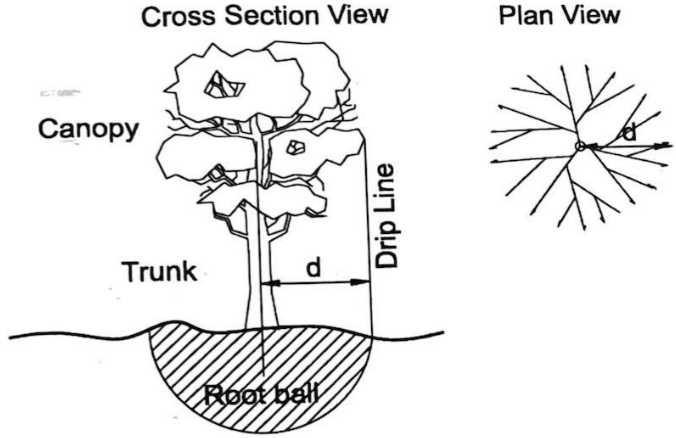
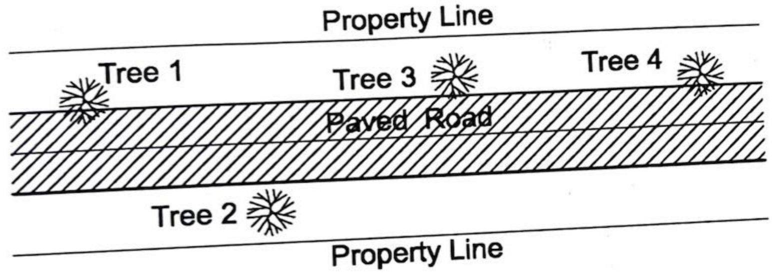


Use equations from last page



As part of an on-going program of road maintenance many municipalities perform a "needs study" which include "static inventories". If a pre-engineering survey is performed, the location of the trunk of trees on the right-of-way is determined as well as the location of the drip line. The drip line is the farthest extent of the branches. If the designer decides that the tree is going to pose a problem to the construction or a danger to the persons using the road, it should be removed. Large trees should be removed from the right-of-way if they are too close to the pavement. Hardwood trees are usually more valuable than softwood trees. A large hardwood tree must be cut down; the limbs removed; the trunk cut into logs and sold if they are of commercial value. A sub-contractor will do this on a lump sum basis. The stump and root ball" is dealt with separately.

Each tree bigger than a specific size must be shown on the contract drawings and labeled as an item to be priced.

One of the methods that the Ministry of Transportation uses to estimate the cost of removing the root ball is to assume that the root ball is a half sphere with the radius equal to the distance from the center of the trunk to the drip line.

A portion of some contract drawings is shown above. Four trees have been identified for removal. The actual location of the tree is not important to this project although in some situations the distance that the waste material has to be trucked may affect the price.

Student ID = 500180985 last six digits = 1+8+0+9+8+5 = 31/2 = 15.5

The distance from the trunk to the drip line for each tree is shown below:

For Tree # 1 d=sum of the last six digits divided by 2 = 1+8+0+9+8+5 = 31/2 = 15.5

For Tree # 2 d=sum of the last five digits divided by 2 = 8+0+9+8+5 = 30/2 = 15

For Tree # 3 d=sum of the last four digits divided by 2 = 0+9+8+5 = 22/2 = 11

For Tree # 4 d=sum of the last six digits divided by 2 = 1+8+0+9+8+5 = 31/2 = 15.5

Your job is to estimate the cost of clearing this section of the right-of-way:

a) The contractor is going to charge you $1,500.00 to cut down and remove each tree.

b) Estimate the volume of the root ball for each of the trees. Since this is just an estimate round your answer up to the next full cubic meter.

c) It is going to cost you $145.00 per $meter^3$ to excavate the material in the root ball. How much will you have to pay to have each root ball excavated?

d) If the trucks that you have available have a capacity of 7 $meter^3$, how many full truck loads or parts of truck loads of material must be moved?

e) Estimate the total cost of this part of the project.

FORMULAS FOR CALCULATING BEARINGS AND LENGTHS OF LINES FROM CO-ORDINATES

Bearing = $\tan^{-1}\left[\frac{E_2-E_1}{N_2-N_1}\right]$

Length = $\sqrt{(N_2-N_1)^2+(E_2-E_1)^2}$

FORMULAS FOR CIRCULAR CURVES

$$R_{min} = \frac{V^2}{127(e_{max}+f)}$$

This is a metric formula. R will be in meters. The values of e and f are found in the chart below

emax = pavement superelevation (meters/meter)
f = friction coefficient
V = the speed in kilometers per hour
R = the radius of the curve in meters

$T_c = R \times \tan\frac{\Delta_c}{2}$

$LC_c = 2 \times R \times \sin\frac{\Delta_c}{2}$

$M = R\left(1-\cos\frac{\Delta_c}{2}\right)$

T = length of sub-tangent
LC_c = long chord
M = mid-ordinate
E = external
L = length of curve

$E = R\left(\frac{1}{\cos\frac{\Delta_c}{2}} - 1\right)$ or $E = R\left(\sec\frac{\Delta c}{2} - 1\right)$

$L_c = 2\pi R\left(\frac{\Delta_c}{360°}\right)$

$A_{Sct} = R^2\left(\frac{\pi\Delta_c}{360°}\right)$

$A_{Sgt} = R^2\left(\frac{\pi\Delta_c}{360°} - \sin\frac{\Delta_c}{2} \bullet \cos\frac{\Delta_c}{2}\right)$

$A_{Fit} = R^2\left(\tan\frac{\Delta_c}{2} - \frac{\pi\Delta_c}{360°}\right)$

FORMULAS FOR LAYING OUT HORIZONTAL CURVES

Station of BC = Station of PI – T_c

Station of EC = Station of BC + L_c

Deflection Angle $\delta = \left[\frac{1}{L_c}\right] \bullet \left[\frac{\Delta_c}{2}\right]$

Chord Length = **2 • R • sin Deflection Angle**

FORMULAS FOR SPIRAL CURVES

Delta for the spiral curve $\Delta_s = \frac{90}{\pi} \bullet \frac{Ls}{R}$

Spiral Tangent $T_s = (R+P) \bullet \tan\frac{\Delta}{2} + Q$

Station of TS = Station of PI – T_s

Station of SC = Station of TS + L_s

Station of CS = Station of SC + L_c

Station of ST = Station of CS + L_s

Delta for the circular curve $\Delta_c = \Delta - 2\Delta_s$

Deflection angle for points on the spiral curve

$$\delta = \left[\frac{l}{L_s}\right]^2 \bullet (\theta_s)$$

"*l*" is the distance along the curve from the TS to the point that is being located. Answer will be in the same units as θ_s

Chord lengths for spiral (*c*)

$$c = \sqrt{X^2+Y^2}$$

Where $X = l - \frac{l^5}{40A^4} + \frac{l^9}{3456A^8}$

$$Y = \frac{l^3}{6A^2} - \frac{l^7}{336A^6} + \frac{l^{11}}{42240A^{10}}$$

FORMULAS FOR SUPERELEVATION

CALCULATIONS FOR POINTS IN TANGENT RUNOUT

To calculate the difference in elevation between the centerline and either edge of the pavement at Normal Crown use:

Crossfall across (½ pave)= slope of pavement • width of (½ pave)

(Make sure that units of slope and pavement width are consistent)

Tangent Runout Ratio $\left(\frac{1}{400}\right) = \frac{\textbf{Fall across ½(pave)}}{\textbf{Length of Tangent Runout}}$

rearranging this formula gives us:

$$\textbf{Length of Tangent Runout} = \frac{\textbf{Fall across ½(Pave)}}{\left(\frac{1}{400}\right)}$$

Note: $\frac{1}{400}$ is another way of writing 1:400 which represents the value of the Tangent Runout specified in the design.

The term "tangent runout" may be used to designate **two** distinct items:

1. It may be used to define the **rate** at which the edge of the pavement may be raised relative to the horizontal distance travelled along the road. It is often expressed as a ratio such as 1:400 which means that to raise the edge of the pavement 1 meter we must move along the road 400 meters.
2. It can also mean the distance along the road over which the edge of the pavement is raised from a **Normal Crown** to one where the **Outside Lane of Roadway is Horizontal.**

Tangent Runout Ratio $\left(\frac{1}{400}\right) = \frac{\textbf{Fall across (width ½ pave)}}{\textbf{Length of Tangent Runout}}$

The term on the left side of the equation is the ratio known as the **Tangent Runout Ratio** (i.e. something similar to 1:400). If we know the size of the Crossfall at Normal Crown, we can substitute it into the right side of the equation, and solve for the length of the Tangent Runout:

$$\textbf{Length of Tangent Runout} = \frac{\textbf{Fall across (width ½ pave)}}{\left(\frac{1}{400}\right)}$$

In order to calculate the difference in elevation at any Station that falls somewhere in the Tangent Runout, we can re-write the equation in the following form.

$$\textbf{Crossfall at any station} = \frac{\textbf{Crossfall at Normal Crown} \bullet \textbf{Distance from TS}}{\textbf{Length of Tangent Runout}}$$

CALCULATIONS FOR POINTS IN THE SPIRAL

The Outer Edge of the Pavement continues to be raised (at a different rate) along the length of the Spiral until the slope from the Centerline to the Outer Edge is the Maximum Super Elevation. The Crossfall when the slope of the pavement is at maximum superelevation is calculated using:

$$\textbf{Crossfall}_{max} = \textbf{e}_{max} \bullet \textbf{Width (½ pave)}$$

The following formula can be used to determine:

$$\frac{\textbf{Cross Fall}_{max}}{L_s} = \frac{\textbf{Cross Fall at any Station}}{\textbf{Distance from TS}}$$

1. the distance from the TS to any station if the difference in elevation between the centerline and the edge of the pavement is known by rearranging the formula to the following form:

$$\text{Distance from the TS} = \frac{\text{Crossfall at any Station} \cdot L_s}{\text{Crossfall}_{max}}$$

2. the difference in elevation between the centerline and the edge of pavement if the distance from the TS is known.
rearranging this formula gives us:

Crossfall at any Station

$$= \frac{\text{Distance from TS} \cdot \text{Crossfall}_{max}}{L_s}$$

NOTE: The station TS may be replaced by ST if the "other" spiral is being calculated.

FORMULAS FOR VERTICAL CURVES

$A = |g_2 - g_1|$

$L = KA$

$x = -g_1(\frac{L}{A})$ **NOTE**: in this formula "x" represents the distance from the BVC to the High Point or the Low Point.

Table 11.3 (Kavanagh)

Design Speed	Stopping Site Distance	K Factor	
		Crest (m)	Sag (m)
40	45	4	8
50	65	8	12
60	85	15	18
70	110	25	25
80	135	35	30
90	160	50	40
100	185	70	45
110	215	90	50
120	245	120	60
130	275	150	70
140	300	180	80

Sta. of BVC = **Sta. of PVI** − $\frac{\text{Length of Vertical Curve}}{2}$

Sta. of EVC = **Sta. of PVI** + $\frac{\text{Length of Vertical Curve}}{2}$

Elevation of Mid-Chord = $\frac{Elev.BVC + Elev\ EVC}{2}$

Tangent Offset at PVI = $\frac{Elev\ PVI - Elev\ Mid\ chord}{2}$

$d = \frac{\text{difference in elevation of PVI and mid-chord}}{2}$

Tangent Offset at any point
in the vertical curve = $\frac{d(x)^2}{(L/2)^2}$ or $\frac{(4d)x^2}{L^2}$ or $(\frac{x}{½L})^2 d$

d = tangent offset at the VPI
L = length of the vertical curve

NOTE: in this formula

> **Elevation of BVC** = **Elev. PVI** + $g_1 \cdot (Sta\ BVC - Sta\ PVI)$
>
> **Elevation of EVC** = **Elev. PVI** + $g_2 \cdot (Sta\ EVC - Sta\ PVI)$
>
> *If g is in m/m the Length (L) must be in meters.*

x = the distance from the BVC or the EVC to the point in question

> **Elevation of BVC** = **Elev. PVI** + $\frac{g_1 \cdot (Sta\ BVC - Sta\ PVI)}{100}$
>
> **Elevation of EVC** = **Elev. PVI** + $\frac{g_2 \cdot (Sta\ EVC - Sta\ PVI)}{100}$
>
> *If g is given as a percentage.*