Carleton University
Department of Civil & Environmental Engineering

CIVE 3304A Traffic Engineering and Planning

Model Answer for Assignment 2

Vertical Curve Elements

1. *A 600 m vertical curve connects a +3% grade to a –5% grade. If the vertical tangents intersect at Station 52+60 and elevation 877.62 m from sea level, calculate the elevations at the PVC, PVT, highest point, and Station 54+00.*

A = +3 – (-5) = 8   St (PVI)= 52+60   Elevation (PVI) = 877.62 m

L = 600 m

PVC

Station of (PVC) = St. (PVI) – $\frac{L}{2}$ = 5200 + (60 – 300) = 4960 = 49+60

Elevation of (PVC) =Elevation (PVI) - $\frac{g_1}{100} \times \frac{L}{2}$ = 868.62 m

PVT

Station of (PVT) = St. (PVI) + $\frac{L}{2}$ = 5200 + (60 + 300) = 5560 = 55+60

Elevation of (PVT) =Elevation (PVI) + $\frac{g_2}{100} \times \frac{L}{2}$ = 862.62 m

Highest Point:

$$x_{hp} = \frac{g_1}{A} L = \frac{3}{8} \times 600 = 225\ m$$

Elevation of highest point = $z_{hp} = 868.62 + 225 * \frac{g_1 L}{100} - \frac{A \times 225^2}{200L} = \cdots$

... 868.62 + 6.75 – 3.375 ≈ 872 m

At Station (54+00):

x= (54+00) – (49+60) = 440 m

Elevation at station (54+00) = Elevation of (PVC) + $\frac{g_1 L}{100} x - \frac{Ax^2}{200L} =$ 868.91 m

2. *A –3% grade and a 0% grade meeting at station 26+42 and elevation 255.74 m are joined by a 300 m vertical curve. The curve passes under an overpass at Station 27+00. If the lowest elevation of the overpass is 261.85 m, calculate the available clearance.*

   A = -3 – (0) = -3   St (PVI)= 26+42   Elevation (PVI) = 255.74 m
   L = 300 m

   Station of (PVC) = St. (PVI) $-\frac{L}{2} = 26+42 - \frac{300}{2}$ = 24+92

   Elevation of (PVC) =Elevation (PVI) – $\frac{g_1}{100} \times \frac{L}{2} = 255.74 - \frac{(-3)}{100} \times \frac{300}{2}$ = 260.24 m
   PVC old 247.54 m
   <u>At Station (27+00):</u>

   x= St(27+00) – St (PVC) = 2700 – (2400+92) = 208 m

   Elevation at station (27+00) = Elevation of (PVC) +
   $\frac{g_1(X)}{100} + \frac{AX^2}{200L} = 260.24 + \frac{(-3)(208)}{100} - \frac{(-3)(208)^2}{200(300)}$ = 256.16 m

   Therefore, clearance available = 261.85 – 256.16 = 5.69 m

3. *Determine the minimum length of a vertical curve between +0.5% grade and a -1.5% grade to provide adequate sight distance. The vertical curve must provide 250 m stopping sight distance. Assume that the driver eye height is (h_1) =1.07 m and the object height (h_2) = 0.15 m.*

A = +0.5 – (-1.5) = 2.0 (Crest)

Assume L≤S:

L = 2*250 – $\frac{200(\sqrt{1.07}+\sqrt{0.15})^2}{2}$ = 297.87 m which is NOT consistent with the assumption.

Assume L>S:

L = $\frac{2*250^2}{200(\sqrt{1.07}+\sqrt{0.15})^2}$ = 309.21 m which is consistent with the assumption.

Therefore the minimum length of this vertical curve to provide available sight distance is 309.21 m

4. *A vertical curve joins a -1.2% grade to a +0.8% grade. The PVI of the vertical curve is at station 75+00 and elevation 49.50 m above sea level. The centerline of the roadway must clear a sewer located at station 75 + 50 by 0.8 m. The elevation of the bottom of the sewer is 50.10 m above sea level. The diameter of the sewer line is 1.0 m. What is the minimum length of the vertical curve that can be used?*

A = -1.2 – (0.8) = -2.0 St (PVI) = 75+00 Elevation (PVI) = 50.90 m

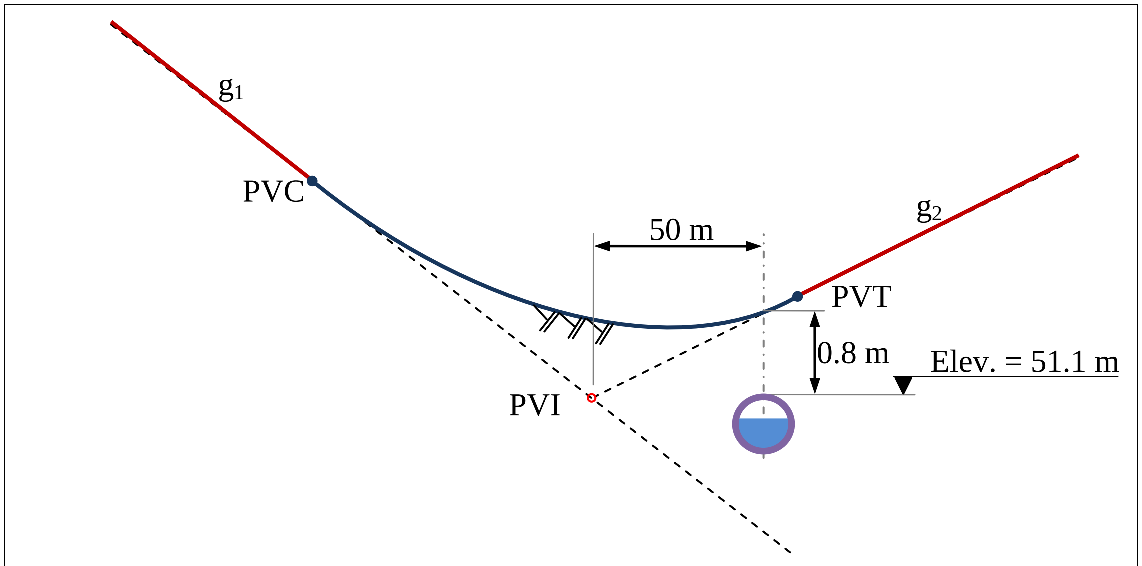

Figure 2.4.1 A sketch of the vertical alignment of the sag curve. Indicated is the position of the sewer.

Distance between PVI and the sewer centreline = (75+00) – (75+50) = 50.00 m
Elevation of top of sewer is 50.10 + 1.0 = 51.1 m

Therefore, Elevation of roadway (pavement surface) = 51.10 + 0.80 = 51.90 m

Elevation of the roadway above the pipe can be calculated as follows:

$$\text{Elevation (PVC)} + g_1\left(50+\frac{L}{2}\right) - \frac{A\left(50+\frac{L}{2}\right)^2}{2L} = \ldots$$

$$\ldots \text{ Elevation (PVI)} - \frac{-1.2}{100} * \left(\frac{L}{2}\right) + -\frac{1.2}{100} * \left(50+\frac{L}{2}\right) - \frac{-\frac{2.0}{100}*\left(50+\frac{L}{2}\right)^2}{2L} = \ldots$$

$$\ldots\ 49.50 - \frac{1.2}{100} * (50) - \frac{-\frac{2.0}{100}*\left(50+\frac{L}{2}\right)^2}{2L} = 51.90 \text{ m}$$

Therefore, L can be found by solving the following quadratic equation:

$$49.50 - \frac{1.2}{100} * (50) - \frac{-\frac{2.0}{100}*\left(50+\frac{L}{2}\right)^2}{2L} = 51.90$$

$$0.01 * \frac{\left(50+\frac{L}{2}\right)^2}{L} = (2.4+0.6)$$

$0.01 * \left(50 + \frac{L}{2}\right)^2 = (3.0) * L$

$0.01 * \left(2500 + 50L + \frac{L^2}{4}\right) = 3L$

$2500 + 50L + \frac{L^2}{4} = 300L$

$L^2 - 4 * 250L + 4 * 2500 = 0$

$L = \frac{1000 \pm \sqrt{1000^2 - 40000}}{2} = \frac{1000 \pm 979.79}{2} \simeq 990\ m$ (reject the solution 10.1 m since it is inconsistent with initial assumptions in Figure 2.4.1)