Paper Report for Possible Road Locations within Saint Edwards State Park

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Project #1
Submitted to: Professor Peter Schiess on April 4th, 2009
ESRM 468 - Forest Operations – Paper Road Locations

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Summary

The purpose of this report is to establish two alternative options for construction of a new forest road within Saint Edwards State Park. The road routes (#1 or #2) must begin at the predetermined landing location in the southwestern region of the park and connect either to the existing road to the north, or the existing road to the east. Both proposed roads are subject to the following constraints:

- Remain within St. Edwards Park property boundaries
- Roads must have a running surface of 12’
- Grade ≤ 10% adverse, 15% favorable
- Curve radius ≥ 60’
- Switchback regions must have a sideslope < 35%
- Roads < 150’ from streams must be < 500’ long

Other considerations affecting design and road option #1 or #2 selection are as follows:

- Management objectives: road purposes
- Topography, soil, vegetation, and climate
- Environmental and social-political constraints
- Traffic requirements, road uses, and service levels
    - Average daily traffic (ADT)
    - Traffic service levels
    - Road users
- Vehicle characteristics
    - Critical Vehicles
- Economic parameters
- Safety

Objective

Once we have established two alternative routes for new road construction, we must analyze critical factors and determine which road would be the better choice.

Sociopolitical and Environmental Factors

The effects of road construction on this specific section of land at Saint Edwards would be of great importance to the public as a whole. However, because it is only a representative design area, other factors may be more relevant. First we need to consider the level of human development in the area. Residential housing surrounds the region and careful planning is essential to avoid boundary disputes. Second, public opinion must be taken into consideration at any location and it may be important to provide notice of a land use proposal as well as an opportunity for public input. Other social factors to consider are the region’s economy, a community’s environmental involvement level, and the possible public use of the new road.

Knowledge of the physical environment surrounding a proposed sight is a vital component for successful road construction. Features of the topography will dictate how easy or difficult a job will be and should be recorded while in the field. Ground conditions that will affect construction positively or negatively are listed in Table 1 below. These possible control points can help determine the best route to follow.

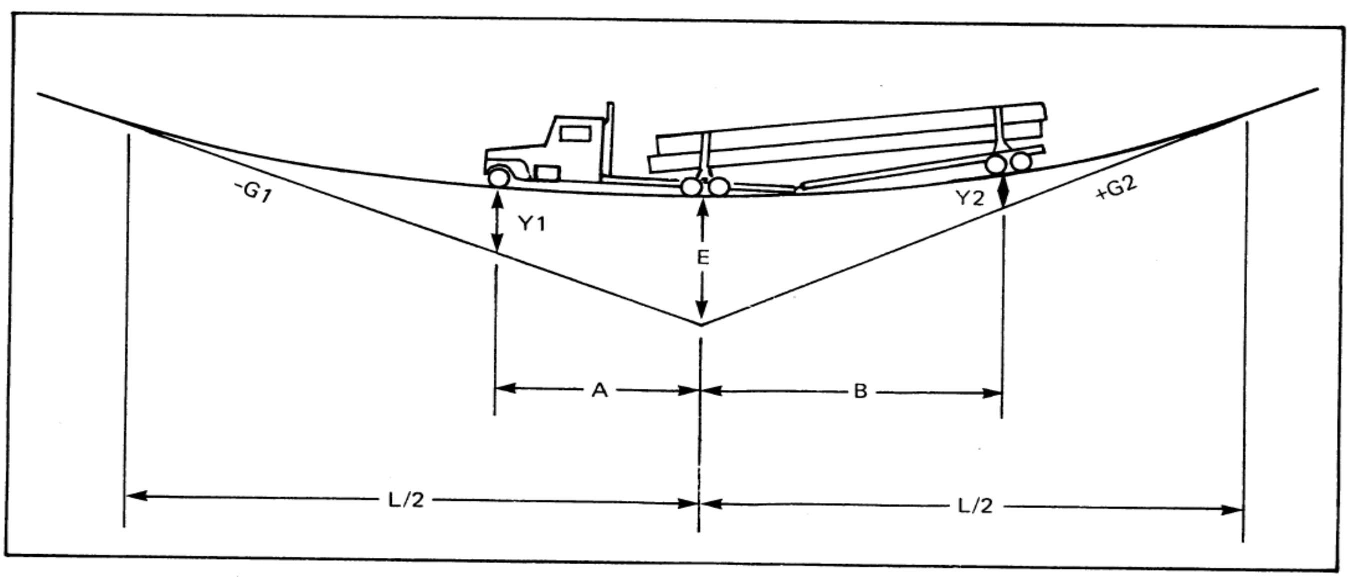
Conditions that do not favor construction	Features that favor economical construction
Swamps	Reasonable Side Slopes
Rock Bluffs	Desirable Stream Crossings
Ponds and Lakes	Saddles (passes) in Ridge Lines
Excessively Steep Terrain	Area Suitable for Switchback Construction
Unstable Soils	Start and Finish Points (junctions and landings)
Sips	
Environmentally Sensitive Areas	
Culturally Sensitive Areas	

Table 1. Unfavorable and Favorable Topographic Features (1)

There are many other regionally important environmental factors to consider such as soil types, rain or snowfall intensities, stream volatility, and geological conditions. When these parameters are coupled with social views the combined effect can be a driving factor in the decision on where a road should be built.

Users, traffic, and vehicle factors

General assumptions have been made that a single-lane, compacted gravel road with a ditch is being constructed and can provide the necessary components needed to conduct harvesting operations at this location. For our purposes an average logging truck is our design vehicle and has these general characteristics:



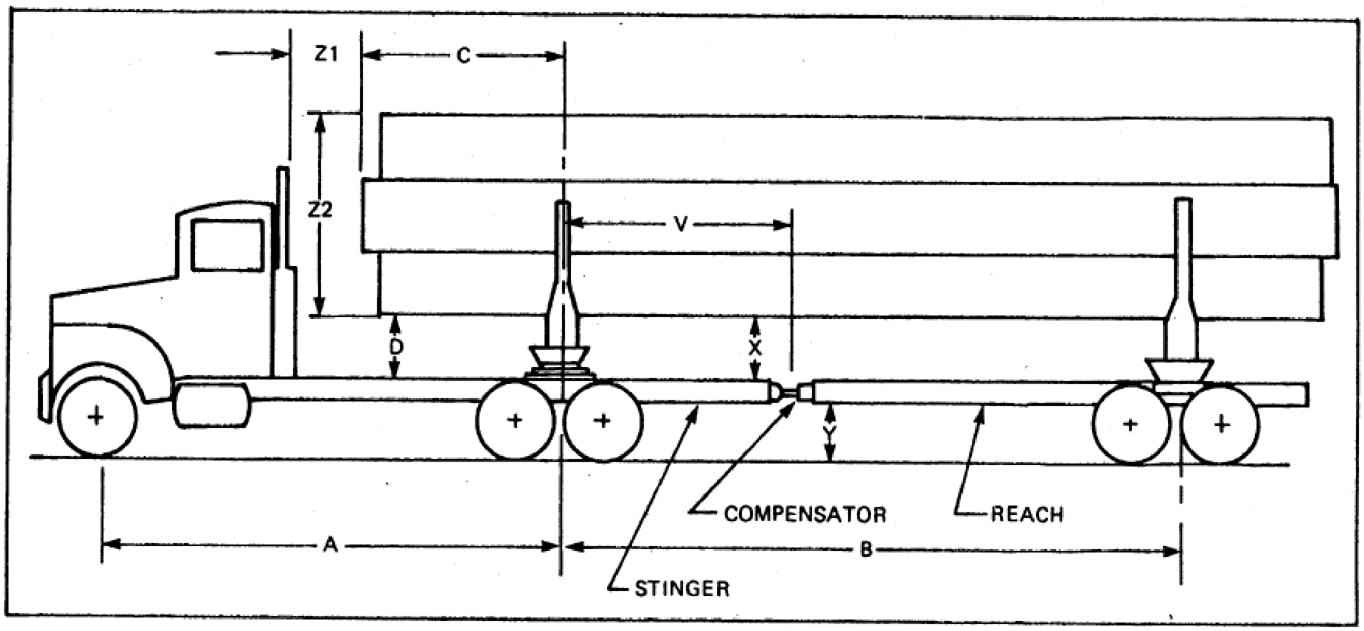


Figure 1. Log Truck Geometry and Dimensions (2)

The type of users and vehicles on the road are important because it provides information about factors like turnout spacing, lane width, surface cover, curve widening, and turnarounds. The purpose of the road can also give a good idea about average daily traffic (ADT), given we know a busy logging road handles about 10 trucks a day. In 1982 the USDA Forest Service produced a chart describing traffic service levels and how they control design, construction, and forest road uses. This information is broken up by flow, volume, vehicle types, and critical vehicles and can help guide planners. Critical vehicles that must be considered are the largest vehicles by weight or size, and those with unique configurations. In this case the critical vehicles may be a log yarder or semi truck trailer caring construction equipment. In either case, special accommodations and considerations may be required.

Travel Time

Curve radius, road widths, and the horizontal alignment play a role in travel times and in costs. In Table 2 below the Forest Service provides an example of a horizontal alignment classification based on number of curves and curve radius. One can see that the lower the number of curves, and the larger the curve radius, the better the conditions are for road travel. Straight roads are faster, more cost effective, and safer.

Table 2. Radius of Curves and Number of Curves per Kilometer (2)

[Average radius (m)] / [# of curves / km]

Poor = < 4 Good = 10 - 20
Fair = 4 - 10 Excellent = > 20

More evidence supporting reduced travel times based on road curvature and width is presented in Figure 2. It shows a relationship between curve radius and speed using variable road widths.

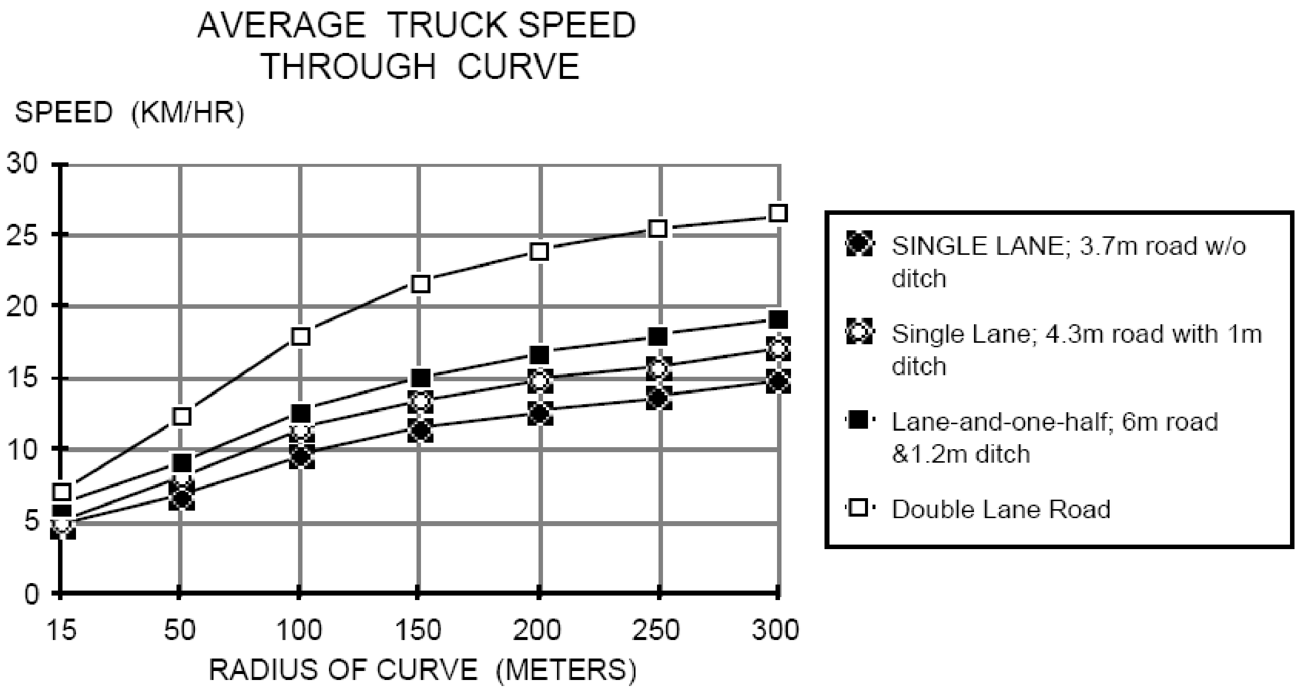


Figure 2. Relationship Between Travel Speeds and Curves at Varied Width

For our general purposes a standard logging truck has about 300 horse power, a loaded weight less than 80,000 lbs, and empty weight of about 20,000lbs.(3) Grade has major impacts on truck speed and varies greatly whether loaded or unloaded, thus impacting travel time. Figure 3 shows this relationship. In general, increased slope and variable terrain increase travel time. The other major factor impacting travel times are "the type of road surface, alignment, road width, sight distance, climate, rated vehicle performance, and psychological factors (such as fatigue, degree of caution exercised by driver, etc.)."(2)

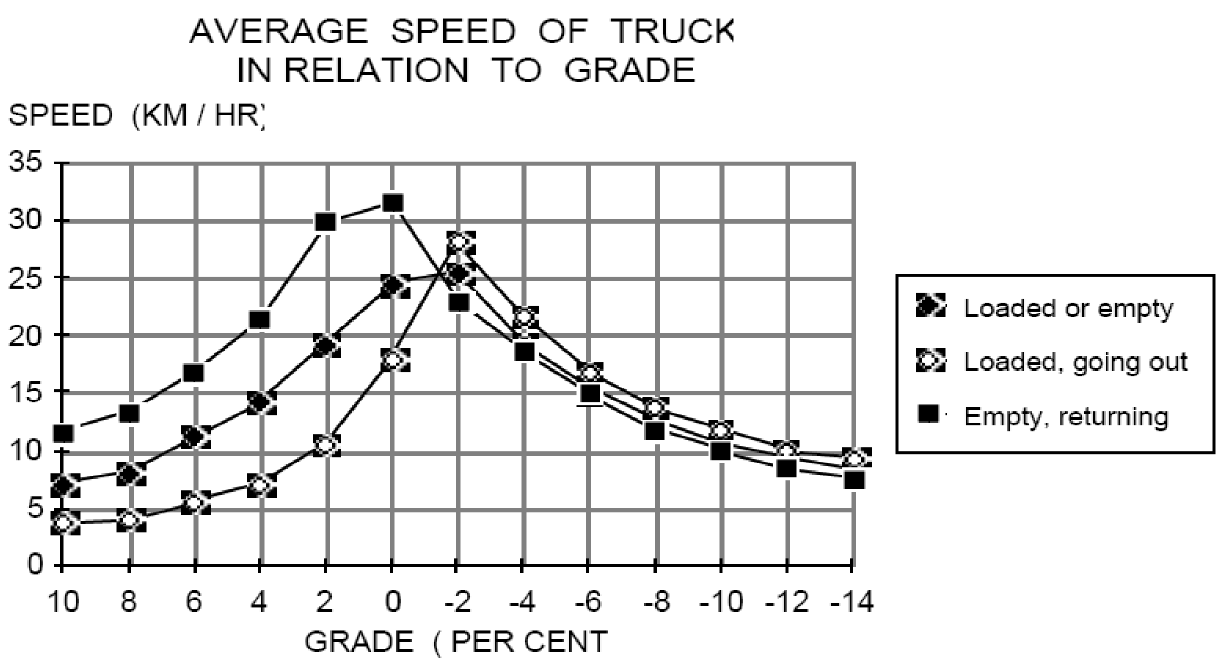


Figure 3. Truck Speed in Relation to Road Grade (2)

	(US Forest Service, 1965) Relationship between travel time per kilometer, surface type, alignment, and grade.										
		Percent Grade in Direction of Load (Adverse)									
	Good Alignment	+10	+9	+8	+7	+6	+5	+4	~	+2	0
Single lane with turnouts (truck lane with 3 ft ditch)	1. Paved	7.93	7.28	6.59	5.93	5.38	4.85	4.32	~	3.32	3.2
	2. Gravel	8.21	7.56	6.87	6.21	5.63	5.1	4.6	~	3.57	3.2
	3. Dirt	8.49	7.81	7.12	6.43	5.85	5.35	4.82	~	4.18	3.2
		Percent Grade in Direction of Load (Favorable)									
	Good Alignment	-2	-4	-6	-7	-8	-9	-11	-12	-14	
Single lane with turnouts (truck lane with 3 ft ditch)	1. Paved	3.2	3.2	3.2	3.34	3.53	3.87	4.53	4.87	5.59	
	2. Gravel	3.2	3.2	3.25	3.44	3.65	3.97	4.62	4.97	5.68	
	3. Dirt	3.2	3.2	3.31	3.5	3.72	4.06	4.72	5.06	5.75	

Table 3. Relationship Between Travel Time, Surface Type, Alignment, and Grade (2)

Locations of Route #1 and #2

Using "Pegger" technology we developed the two probable paths from the landing to our destinations. The pegger tool takes into consideration our constraint parameters of grade and sideslope while providing possible options for directions we may choose to follow. Figure 4 shows the two paths created as well as a detailed layout of general ground slopes through the region and a piece by piece breakdown of the road we choose to do reconnaissance for (Route #2). The road we chose is outlined below and divided into sections based on changes in terrain. While road #1 has less curves, road #2 ultimately covers flatter ground, which we felt was the safest route for heavy log trucks.

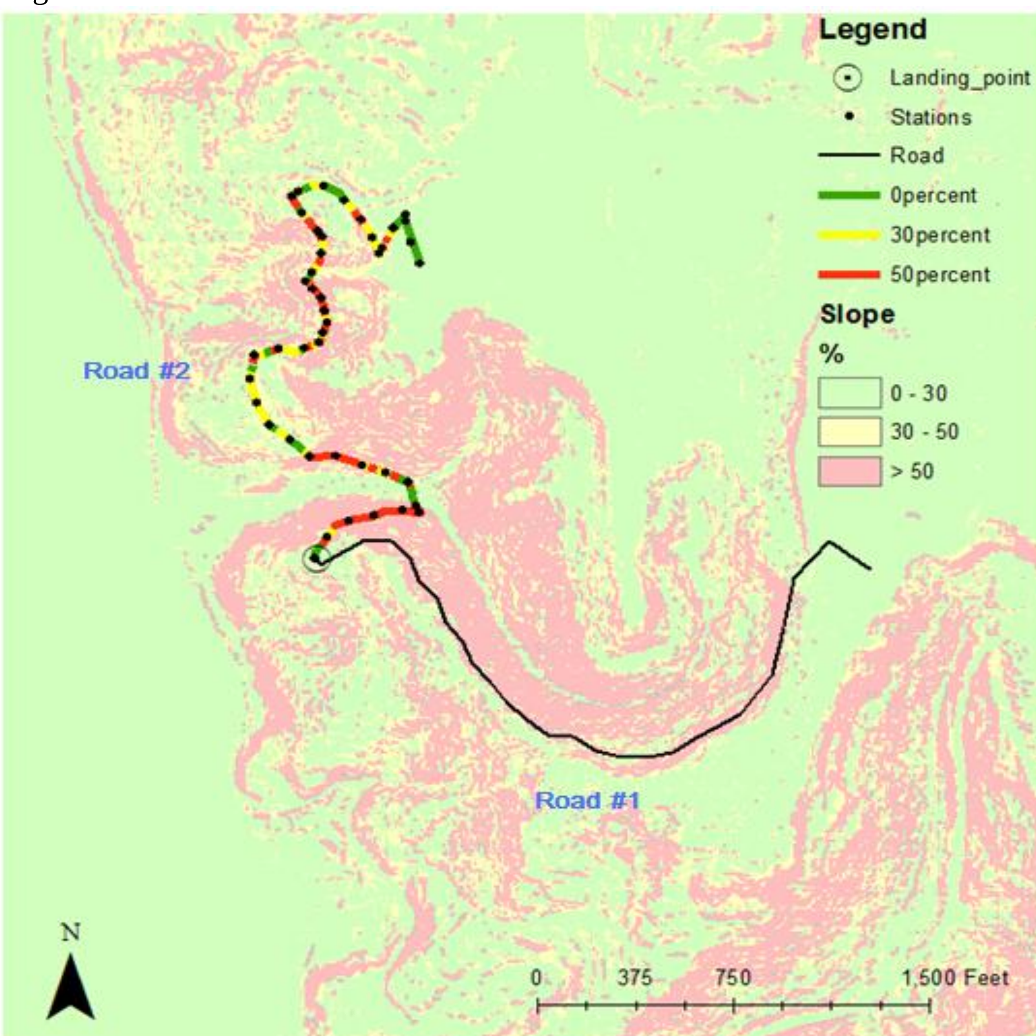
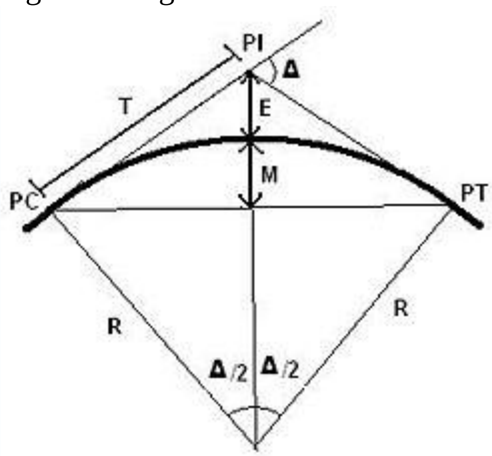


Figure 4. Our Two Proposed Options for Roads within St. Edwards State Park

The additional reasons we selected road 2 have to do with negligible travel time, social factors, and environmental preferences. Because both roads are short, less than a mile, travel times are not as important as they would be on a long road. Vehicles using either road would need to spend little time travelling them. With neighborhoods along the southern border of the park, it seemed more prudent to travel parallel to the shoreline and keep trucks using the road as far away from the homes as possible. This should reduce problems during construction and during use related to factor such as dust and noise. Though road 1 provided a somewhat simpler path on paper, the steeper slopes running up hill from, and parallel to a stream could produce environmental problems. Problems could transpire in the form of increased sediment loading within the stream or complete blockage should a landslide occur. Though road 2 is more sinuous which may complicate construction ease and travel times, it seems to be the better choice based on social, environmental, and economic factors. However, because this is a park special considerations may need to be utilized to improve safety. Multiple curves and very sharp curves reduce visibility and may be a safety hazard. Some trees may need to be removed on curves or other options considered, improving safety.

Additional Design Elements

There are a number of important design elements that have not yet been covered. Curve calculations such as the number of curves in each 100 foot section and the radius of those curves can provide useful information about road travel. During turns two forces act on a vehicle, gravity and centripetal force. Based on velocity the centripetal force may be higher or lower for any given radius. So, curves are built with a slight tilt to help offset these forces. Below, in Figure 5 is a normal horizontal curve plan. It geometrically describes the characteristic of a standard curve, showing curve length and angle.



$$T = R \tan\left(\frac{\Delta}{2}\right)$$

Where:

- T= tangent length (in length units)
- Δ= central angle of the curve, in degrees
- R= curve radius (in length units)

Figure 5. Road Curve Plan View (5)

Sight distance and stopping sight distance are also design factors that play a role in travel times, safety, and overall usability. Finally, there are design areas where the grade of the road must be very low. These regions include tight ridges, curves, gullies, saddles, and at stream crossings. (1)

Slope Considerations and Calculations

Appendix 3 provides a detailed graphical explanation surrounding cut and fill variable based on slope. In cases where the slope is greater than 50% a "Full Bench" cut must occur to provide adequate strength for road survival. This requires more work, time, and money. Slopes of 40% and 20% require les cut and fill and thus save time and money. In the case of the two roads locations we laid out, route #1 has a slope that is continuously steeper than route #2. In fact most of route #1 is in the greater than 50% slope region and will require more cut and fill. Below is the breakdown of cut volume for each road and it provides evidence that more cutting is required on road #1.

Road 1						
Slope Class	Length (ft)	Width (ft)	Cross Section Area (ft^2)	Surface Area (ac)	Cut Volume	Ballast Volume
0-30%	614	44 1/12	20.1	0.6	457	318
30-50%	320	56 11/12	53.5	0.4	634	166
>50%	2159	67 ½	270.8	3.3	14719	1119
	3093			4.4	15810	1604
Road 2						
Slope Class	Length (ft)	Width (ft)	Cross Section Area (ft^2)	Surface Area (ac)	Cut Volume	Ballast Volume
0-30%	907	44 1/12	20.1	0.9	675	470
30-50%	1132	56 11/12	53.5	1.5	2243	587
>50%	1393	67 1/2	270.8	2.2	9498	722
	3431			4.6	12416	1779
Road 1	Clearing / Grubbing	Excavation	Ballast	Cross Drain Culverts	Stream Culverts	
Slope Class						
0-30%	373	$411	$3,182	$600.00		
30-50%	251	$571	$1,660	$300.00		
>50%	2007	$13,247	$11,193	$2,200.00		
	2631	$14,229	$16,035	$3,100.00		
Road 2	Clearing / Grubbing	Excavation	Ballast	Cross Drain Culverts	Stream Culverts	
Slope Class						
0-30%	550	$607	$4,700	$900.00		
30-50%	887	$2,018	$5,869	$1,100.00		
>50%	1295	$8,548	$7,223	$1,400.00		
	2733	$11,174	$17,792	$3,400.00		

Table 4. Slope Class Evaluation for Cut and Ballast Volumes

Costs Evaluation and Calculations

The cost associated with each road varies in many areas which can be seen in the lower half of Table 4. However, in the end the cost of either road is similar, only varying by about a $1000. Though the excavation cost for road #1 are higher, the ballast costs are lower, and as you can see in Table 5, road #2 is longer. These factors offset each other. Again because the roads are short, only about 3100 feet and 3400 feet, the costs do not vary by much. One factor that will become more apparent during reconnaissance is the number of stream crossing present. If unrecorded streams exist in the area, it may drive up the cost. Stream culvert costs are currently an uncalculated factor that have not been considered in our costs.

Road 1			
0-30	30-50	50+	
211	81.6	441	
39.7	29.2	142	
37	61.2	210	
31	48.5	313	
295	30.2	155	
	42.1	212.9	
	27.3	419.8	
		129.8	
		33.7	
		101.5	
613.7	320.1	2158.7	3092.5

Road 1			
0-30	30-50	50+	
69	34.2	39.4	
59.4	57.7	348.3	
68	41.2	50.1	
88.9	20.7	30	
30.5	46.4	31	
26.9	237.9	32	
35.7	29.4	206	
15.9	72.5	42	
18.3	29.2	37.8	
26	20.9	23.5	
24.2	25.7	25.7	
24	10.2	47.7	
30.3	52	164.9	
119	61.6	29.1	
72.8	29.2	118.2	
197.6	22.8	51.7	
	55.5	70.8	
	36.1	12.2	
	53.2	32.6	
	110.9		
	36.9		
	47.6		
906.5	1131.8	1393	3431.3
9.1	11.3	13.9	

Table 5. Road Length Calculations by Grade

References Cited

1. Chapter 6. Laying Out The Roadline
2. Chapter 2. Road Planning and Reconnaissance.
3. Herick, Jill. Jan 1990. Route Selection and Field Reconnaissance Prep St. Edwards Park.
4. http://www.ruraltech.org/tools/#pegger
5. Fundamentals of Transportation/Horizontal Curves From Wikibooks http://en.wikibooks.org/wiki/Main_Page
6. Boudreaux *et al*. April 2004. Paper Location of a Road Through St. Edwards Park.
7. Economic Analysis Notes, ESRM468 2009 http://courses.washington.edu/esrm468/Assignments%20468/Paper%20Plan/04_Paper%20location_2009.ht

Appendix

1. Economic Analysis Notes (7):
   http://courses.washington.edu/esrm468/Assignments%20468/Paper%20Plan/04_Paper%20location_2009.htm

Road construction costs consist of

-Clearing & grubbing
clearing is the process of removing (felling) timber from the right of way
grubbing is the process of removing stumps/rootwads from the construction area.
Typically a common cost value used for clearing & grubbing is $ 600.-/acre

-Excavation; use table values below

U.S.F.S. unit rate for excavation.*

Type of Material	Base Unit DOLLARS/CYD
Common	$0.90
Rippable	$1.80
Solid	$3.60

Slope Adjustment Factor adjust base rate with factor below, based on material

0-30% : 1.0
30-50% : 1.2
Over 50% : 1.4

-Rock (Road ballast); @ $ 10.-/cubic yard in-place

-Cross drain culverts @ 100.-/station
stream culverts separate, if any

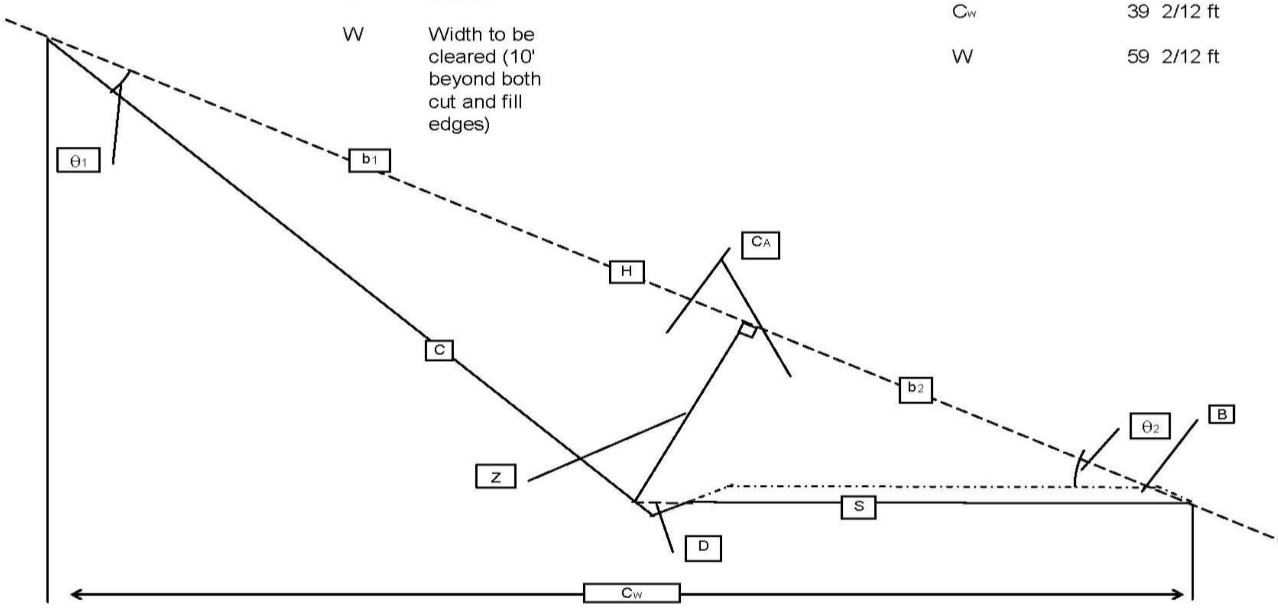
Report the costs as total $ values and also in $/station.
Provide the relative ratios (percent) of each cost component in the total (e.g. clearing/grubbing, ballast, excavation, drainage/culverts)

2. Station Locations, Distances, Grades, and Azimuth

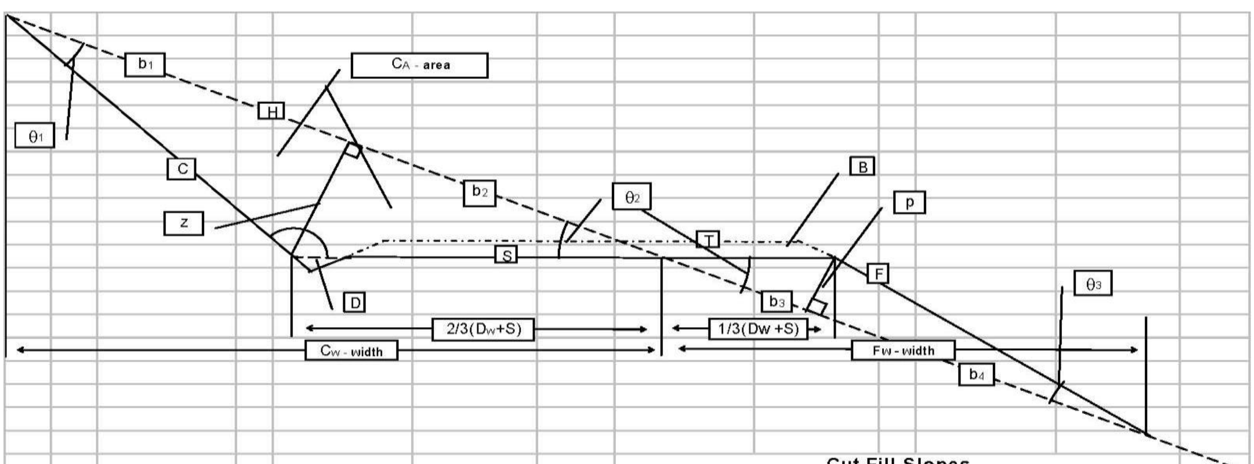
Station	Distance	Grade	Azimuth	Station	Distance	Grade	Azimuth
0+00	100	-15		20+00	53	10	348
1+00	100	-15	28	20+49	49	10	319
2+00	100	-15	50	21+00	51	10	38
3+00	100	-15	77	21+50	50	10	22
4+00	100	-15	77	22+00	50	10	4
4+67	67	-15	94	23+00	100	10	321
5+00	33	0	339	23+75	75	10	321
6+00	100	0	341	24+00	25	10	330
7+00	100	10	290	25+00	100	10	61
8+00	100	10	290	25+77	77	10	78
9+00	100	10	290	26+00	23	10	128
10+00	100	10	270	27+00	100	10	141
11+00	100	10	312	28+00	100	10	152
12+00	100	10	306	29+00	100	10	152
13+00	100	10	332	30+00	100	10	18
14+00	100	10	346	30+73	73	10	27
15+00	100	10	8	31+00	27	10	27
16+00	100	10	74	32+00	100	10	25
17+00	100	10	87	32+77	77	0	9
18+00	100	10	67	33+00	100	0	246
18+59	59	10	22	34+00	100	0	341
19+00	41	10	22	35+00	100	0	
19+47	47	10	348				

3. Slope Factors for Cut and Fill (6)

				Full Bench (>50%)	
H	Hill Slope	T width	12.0 ft	Hill Slope %	60%
C	Cut Slope	B depth	1.0 ft	θ_1	14° 2/60
D	Ditch	S width	16.0 ft	θ_2	30° 58/60
S	Subgrade	D depth	1.0 ft	z	8 1/12 ft
T	Travelled Way	D width	3.0 ft	b_2	13 5/12 ft
F	Fill Slope			b_1	32 3/12 ft
B	Ballast			C_A	184.1 ft²
				C_w	39 2/12 ft
W	Width to be cleared (10' beyond both cut and fill edges)			W	59 2/12 ft



Slope Factors for Full bench with >50% (Above) Slope Factors for 40% and 20% (Below)



				Cut Fill Slopes			
H	Hill Slope	T width	12.0 ft	Hill Slope %	20%	Hill Slope %	40%
C	Cut Slope	B depth	1.0 ft	θ_1	33° 41/60	θ_1	23° 12/60
D	Ditch	S width	16.0 ft	θ_2	11° 19/60	θ_2	21° 48/60
S	Subgrade	D depth	1.0 ft	z	2 6/12 ft	z	4 8/12 ft
T	Travelled Way	D width	3.0 ft	b_2	12 5/12 ft	b_2	11 9/12 ft
F	Fill Slope	$2/3(D_w+S)$	12 8/12 ft	b_1	3 9/12 ft	b_1	11 0/12 ft
B	Ballast	$1/3(D_w+S)$	6 4/12 ft	C_A	20.1 ft²	C_A	53.5 ft²
				C_w	15 10/12 ft	C_w	21 1/12 ft
W	Width to be cleared (10' beyond both cut and fill edges)			θ_3	22° 23/60	θ_3	11° 53/60
				p	1 3/12 ft	p	2 4/12 ft
				b_3	6 3/12 ft	b_3	5 11/12 ft
				b_4	3 0/12 ft	b_4	11 2/12 ft
				F_w	9 1/12 ft	F_w	15 10/12 ft
				W	44 11/12 ft	W	56 11/12 ft

4. Station Locations, Grade, and Travel Path