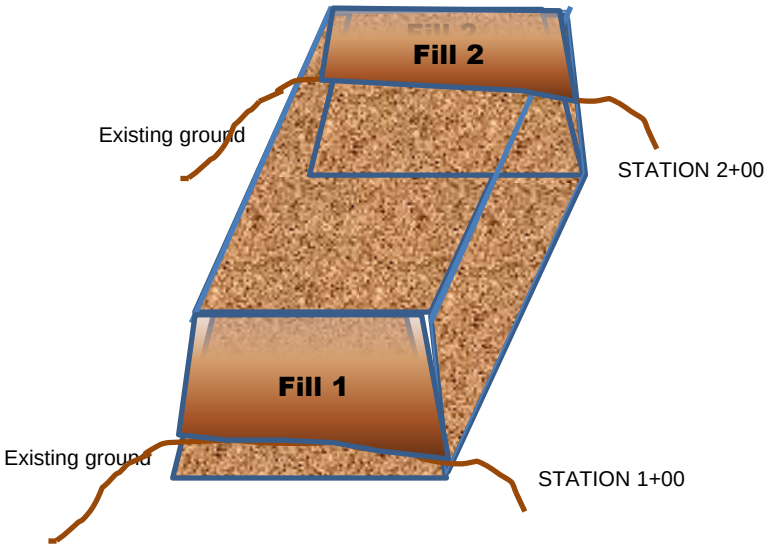
Average end area Method $V = \frac{A_1 + A_2}{2} L$

Prismoidal Method – This is a more accurate formula, which takes out most of the error accrued by the average end area method. $V_p = \frac{L(A_1 + 4A_m + A_2)}{6}$

Pyramid Method - If one end area has a value of zero, the earthwork volume can be considered a pyramid and the correct formula would be:

$V = \frac{AL}{3}$

Cut and Fill between two Stations

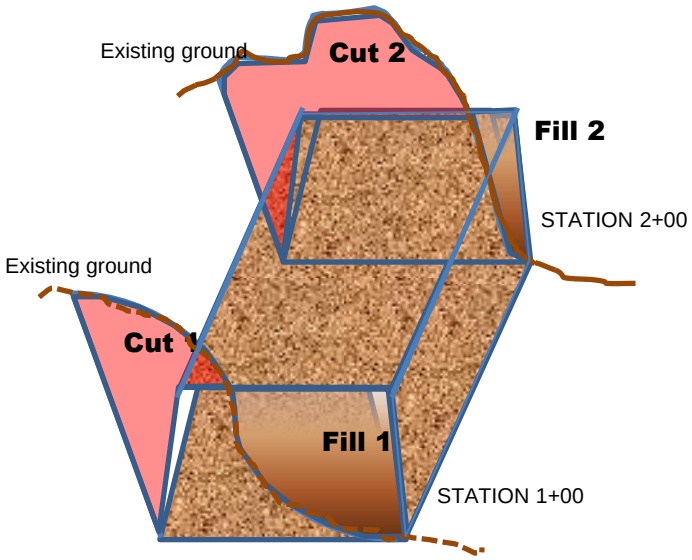


To figure out what is the total net fill between station 1+00 and 2+00.

Step 1: figure out total fill area per station. The area is usually given.
- STA 1+00 = Fill 1 area = $100ft^2$
- STA 2+00 = Fill 2 area = $40ft^2$

Step 2: Use formula to calculate the fill volume between stations
- Volume fill = $(100ft^2+40ft^2)/2$ x 100ft = $7000\ ft^3$

Step 3: Convert Cubic Feet to Cubic Yards
CY soil = CF soil/27 = $7000\ ft^3$ /27 = 260 CY Fill



To figure out what is the total net cut/fill between station 1+00 and 2+00.

Step 1: figure out total cut/fill area per station. This is usually given.
STA 1+00 = Cut 1 area = $85ft^2$,
Fill 1 area = $100ft^2$
STA 2+00 = Cut 2 area = $140ft^2$,
Fill 2 area = $20ft^2$

Step 2: Use above formula to calculate the cut/fill volume between stations
Volume cut = $(85ft^2+140ft^2)/2$ x 100ft = $11250\ ft^3$
Volume fill = $(100ft^2+20ft^2)/2$ x 100ft = $6000\ ft^3$

Step 3: Find total net cut or fill between stations
- Total cut or fill = Volume cut – Volume fill
- Total cut = $11250ft^3$ - $6000ft^3$ = $5250\ ft^3$ Cut

Step 4: Convert Cubic Feet to Cubic Yards
CY soil = CF soil/27 = $5250\ ft^3$ /27
= 194.44CY Cut

Cut and Fill between multiple Stations

Station #	Cut Area	Fill Area	Cut Vol	Fill Vol	Net Vol	Cum Cut
0+00	175	125	7300	6200	1100	1100
0+50	117	123				
1+00	238	250	8875	9325	-450	650
1+50	211	240	11225	12250	-1025	-375
2+00	198	180	10225	10500	-275	-650
2+50	140	141	8450	8025	425	-225
3+00	258	200	9950	8525	1425	1200

To figure out what is the total net cut/fill between stations 1+00 and 3+00. Columns Station #, Cut Area, and fill area will be given

Step 1: Complete " Cut Vol "
Step 2: Complete the "Fill Vol"
Step 3: Complete the "Net Cut"
Step 4: Complete the Cum Cut

Problem:
A roadway is to be designed on a level terrain. This roadway is 150 meters in length. Four cross sections have been selected, one at 0 meters, one at 50 meters, one at 100 meters, and one at 150 meters. The cross sections, respectively, have areas of 40 square meters, 42 square meters, 19 square meters, and 34 square meters. What is the volume of earthwork needed along this road?

Solution:
Three sections exist between all of these cross sections. Since none of the sections end with an area of zero, the average end area method can be used. The volumes can be computed for respective sections and then summed together.

- Section between 0 and 50 meters:

$$V = \frac{A_1 + A_2}{2} L = \frac{40 + 42}{2} 50 = 2050 \; cubic - meters$$

- Section between 50 and 100 meters:

$$V = \frac{A_1 + A_2}{2} L = \frac{42 + 19}{2} 50 = 1525 \; cubic - meters$$

- Section between 100 and 150 meters:

$$V = \frac{A_1 + A_2}{2} L = \frac{19 + 34}{2} 50 = 1325 \; cubic - meters$$

- Total Volume is found to be:

$$2050 + 1525 + 1325 = 4900 \; cubic - meters$$