CE 397 - Railway Project Design and Construction

Final Report on Cement Plant Connection Track Project

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Contents

Sl No.	***Topic***	***Page Number***
1	Introduction	3
2	Track Geometry	3
2.1	- Horizontal Geometry	3
2.2	- Vertical Geometry	6
3	Earthwork	10
4	Alternative Route Selection	12
4.1	- Average Railroad Operating Costs	12
4.2	- Operating Cost Calculation	12
4.3	- Capital Cost Estimating	14
4.4	- Economic Justification of the Project	17
4.5	- Alternative Analysis	17
5	Route Operations Analysis	18
5.1	- Ruling Grade and Train Resistance	18
5.2	- Locomotive Drawbar Pull Calculation	19
5.3	- Number of Locomotives Required per Train	20
5.4	- Fuel Consumption	21
5.5	- Train Acceleration	23
6	Appendix	25

Appendix Details

Topic	***Page Number***
Appendix A: Horizontal Geometry Option S & L	25
Appendix B: Vertical Geometry for Alternative S	26
Appendix C: Vertical Geometry for Alternative L	31
Appendix D: Earthwork Calculation for Alternative S	36
Appendix E: Earthwork Calculation for Alternative L	39
Appendix F: Operating Cost Calculation for Alternative S	43
Appendix G: Operating Cost Calculation for Alternative L	45
Appendix H: Acceleration from STA 00+00	47

1. Introduction

This project analyses two alternatives for connection between two connection points on the South Railroad create two possible alternative alignments to consider for the build-out:

1. West Alignment (a.k.a. Alignment L), a longer but relatively flat alignment skirting the Ellis town limits to the west and connecting to the west end of the South Railroad passing siding (a.k.a. Ellis Siding)
2. East Alignment (a.k.a. Alignment S), a shorter alignment that passes east of the Ellis town limits and crosses the Cottonwood River before connecting to the east end of Ellis Siding.

This report includes Preliminary track alignment design and earthwork calculations followed by economic justification and alternative analysis for both the alternatives. After which a final alternative is proposed. A Route operations analysis for the selected alternative is discussed thereafter.

2. Track Geometry

For clarity various curves are labelled in Figure 1 and shall be addressed by the labelled name hereafter.

2.1 Horizontal Alignment

The following processes were used to determine the deflection angle, minimum allowable degree of curvature based on site geometry, and the stationing for the TS, SC, CS, and ST for all nine horizontal curves. Of the two alternatives, curves C1 & C2 are shared between both while curve numbers followed by "-S" or "-L" correspond to their respective alternatives.

Deflection angles were found using the bearings written on the site plan, displayed in degree, minute, second notation below in *Table 3: Horizontal Curve Measurements & Stationing.* Standards for determining minimum degree of curve can be seen in the table below followed by a table of possible degree of curve sizes.

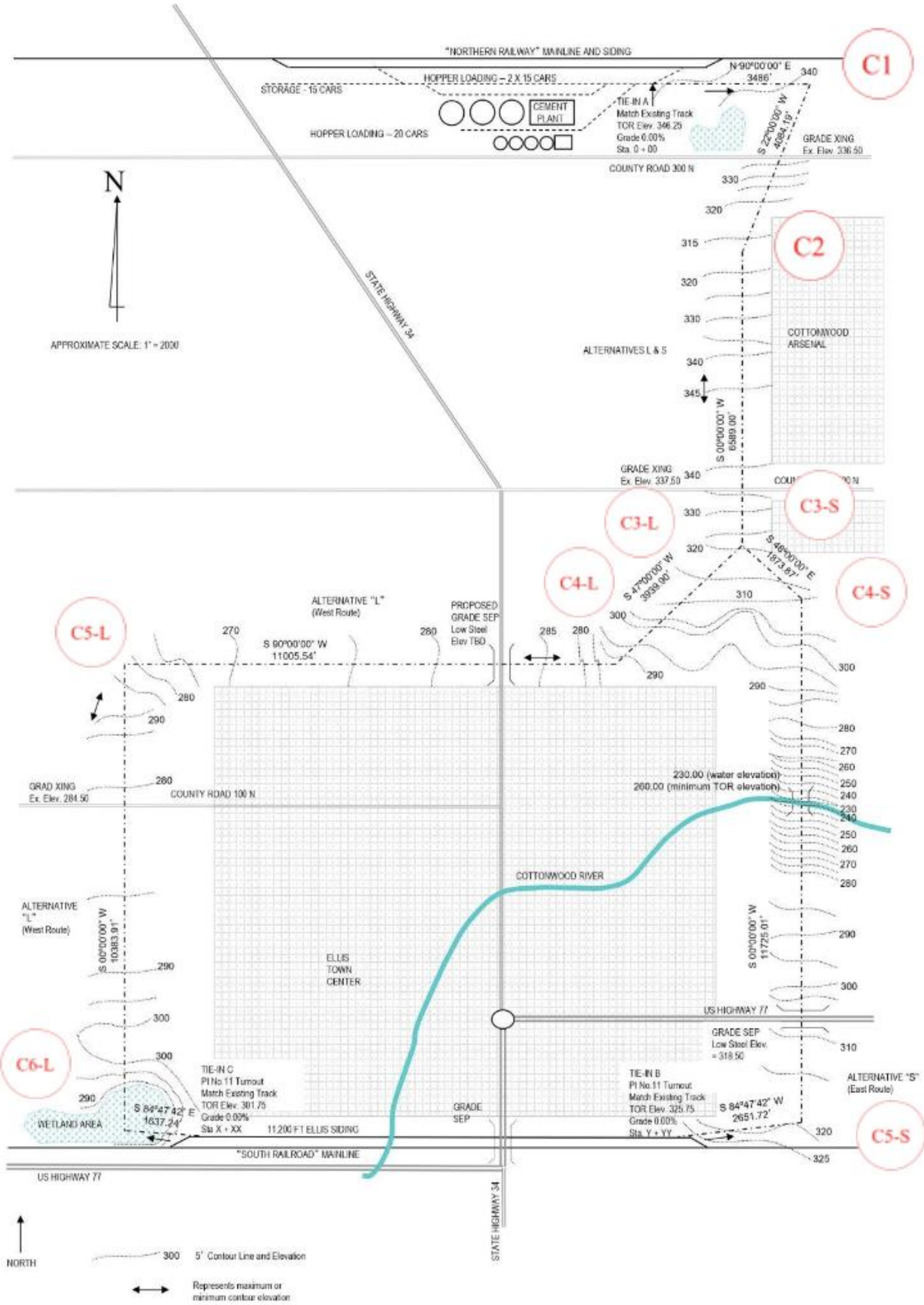


Figure 1: Curve notation

Table 1: Standards for Determining Minimum Deg. of Curve

Limit	Limiting Distance	Min or Max	Value (ft)
All Curves	PT to PS between curves	Min	0.00
Turnout (No.11)	PT to PI of Turnout	Min	93.31
Reverse Curves	PT to PS between RCs	Min	150.00

Table 2: Possible Degree of Curve Sizes & Measurements

Degree of Curve	Radius (ft)	Superelevation (in)	Max Speed (mph)	Spiral Length (ft)
3°	1910.08	1	30	50
5°	1146.28	2.25	20	100
7.5°	764.49	1	20	50

Final degree of curves was found by first calculating all stationing under the smallest possible curve, 3°, checking the limiting measurements, and increasing the curvature as needed. Stationing was found by first establishing all PI-to-PI distances from the site layout, calculating the curve tangent distances based on curve radius and deflection angle (see *Equation 1* below), and the curve length from the degree of curvature and deflection angle (see *Equation 2* below). Those variables were then used to find each curve's PC and PT in relation to track tangents, spiral length values were used to find each curve's TS, SC, CS, & ST in relation to track tangents, and finally all values were converted to station values with 0+00 starting at Tie-In A as per the site layout.

Equation 1: Curve Tangent Distances

$$\boldsymbol{T = R\,tan(I/2)}$$

Equation 2: Length of Curve

$$Lc = (I/D) * 100$$

These steps were followed to create the final horizontal curve measurement and stationing guidelines for both alternatives as shown in the table below.

Table 3: Horizontal Curve Measurements & Stationing (1 STA = 100' has been assumed, for 500' stationing divide each value by 5)

Curve Number	Degree of Curve	Deflection Angle	TS STA	SC STA	CS STA	ST STA
C1	3°	112°00'00"	6+29.19	6+79.19	43+62.52	44+12.52
C2	3°	22°00'00"	52+43.62	52+93.62	59+76.95	60+26.95
C3-S	5°	48°00'00"	116+59.32	117+59.32	126+19.32	127+19.32
C4-S	3°	48°00'00"	131+57.41	132+07.41	147+57.41	148+07.41
C5-S	3°	84°47'42"	238+88.00	239+38.00	267+14.50	267+64.50
C3-L	3°	47°00'00"	113+64.15	114+14.15	129+30.81	129+80.81
C4-L	3°	43°00'00"	152+87.79	153+37.79	167+21.12	167+71.12
C5-L	3°	90°00'00"	250+64.18	251+14.18	280+64.18	281+14.18
C6-L	5°	84°47'42"	354+66.40	355+66.40	371+62.30	372+62.30

2.2 Vertical Alignment

The following process was used to get the elevation of 500 feet stations. First, the contour lines on the site layout were used along with the scale (1" approximated 2000') to get the elevations of each 500-foot station. To do so, the horizontal geometry stationing is used. Starting from STA 0+00, the elevation of the first TS station is computed. Next going along the length of the curve, the elevation of station ST needs to be computed. For this purpose, the PI-ST distance is used. Since, the PI can be found on the site layout, the distance from PI-ST on the site layout provides the elevation at ST which is computed using the following equation:

Equation 3: PI to ST distance

$$E_S = E_0 + d\frac{E_1 - E_0}{l}$$

Where E_0 and E_1 are the elevations of contours before and after the point S. d is the length between the contour before S up to S and l is the length between the contours.
The same process is repeated to get the ground elevation at all the contours and stations of horizontal geometry along the stationing. This gives a crude idea of Top of Rail (TOR) elevations. The results are tabulated in Appendix Sheets "Vertical_Option S_pre" and "Vertical_Option L_pre". To proceed further starting from STA 0+00, the elevations at every 500 feet station are computed using a similar logic. The results are summarized in Appendix Sheets "Vertical_Option S" and "Vertical_Option L".

Next, locations with constraints are identified along the direction of stationing. Further, the ground elevation plus 4.5 feet is plotted, so that 4.5 feet of drainage can be left wherever the TOR follows the ground slope. The projected ground elevations for alternatives L and S and the constraints are shown below.

Figure 2:

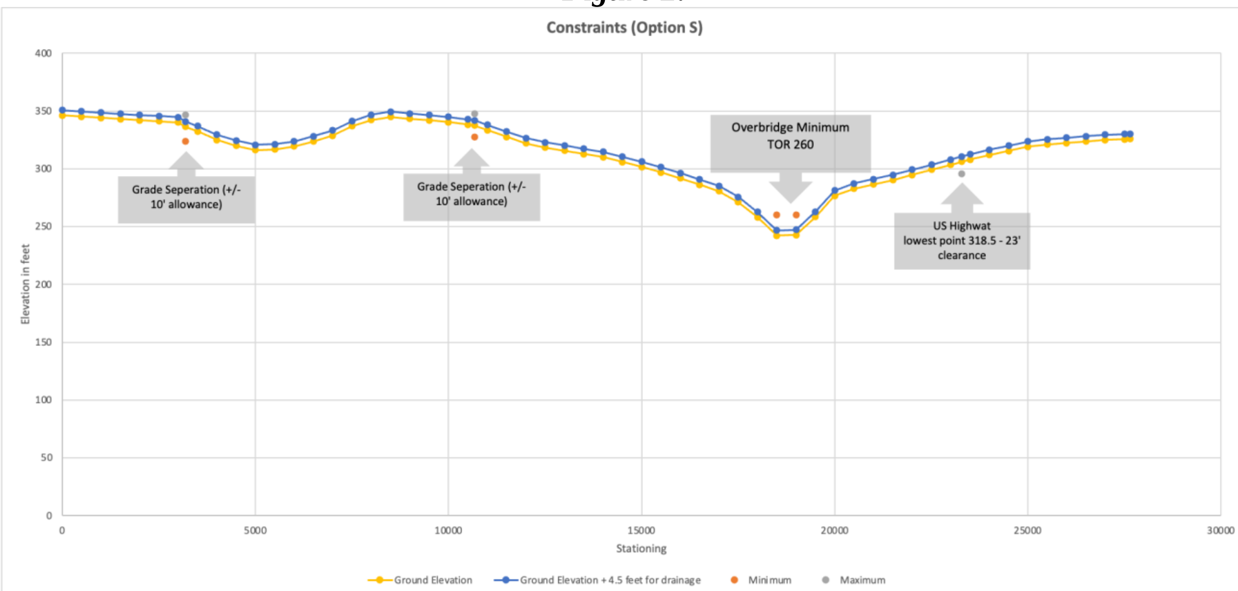
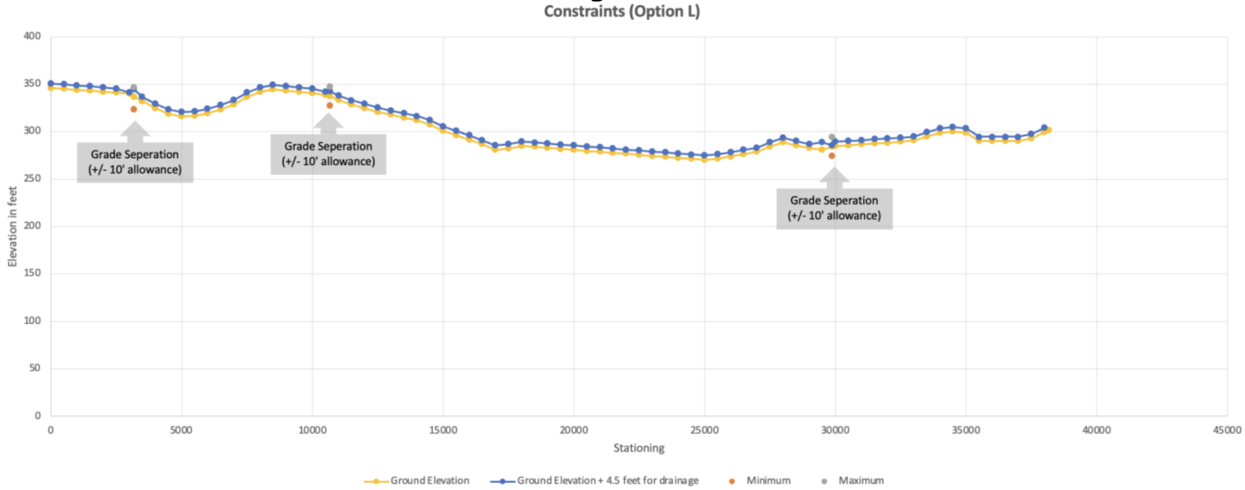


Figure 3:



The final step is to identify the PVI such that the curves fit between the minimum and maximum points and use minimum cut and fill. To do so, the tangent should follow the ground elevations as much as possible. However, the number of PVIs should be practical and limited. Keeping the tradeoff in mind the following PVIs are proposed.

In our proposed vertical alignment, the constraint location either falls on a tangent or when it's a curve, its low (resp. high) point is above (resp. below) the constraint at that location. For instance, at the first constraint, the elevation at PVC is 337.27'. Using the grade equation (Equation 4) the elevation at the grade separation is 334.21' which falls inside the +/- 10' limit. Further, the maximum allowed grade is kept at 1%.

Equation 4: Grade Equation

$$Z = Z_{PVC} + G_1X/100 + RX^2/20000$$

Figure 4:

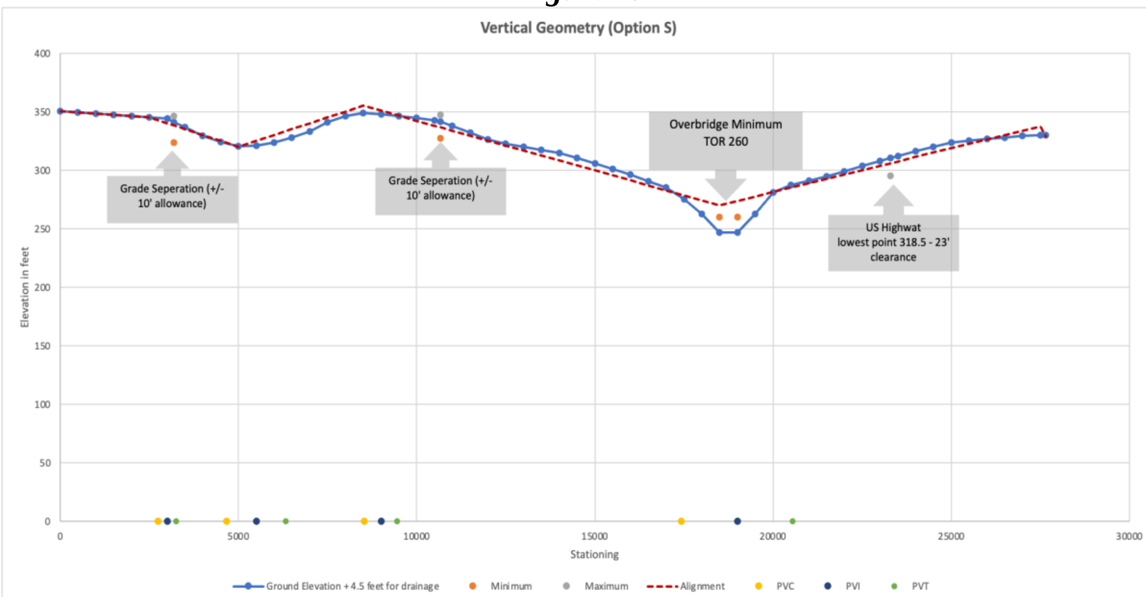
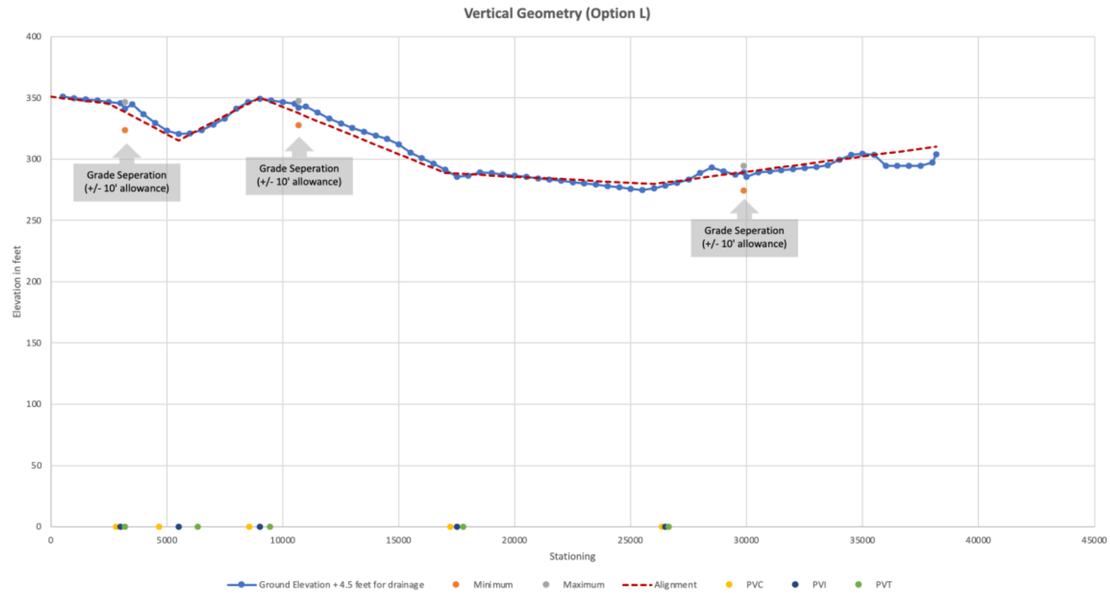


Figure 7:



With the PVIs pointed and given R for crest (-0.2) and sag (+0.12) curves, the PVC, PVI, and PVT tables are computed. The curve number in the tables follows stationing. The following equation is used for calculating the length of the curve.

Equation 5: Length of curve

$$L = (G_2 - G_1) / R$$

Table 4: Alternative S
(1 STA = 100' has been assumed, for 500' stationing divide each value by 5)

Vertical Curve No.	PVC	PVI	PVT	Length
1	27+39.58	30+00.00	32+60.42	520.8
2	46+66.67	55+00.00	63+33.33	1666.7
3	85+37.50	90+00.00	94+62.50	925
4	174+37.50	190+00.00	205+62.50	3125

Table 5: Alternative L
(1 STA = 100' has been assumed, for 500' stationing divide each value by 5)

Vertical Curve No.	PVC	PVI	PVT	Length
1	28+05.00	30+00.00	31+95.00	390
2	46+66.67	55+00.00	63+33.33	1666.7
3	85+57.50	90+00.00	94+42.50	885
4	172+20.83	175+00.00	177+79.17	558.3
5	263+54.17	265+00.00	266+45.83	291.7

3. Earthwork

The vertical geometry is further used to develop preliminary earthwork quantity estimates for each alignment. The first step was determining the excavation and embankment end area quantities at each 500' station. The relationship between the proposed preliminary vertical alignment TOR elevations and the existing ground elevations was used to classify each end area as All-Cut, All-Fill, or Cut & Fill based on the required geometry provided in the BNSF "Single Track - Curves" typical cross-section. The most notable requirements from this typical section are a 14' subgrade shoulder width, 2:1 side/back slopes, and a minimum 2' elevation between the subgrade shoulder and the ditch bottom. The equations to determine the trapezoidal end areas can be found below.

Equation 6: End Area of an ALL-FILL Section

$$A = h_{fill}\left(\frac{a_{fill} + b_{fill}}{2}\right)$$

Equation 7: End Area of an ALL-CUT Section

$$A = h_{total}\left(\frac{a_{total} + b_{total}}{2}\right) - h_{subgrade}\left(\frac{a_{subgrade} + b_{subgrade}}{2}\right)$$

Equation 8: End Areas of a CUT & FILL Section

$$A_{cut} = 2 \times h_{ditch}\left(\frac{a_{ditch} + b_{ditch}}{2}\right)$$

$$A_{fill} = h_{fill}\left(\frac{a_{fill}+b_{fill}}{2}\right) \textit{ (Same as before)}$$

The area for an All-Fill section is simply the trapezoidal area formed between the top of subgrade and the existing ground. The area for an All-Cut section is calculated using the total trapezoidal area formed between the existing ground and the ditch bottom elevations and then subtracting the area formed by the subgrade. The cut area for a Cut & Fill section is the area of the two trapezoidal ditches formed around the subgrade. The fill area for this type of section is the same as before.

The top of subgrade elevation was determined by using a 3.25' track structure depth. This depth is composed of a 7" rail, 1" tie plate, 7" crosstie, 12" ballast, and 12" subballast. The depths of the ballast and subballast were provided in the notes of the provided BNSF track section sheet. The total volumetric quantities of cut and fill for each route were determined using the average end-area approach (see *Equation 9* below). The complete results can be found in the appendix with cut and fill volumes shown over each 500' length between stations and the total volumes for each alignment. A 10% shrinkage factor was also applied to the earthwork embankment quantities. Alignment S has a cut volume of 111,699 yd^3 and a fill volume of 189,894 yd^3. This results in 78,195 yd^3 of extra material required to construct embankments. Alignment L has a cut volume of 112,333 yd^3 and a fill volume of 149,327 yd^3. This results in 36,995 yd^3 of extra material required to construct embankments.

Equation 9: Average End-Area Earthwork Volume

$$\boldsymbol{V_{12} = L \times (A_1 + A_2)/2}$$

The summary of each of the earthwork elements are provided below. Further details are provided in Appendix G and H.

Table 6: Earthwork Quantities

	Option S	**Option L**	**Units**
Fill	189,893.84	149,327.30	CY
Cut	111,698.60	112,332.61	CY
Sub ballast	28,669.93	39,587.85	CY
Topsoil (2" depth)	11,073.45	12,133.11	CY
Seeding	41.182234	45.123143	AC

4. Alternative Route Selection

4.1 Average Railroad Operating Costs

The average values are summarized below in Table 7.

LINE ITEM	*U.S.*
Total Operating Expense ($000)	40980029
Gross Ton-Miles (Excluding Loc) (000)	3257605196
Train-Miles	562607133
Revenue (Ton-Miles of Freight (000))	1771896504
Operating cost per million gross ton-miles	12579.8022
Operating cost per million revenue ton-miles	23127.778
Operating cost per train-mile	72.839512

Table 7: Average Railroad operating cost

4.2 Cement Spur Operating Cost Calculation

To find the operating cost of the two alignment options, a hypothetical straight line that is 4 miles long with no curves or grade changes was used to create a base line for operating costs. It was found that the cement plant would generate **2.36 MGT/year** of traffic, which mapped onto the hypothetical "SL" track of 4 miles equates to **9.43 MGTM/year** of traffic. Using the operating cost per MGTM value found in section 4.1, this traffic equates to roughly **$127,000** in operating costs per year.

To find an operational cost estimation for the two alignments, we will add onto this base SL cost with the additional cost expected due to additional distance, curve, and grade on the alternatives. Curvature will be converted to equivalent curve miles and grade to equivalent grade miles and then treated as additional miles to be added onto the straight-line track. The table below shows the additional operating cost for added distance, curvature, and grade as well as the equivalent curve miles and grade miles for alternatives S and L.

The summary of operating cost analysis is given in Table 8. More details are provided in Appendix.

Calculation	Value	Units		
Traffic	2.36	MGT/year		
SL Traffic	9.43	MGTM/year		
SL Operating Cost	$127,364	per year		
Calculation	**Value (S)**	**Units**	**Value (L)**	**Units**
Additional Operating Cost - Distance	$20,790	per year	$59,517	per year
Equivalent Curve Miles	0.954	miles	1.21	miles
Additional Operating Cost - Curve	$7,773	per year	$9,847	per year
Equivalent Grade Miles	18.13	miles	14.30	miles
Additional Operating Cost - Grade	$110,204	per year	$86,935	per year
Operating Cost	$266,130	per year	$283,663	per year

Table 8: Operating Cost Analysis

4.3 Capital Cost Estimation

The Capital costs for each alternative is summarized below. The following specifics are used:

Alignment L (Long) Specifics:

- Three county road highway-rail grade crossings require flashing lights and gates.
- One proposed two-lane state highway grade separation
  - Low-steel elevation is set by track designer (i.e. not a fixed constraint)
  - Grade separation road/bridge construction estimate is \$3 million + \$150,000 × (Z – 283) where Z is the proposed top of rail at the grade separation location
- Alignment crosses a wetland area near the tie-in at the west end of the passing siding that must be mitigated at project expense using an approved means.

Alignment S (Short) Specifics:

- Two county road highway-rail grade crossings require flashing lights and gates.
- One four-lane US highway grade separation
  - Low steel elevation constrained to Elev 318.50' by nearby development (sets maximum top of rail elevation under overpass) Roadway and bridge engineer's construction estimate is \$7 million.
- One Cottonwood River railroad bridge (minimum top of rail elev. = 260.00')
  - Bridge engineer's construction estimate is \$1.5 million + \$100,000 × (D – 260) where D is the proposed top of rail elevation low point on the bridge

Additionally, the following assumption has been made:

- The mobilization of both alternatives is assumed to be same
- For Wetland mitigation USACE mitigation plan[1] has been used. The wetland is assumed to be of "good" quality and the area is assumed to be 6,480,000 sq estimated as a circle.

[1] https://www.swf-wc.usace.army.mil/lewisville/pdf/H_Appnd_AppendixLMitigationCosts.pdf

Table 9: Capital Costs for Alternative S:

Description	Quantity	Unit	Cost/Unit	TOTAL
Sitework				$3,037,442.7
Mobilization	1	EA	$500,000.00	$500,000.00
Embankment	189,893.84	CY	$5.00	$949,469.18
Excavation	111,698.60	CY	$4.00	$446,794.41
Subballast	28,669.93	CY	$35.00	$1,003,447.41
Topsoil (2" Depth)	11,073.45	CY	$5.00	$55,367.23
Seeding	41.182234	AC	$2,000.00	$82,364.47
Structures				$2,175,000.00
Cottonwood River railroad bridge @ 266.75 feet	1	EA	$2,175,000	$2,175,000.00
Drainage				$52,120.0
2' x 2' Box Culvert - Extend	38	LF	$210.00	$7,980.00
3' x 2' Box Culvert - Extend	38	LF	$250.00	$9,500.00
4' x 4' Box Culvert - Extend	38	LF	$280.00	$10,640.00
Headwalls & Wingwalls	3	EA	$8,000.00	$24,000.00
Roadway and Grade Crossings				$7,300,000.00.
Grade Crossing (four-lane US highway grade separation)	1	EA	$7,000,000	$7,000,000.00
Protection - Lights and Gates (county road)	2	EA	$150,000.00	$300,000.00
Track - 136# CWR New - Wood Ties & Ballast				$6,919,510.00
Install Siding Track	27646	TF	$185.00	$5,114,510.00
No. 11, RBM Turnout - Powered	1	EA	$305,000.00	$305,000.00
Signal Control Points (before & after bridge)	2	EA	$750,000.00	$1,500,000.00
Stabilization				$5,16,058.67
Geotextile Fabric	86009.7778	SY	$2.00	$172,019.56
Subgrade Lime Stabilization (6")	86009.7778	SY	$4.00	$344,039.11
Subtotal				$20,000,131.3
ROW Acquisition	63.466483	Acres	$10,000.00	$634,664.83
Subtotal				$20,634,796.1
Contingency % of Total	20	%		$4,126,959.24
Total				**$24,761,755.4**

Table 10: Capital Costs for Alternative L:

Description	Quantity	Unit	Cost/Unit	TOTAL
Sitework				$3,232,453.60.
Mobilization	1	EA	$500,000.00	$500,000.00
Embankment	149,327.30	CY	$5.00	$746,636.50
Excavation	112,332.61	CY	$4.00	$449,330.44
Subballast	39,587.85	CY	$35.00	$1,385,574.81
Topsoil (2" Depth)	12,133.11	CY	$5.00	$60,665.56
Seeding	45.123143	AC	$2,000.00	$90,246.29
Structures				$0.00
None				$0.00
Drainage				$70,760.00.
2' x 2' Box Culvert - Extend	38	LF	$210.00	$7,980.00
3' x 2' Box Culvert - Extend	38	LF	$250.00	$9,500.00
4' x 4' Box Culvert - Extend	38	LF	$280.00	$10,640.00
4' x 4' Box Culvert - Extend	38	LF	$280.00	$10,640.00
Headwalls & Wingwalls	4	EA	$8,000.00	$32,000.00
Roadway and Grade Crossings				$3,645,000.00
proposed two-lane state highway grade separation @ 284.3'	1	EA	$3,195,000	$3,195,000.00
Protection - Lights and Gates (county road)	3	EA	$150,000.00	$450,000.00
Track - 136# CWR New - Wood Ties & Ballast				$8,867,190.0
Install Siding Track	38174	TF	$185.00	$7,062,190.00
No. 11, RBM Turnout - Powered	1	EA	$305,000.00	$305,000.00
Signal Control Points (before & after bridge)	2	EA	$750,000.00	$1,500,000.00
Wetland	1	EA	$1,555,200.00	$1,555,200.00
Stabilization				$712,581.33
Geotextile Fabric	118763.556	SY	$2.00	$237,527.11
Subgrade Lime Stabilization (6")	118763.556	SY	$4.00	$475,054.22
Subtotal				**$18,083,184.9**
ROW Acquisition	87.6354454	Acres	$10,000.00	$876,354.45
Subtotal				$18,959,539.39
Contingency % of Total	20	%		$3,791,907.88
Subtotal				**$22,751,447.2**

4.4 Economic Justification of the Project:

a) The rate of return method was used to calculate the revenue required to provide a 20% return for each route. Using the previously calculated capital costs and annual operating expenses, Alignment S requires an annual revenue of $5,218,451 while Alignment L requires an annual revenue of $4,833,989.
b) The annual revenue ton-miles generated by traffic from the cement plant on the South Railroad was calculated for each route. This was calculated by multiplying the distance traveled on each route, the weight of the railcar contents, and the annual cars. Alignment S generates 1,342,546,712 revenue ton-miles while Alignment L generates 1,345,676,792 revenue ton-miles.
c) The revenue benefit of the project to the plant is in the form of savings from reduced shipping rates on the South Railroad due to competitive access with the Northern Railway. To justify the construction of each route, the cement plant must obtain a benefit of $0.0039 per revenue ton-mile for Route S and $0.0036 per revenue ton-mile for Route L.
d) If the plant is currently paying the Northern Railway a rate of $0.050 per revenue ton-mile to ship cement, the South Railroad must quote the plant $0.0461 per revenue ton-mile for Route S and $0.0464 per revenue ton-mile for Route L to justify each project. This represents 7.77% and 7.74% discounts for Route S and Route L, respectively, from the current shipping rate.

4.5 Alternative Analysis:

After comparing the two alternatives, Alternative L is recommended as the final route. The main reason is that its construction cost is $2 million less than Alternative S. This route also avoids the construction and maintenance costs that would arise from the Cottonwood River Bridge. Alternative L has a $384k lower annual required revenue to obtain a 20% (or 5-year) rate of return. Another benefit of Alternative L is that it crosses a state highway while Alternative S crosses a US highway. This results in a lower risk of construction delays as a state highway requires less coordination with highway departments compared to crossing a US highway.

Alternative L is chosen for further analysis and is proposed to be built.

5. Route Operations Analysis (Alternative L)

5.1 Ruling Grade and Train Resistance for Selected Alignment

Suppose we have an alignment with g grade and d degree of curve, the train has N cars each weighing W and having n axles, V is the velocity of the train then,

$$Curve\ resistance\ =\ 20g\ pounds\ per\ ton$$

$$Grade\ resistance\ =\ 0.8d\ pounds\ per\ ton$$

$$Modified\ Davis\ air\ resistance\ =\ 0.6\ +\frac{20n}{W}+\ 0.01V\ +\frac{KV^2}{W}\ pounds\ /\ ton$$

Total Resistance hence is,

$$R\ =\left(\ 20g+\ 0.8d+\ 0.6\ +\frac{20n}{W}+\ 0.01V\ +\frac{KV^2}{W}\right)*W*N\ pounds$$

The parameter values are summarized below.

The parameters are summarized below:

Table 11: Parameter Values

Parameter	**Symbol**	**Values**	**Units**	**Converted Values**	**Converted Units**
Number of Axles	n	4			
Air Resistance	k	0.07			
Grade Resistance Coefficient		20	pounds/ton/percent grade		
Curve Resistance Coefficient		0.8	pounds/ton/degree of curvature		
Gross railcar load		286,000	pounds per car	143	tons/car
Empty tare weight		57,300	pounds per car	28.65	tons/car
Design speed		30	mph		
Yard speed		20	mph		
Hoppers		44	cars		

The resistance of each section is summarized below. The section highlighted in orange has maximum positive resistance and section in green has the maximum negative resistance.

Table 12: Train Resistance

Begin STA	End STA	Type	Length	Maximum Speed	Grade (SB)	Curvature	SB loaded train resistance	Grade (NB)	NB empty train resistance
0+00.00	6+29.19	Tangent	629.189945263185	20	-0.22	0	-17899.2	0.22	11307.12
6+29.19	30+00.00	Curve	2370.810054736810	30	-0.22	3	-629.2	0.22	15998.62
30+00.00	44+12.52	Curve	1412.523278596520	30	-1	3	-98784.4	1	35663.98
44+12.52	52+43.62	Tangent	831.098004385412	30	-1	0	-113885.2	1	32638.54
52+43.62	55+00.00	Curve	256.378717018069	30	-1	3	-98784.4	1	35663.98
55+00.00	60+26.95	Curve	526.954616315264	30	1	3	152895.6	-1	-14760.02
60+26.95	90+00.00	Tangent	2973.045383684740	30	1	0	137794.8	-1	-17785.46
90+00.00	113+64.15	Tangent	2364.146254272110	30	-0.77	0	-84942	0.77	26839.78
113+64.15	129+80.81	Curve	1616.666666666670	30	-0.77	3	-69841.2	0.77	29865.22
129+80.81	152+87.79	Tangent	2306.973057572030	30	-0.77	0	-84942	0.77	26839.78
152+87.79	167+71.12	Curve	1483.333333333330	30	-0.77	3	-69841.2	0.77	29865.22
167+71.12	175+00.00	Tangent	728.880688155859	30	-0.77	0	-84942	0.77	26839.78
175+00.00	250+64.18	Tangent	7564.178790581550	30	-0.1	0	-629.2	0.1	9947.74
250+64.18	265+00.00	Curve	1435.821209418450	30	-0.1	3	14471.6	0.1	12973.18
265+00.00	281+14.18	Curve	1614.178790581550	30	0.25	3	58515.6	-0.25	4148.98
281+14.18	354+66.40	Tangent	7352.224239861170	30	0.25	0	43414.8	-0.25	1123.54
354+66.40	372+62.30	Curve	1795.900000000000	30	0.25	5	68582.8	-0.25	6165.94
372+62.30	381+74.22	Tangent	911.916180738939	20	0.25	0	41245.6	-0.25	-542.52
							MAXIMUM		152895.6
							MINIMUM (MAX NEGATIVE)		-113885.2

5.2 Locomotive Drawbar Pull Calculation

The maximum tractive effort was calculated using the following equation:

$$F_T = 308(P/V) < \mu W_L$$

Sample calculation using the given locomotive characteristics and the maximum design speed for the first section:

$$F_T = 308(4400/20) < 0.33 * 429{,}000$$

$$F_T = 67{,}760 \; pounds < 141{,}570 \; pounds$$

The locomotive resistance was calculated using the Modified Davis equation while considering grade and curve resistances. The locomotive drawbar pull was calculated by taking the difference between maximum tractive effort and drawbar pull for each direction. A summary of the results is provided below.

Table 13: Locomotive Drawbar Pull Results

Begin STA	End STA	Maximum Speed	Grade	Curvature	Maximum Tractive Effort (pounds)	Grade Resistance SB (pounds)	Grade Resistance NB (pounds)	Curve Resistance (pounds)	Locomotive Resistance SB (pounds/locomotive)	Drawbar Pull SB (pounds/locomotive)	Locomotive Resistance NB (pounds/locomotive)	Drawbar Pull NB (pounds/locomotive)
0+00.00	6+29.19	20	-0.22	0	67760.0	-943.8	943.8	0	-624.2	68384.2	1263.4	66496.6
6+29.19	30+00.00	30	-0.22	3	45173.3	-943.8	943.8	514.8	-52.9	45226.3	1834.7	43338.7
30+00.00	44+12.52	30	-1	3	45173.3	-4290	4290	514.8	-3399.2	48572.5	5180.9	39992.5
44+12.52	52+43.62	30	-1	0	45173.3	-4290	4290	0	-3914.0	49087.3	4666.1	40507.3
52+43.62	55+00.00	30	-1	3	45173.3	-4290	4290	514.8	-3399.2	48572.5	5180.9	39992.5
55+00.00	60+26.95	30	1	3	45173.3	4290	-4290	514.8	5180.9	39992.5	-3399.2	48572.5
60+26.95	90+00.00	30	1	0	45173.3	4290	-4290	0	4666.1	40507.3	-3914.0	49087.3
90+00.00	113+64.15	30	-0.77	0	45173.3	-3303.3	3303.3	0	-2927.3	48100.6	3679.4	41494.0
113+64.15	129+80.81	30	-0.77	3	45173.3	-3303.3	3303.3	514.8	-2412.5	47585.8	4194.2	40979.2
129+80.81	152+87.79	30	-0.77	0	45173.3	-3303.3	3303.3	0	-2927.3	48100.6	3679.4	41494.0
152+87.79	167+71.12	30	-0.77	3	45173.3	-3303.3	3303.3	514.8	-2412.5	47585.8	4194.2	40979.2
167+71.12	175+00.00	30	-0.77	0	45173.3	-3303.3	3303.3	0	-2927.3	48100.6	3679.4	41494.0
175+00.00	250+64.18	30	-0.1	0	45173.3	-429	429	0	-53.0	45226.3	805.1	44368.3
250+64.18	265+00.00	30	-0.1	3	45173.3	-429	429	514.8	461.9	44711.5	1319.9	43853.5
265+00.00	281+14.18	30	0.25	3	45173.3	1072.5	-1072.5	514.8	1963.4	43210.0	-181.7	45355.0
281+14.18	354+66.40	30	0.25	0	45173.3	1072.5	-1072.5	0	1448.6	43724.8	-696.5	45869.8
354+66.40	372+62.30	30	0.25	5	45173.3	1072.5	-1072.5	858	2306.6	42866.8	161.6	45011.8
372+62.30	381+74.22	20	0.25	0	67760.0	1072.5	-1072.5	0	1392.1	66367.9	-752.9	68512.9

5.3 Number of Locomotives Required per Train

a) The number of locomotives required was found by dividing the calculated train resistance by the drawbar pull in each direction. The largest positive value is highlighted below, and it is for a loaded southbound train. From this, we can conclude that 4 locomotives are required to power the train on a round trip.

Begin STA	End STA	# locomotives SB	# locomotives NB
0+00.00	6+29.19	-0.26	0.17
6+29.19	30+00.00	-0.01	0.37
30+00.00	44+12.52	-2.03	0.89
44+12.52	52+43.62	-2.32	0.81
52+43.62	55+00.00	-2.03	0.89
55+00.00	60+26.95	3.82	-0.30
60+26.95	90+00.00	3.40	-0.36
90+00.00	113+64.15	-1.77	0.65
113+64.15	129+80.81	-1.47	0.73
129+80.81	152+87.79	-1.77	0.65
152+87.79	167+71.12	-1.47	0.73
167+71.12	175+00.00	-1.77	0.65
175+00.00	250+64.18	-0.01	0.22
250+64.18	265+00.00	0.32	0.30
265+00.00	281+14.18	1.35	0.09
281+14.18	354+66.40	0.99	0.02
354+66.40	372+62.30	1.60	0.14
372+62.30	381+74.22	0.62	-0.01

Table 14: Locomotives Required per Train

b) The largest negative value for train resistance was found to be -113,885 pounds in the southbound direction. Adding the locomotive resistance of -3,914 pounds/locomotive for this section with a total of 4 locomotives, we find the total resistance to be -129,541 pounds. The dynamic braking force is found using the equation below.

$$F_{Bd} = 616(P/V) < F_{Bdmax}$$

$$F_{Bd} = 616(4400/30) < 105{,}000\ pounds$$

$$F_{Bd} = 90{,}347\ pounds < 105{,}000\ pounds$$

Each locomotive provides 90,347 pounds of braking force for a total of 361,388 pounds of dynamic braking force. Therefore, the locomotives provide sufficient dynamic braking force to control the speed of the train.

5.4 Fuel Consumption

Fuel consumption for the given alignment can be calculated using the following steps. First, we must find the power provided by each of the four locomotives determined necessary to traverse the alignment. Assuming the total horsepower is divided equally amongst all locomotives, we divide the train resistance by the four locomotives and then convert to horsepower using the maximum speed allowed on the given segment as shown in the sample calculation for our critical segment in the southbound, loaded direction:

$$Train\ Resistance = 152{,}896\ lbs\ \div 4\ locomotives = 38{,}224\frac{lbs}{locomotive}$$

$$\frac{FV}{308} = P\ (hp)$$

$$38{,}224 * 30\ mph\ \div 308 = 3723\frac{horsepower}{locomotive}$$

Next, we must determine the throttle notch required on each locomotive to achieve the required power output. Use the rated power of 4,400 hp and the required power for each segment to find the notch number, round up any decimals as half notches are not possible. Tractive effort provided under a given notch “n” is also limited by adhesion. This limit is found by multiplying the adhesion limit by (n/8) and was not a factor in any calculations. See the sample calculation below from the same critical segment:

$$P_n = P\left(\frac{n^2}{64}\right) \rightarrow n = \sqrt{\frac{P_n}{P} * 64}$$

$$n = \sqrt{\frac{3723}{4400} * 64} = 7.36 = 8$$

After, we must find the required time to travel the segment in hours, found by dividing length of segment by maximum speed, to calculate horsepower-hours required to traverse the segment. These values are divided by fuel efficiency for a given notch (shown in the table below) to find the gallons of fuel consumed during the traversal of a given segment.

Notch "n"	1	2	3	4	5	6	7	8
hp-hr/gallon	11.2	12.5	18.4	19.2	21.4	22.9	24.1	21.4

Fuel Efficiencies per Notch

These steps were conducted for both the southbound, loaded direction and the northbound, empty direction to create the figures below. Segments that yielded a negative traction demand were assumed to require a negligible fuel consumption and ignored.

Begin STA	End STA	Power per Locomotive (hp/loco)	Required Throttle Notch	Time to Travel Segment (hr)	Hp-hrs required to Travel Seqment	Fuel Consumed to Travel Segment (gal)
55+00.00	60+26.95	3,723.1	8	0.003	14.64	0.684
60+26.95	90+00.00	3,355.4	7	0.019	63.23	2.624
250+64.18	265+00.00	352.4	3	0.009	5.61	0.305
265+00.00	281+14.18	1,424.9	5	0.010	17.51	0.818
281+14.18	354+66.40	1,057.2	4	0.046	51.06	2.659
354+66.40	372+62.30	1,670.0	5	0.011	19.49	0.911
372+62.30	381+74.22	669.6	4	0.009	9.50	0.495

Table 15: Fuel Consumption of Southbound, Loaded Direction

Begin STA	End STA	Power per Locomotive (hp/loco)	Required Throttle Notch	Time to Travel Segment (hr)	Hp-hrs required to Travel Seqment	Fuel Consumed to Travel Segment (gal)
0+00.00	6+29.19	3.5	1	0.006	0.41	0.037
6+29.19	30+00.00	119.4	2	0.015	4.12	0.329
55+00.00	60+26.95	868.4	4	0.003	3.66	0.191
60+26.95	90+00.00	794.8	4	0.019	20.65	1.075
175+00.00	250+64.18	119.4	2	0.048	13.13	1.051
250+64.18	265+00.00	193.1	2	0.009	2.49	0.199
265+00.00	281+14.18	408.0	3	0.010	6.31	0.343
281+14.18	354+66.40	334.3	3	0.046	28.72	1.561
354+66.40	372+62.30	457.1	3	0.011	7.02	0.381
372+62.30	381+74.22	195.8	2	0.009	2.37	0.190

Table 16: Fuel Consumption of Northbound, Empty Direction

The total fuel consumed, and time required to complete a full round trip was found and summarized below. Times and fuel required to accelerate, brake, and load/unload the cars were ignored. It was found that to complete a round trip, it would require 13.9 gallons of fuel and will take 0.49 hours, or roughly 30 minutes.

	Time (hrs)	Fuel Consumed (gal)
Southbound	0.246	8.495
Northbound	0.246	5.357
TOTAL	**0.492**	**13.852**

Table 17: Time and Fuel Consumption Summaries

Assuming this round trip is completed once a day, six days a week for a full year, the annual diesel fuel consumption on this alignment would be **4,321.8 gallons/year**. Taking the previously found value of 1.13 million revenue ton-miles per year gained by operating this service (7.2 miles, 44 cars of 114.35 tons for 312 days a year), we can find that roughly **2,615 revenue ton-miles are achieved per gallon of fuel** while operating this service.

5.5 Train Acceleration

An incremental time-based approach with step size of 5 seconds was used to find the time and distance required to get the train up to 30 mph using the following steps. Starting at a time of 0 seconds, resistance generated by the 4 locomotives was found by the sum of grade, curve, and rolling/aerodynamic (Modified Davis Equation) resistances using the same equations outlined before. The resistance generated by the 44 hopper cars was found using the same methodology. Tractive effort was calculated using the same equations as before with the assumption that notch 8 was used the entire time, and accelerating force was found by subtracting the resistances from the drawbar pull. The following equations were used to find the incremental gain in speed and distance over the 5 seconds of assumed continuous accelerating force:

$$1 = \frac{95.6\,(V_2 - V_1)W}{F_{a1}}$$

$$S_2 = \frac{70\,(V_2^2 - V_1^2)W}{F_{a1}}$$

As the time increments increased and the train (under a point mass assumption) traveled down the proposed alignment, the grade and curve values changed to reflect the sections defined in Section 5.1 of this document. A full table of the calculations including every time step can be found in the Appendix. It was found that it would take the train 865 seconds and 4093.22 feet to reach 30 mph, or in other words, **14 minutes and 25 seconds to reach 30 mph, traveling to STA 40+93.22 in the process.**

In the original calculation of fuel consumption, it was assumed that the train travels at full speed from the instant it starts its journey from STA 00+00. Under these conditions, the train would reach STA 40+93.22 after 100 seconds or **1 minute 40 seconds.** This is a significant decrease in expected travel time given that the total time to travel the was roughly 30 minutes. Including acceleration time to the estimate would increase the time to travel by **12 minutes 45 seconds.** Looking at fuel consumed from the same previous estimations, it was said that fuel consumed during times of negative traction demand (times of braking) would be negligible. Since the entire span from STA 00+00 to STA 40+93 has a negative traction demand (see section 5.2), there was assumed to be no fuel consumed during this time of acceleration. We can calculate how much fuel would be consumed during our time of acceleration by converting the 865 seconds at 4400 horsepower (constant notch 8) to horsepower-hours and dividing by the fuel efficiency at this notch (21.4 hp-hr/gal) to find that it requires **1057 horsepower-hours or 49 gallons of fuel** to accelerate from 0 to 30 mph on this alignment. Comparing that to the 13.8 calculated gallons required to traverse the entire segment, this is quite shocking. Both the additional time and fuel required to accelerate the train are substantial and should not be considered negligible.

Appendix A : Horizontal Geometry for Alternative S and L

Span	Curve Number	Degree of Curve	Deflection Angle	TS STA	SC STA	CS STA	ST STA	I (deg)	D (deg)	T	PI -PI	PT - PC	Curve Length	Newbase STA (PT)	PC STA	E	Radius	Super-elevation	Max Speed	Spiral Length
L & S	POB	-	-	0+00.00	-	-	-										-	-	-	-
L & S	C-1	3°	112°00'00"	6+29.19	6+79.19	43+62.52	44+12.52	112.000	3.000	2831.81	3486.00	654.19	3733.33	4387.52	654.19	1505.70	1910.08	1	30	50
L & S	C-2	3°	22°00'00"	52+43.62	52+93.62	59+76.95	60+26.95	22.000	3.000	371.28	4084.19	881.10	733.33	6001.95	5268.62	35.75	1910.08	1	30	50
S	C-3S	5°	48°00'00"	116+59.32	117+59.32	126+19.32	127+19.32	48.000	5.000	510.36	6589.00	5707.36	960.00	12669.32	11709.32	108.48	1146.28	2.25	20	100
S	C-4S	3°	48°00'00"	131+57.41	132+07.41	147+57.41	148+07.41	48.000	3.000	850.42	1873.87	513.09	1600.00	14782.41	13182.41	180.76	1910.08	1	30	50
S	C-5S	3°	84°47'42"	238+88.00	239+38.00	267+14.50	267+64.50	84.795	3.000	1743.99	11725.01	9130.60	2826.50	26739.50	23913.00	676.41	1910.08	1	30	50
S	POE	-	-								2651.72	907.73		27647.23		0.00	-	-	-	-
L	C-3L	3°	47°00'00"	113+64.15	114+14.15	129+30.81	129+80.81	47.000	3.000	830.53	6589	5387.19	1566.67	12955.81	11389.15	172.75	1910.08	1	30	50
L	C-4L	3°	43°00'00"	152+87.79	153+37.79	167+21.12	167+71.12	43.000	3.000	752.40	3939.90	2356.97	1433.33	16746.12	15312.79	142.85	1910.08	1	30	50
L	C-5L	3°	90°00'00"	250+64.18	251+14.18	280+64.18	281+14.18	90.000	3.000	1910.08	11005.54	8343.06	3000.00	28089.18	25089.18	791.18	1910.08	1	30	50
L	C-6L	5°	84°47'42"	354+66.40	355+66.40	371+62.30	372+62.30	84.795	5.000	1046.61	10383.91	7427.22	1695.90	37212.30	35516.40	405.93	1146.28	2.25	20	100
L	POE	-	-		-	-	-				1637.24	590.63		37802.94			-	-	-	-

	turnout length										TS from PI	ST from PI	reverse dist							
	No. 11	93.31					267+64.50	30409.79		1	629.189945	2856.81005	831.098004							
	reverse curve T						5.069034943			2	3687.90806	396.281941	5632.36132							
	<39 mph	150					41125.78			3	6028.64326	560.356737	438.090855							
							7.788973485			4	998.447593	875.422407	9080.5977							
				TRUE	831.10					5	9956.02011	1768.98989		882.730111						
				TRUE	5632.36															
				TRUE	438.09					3	5733.47358	855.526421	2306.97306							
				TRUE	9080.60					4	3162.49948	777.400521	8293.05948							
										5	9070.46	1935.08	7352.22424							
				TRUE	5337.19					6	9287.30424	1096.60576		540.63424						
				TRUE	2306.97															
				TRUE	8293.06															
				TRUE	7352.22															

Appendix B: Vertical Geometry for Alternative S

Span	Type	Stationing	Contour Elevation	Projected Ground Elevation	CONSTRAINT (FROM BELOW)	CONSTRAINT (FROM TOP) - 23' Clearance	Ground Elevation + 4.5 feet for drainage	Comment	Grade	Vertical Sections	Length of curve in 100'
L & S	500 FEET STATION	0	NA	346.25			350.75			350.75	
L & S	500 FEET STATION	500	NA	345.2083333			349.708333		-0.22	349.65	
L & S	500 FEET STATION	1000	NA	344.1666667			348.666667		-0.22	348.55	
L & S	500 FEET STATION	1500	NA	343.125			347.625		-0.22	347.45	
L & S	500 FEET STATION	2000	NA	342.0833333			346.583333		-0.22	346.35	
L & S	500 FEET STATION	2500	NA	341.0416667			345.541667		-0.22	345.25	
L & S	500 FEET STATION	3000	NA	340			344.5		-1	340.25	5.20833333
L & S	GRADE XING	3181	336.5	336.5	323.6	346.6	341	Should be between 323.6 to 346.6	-1	338.442868	
L & S	500 FEET STATION	3500	NA	332.3492719			336.849272		-1	335.25	
L & S	500 FEET STATION	4000	NA	324.8914116			329.391412		-1	330.25	

L & S	500 FEET STATION	4500	NA	319.8617041			324.361704		-1	325.25	
L & S	500 FEET STATION	5000	NA	316.2906672			320.790667		-1	320.25	
L & S	500 FEET STATION	5500	NA	316.664686			321.164686		1	325.25	16.6666667
L & S	500 FEET STATION	6000	NA	319.2715682			323.771568		1	330.25	
L & S	500 FEET STATION	6500	NA	323.6028678			328.102868		1	335.25	
L & S	500 FEET STATION	7000	NA	328.6028678			333.102868		1	340.25	
L & S	500 FEET STATION	7500	NA	336.7818687			341.281869		1	345.25	
L & S	500 FEET STATION	8000	NA	342.1935785			346.693579		1	350.25	
S	500 FEET STATION	8500	NA	344.7741806			349.274181		1	355.25	
S	500 FEET STATION	9000	NA	343.3456092			347.845609		-0.85	351	9.25
S	500 FEET STATION	9500	NA	341.9170378			346.417038		-0.85	346.75	
S	500 FEET STATION	10000	NA	340.4884664			344.988466		-0.85	342.5	
S	500 FEET STATION	10500	NA	338.3548161			342.854816		-0.85	338.25	
L & S	GRADE XING	10671	337.5	337.5	327.5	347.5	342	Should be between 327.5 - 347.5	-0.85	336.796813	

L & S	500 FEET STATION	11000	NA	333.5515587			338.051559		-0.85	334	
L & S	500 FEET STATION	11500	NA	327.7160558			332.216056		-0.85	329.75	
S	500 FEET STATION	12000	NA	322.1191623			326.619162		-0.85	325.5	
S	500 FEET STATION	12500	NA	318.3157499			322.81575		-0.85	321.25	
S	500 FEET STATION	13000	NA	315.6051987			320.105199		-0.85	317	
S	500 FEET STATION	13500	NA	312.8946475			317.394647		-0.85	312.75	
S	500 FEET STATION	14000	NA	310.1840963			314.684096		-0.85	308.5	
S	500 FEET STATION	14500	NA	305.9405002			310.4405		-0.85	304.25	
S	500 FEET STATION	15000	NA	301.5851951			306.085195		-0.85	300	
S	500 FEET STATION	15500	NA	296.8198439			301.319844		-0.85	295.75	
S	500 FEET STATION	16000	NA	291.8198439			296.319844		-0.85	291.5	
S	500 FEET STATION	16500	NA	286.3655358			290.865536		-0.85	287.25	
S	500 FEET STATION	17000	NA	280.6512501			285.15125		-0.85	283	
S	500 FEET STATION	17500	NA	271.1396877			275.639688		-0.85	278.75	
S	500 FEET STATION	18000	NA	258.1862503			262.68625		-0.85	274.5	

S	500 FEET STATION	18500	NA	242.2793754	260		246.779375	Should be above 260	-0.85	270.25	
S	500 FEET STATION	19000	NA	242.7206246	260		247.220625	Should be above 260	0.75	274	31.25
S	500 FEET STATION	19500	NA	258.4804164			262.980416		0.75	277.75	
S	500 FEET STATION	20000	NA	276.5988244			281.098824		0.75	281.5	
S	500 FEET STATION	20500	NA	282.9128408			287.412841		0.75	285.25	
S	500 FEET STATION	21000	NA	286.5492045			291.049204		0.75	289	
S	500 FEET STATION	21500	NA	290.2268055			294.726805		0.75	292.75	
S	500 FEET STATION	22000	NA	294.6712499			299.17125		0.75	296.5	
S	500 FEET STATION	22500	NA	299.1156943			303.615694		0.75	300.25	
S	500 FEET STATION	23000	NA	303.5601388			308.060139		0.75	304	
S	OVERBRIDGE	23287		306.1111111		295.5	310.611111	Should be below 295.5	0.75	306.152383	
S	500 FEET STATION	23500	NA	308.0045832			312.504583		0.75	307.75	
S	500 FEET STATION	24000	NA	311.9735648			316.473565		0.75	311.5	
S	500 FEET STATION	24500	NA	315.5551492			320.055149		0.75	315.25	
S	500 FEET STATION	25000	NA	319.1367335			323.636734		0.75	319	
S	500 FEET STATION	25500	NA	321.011961			325.511961		0.75	322.75	
S	500 FEET STATION	26000	NA	322.3452944			326.845294		0.75	326.5	
S	500 FEET STATION	26500	NA	323.6786277			328.178628		0.75	330.25	
S	500 FEET STATION	27000	NA	325.0051755			329.505175		0.75	334	
S	500 FEET STATION	27500	NA	325.5820985			330.082099		0.75	337.75	

S	TIE-IN B	27646	325.75	325.75			330.25		0.75	329.330098	

Appendix C: Vertical Geometry for Alternative L

Span	Type	Stationing	Contour Elevation	Projected Ground Elevation	CONSTRAINT (FROM BELOW)	CONSTRAINT (FROM TOP) - 23' Clearance	Ground Elevation + 4.5 feet for drainage	Comment	Grade	Vertical Sections	Length of curve in 100'
L & S	500 FEET STATION	0	NA	346.25						350.75	
L & S	500 FEET STATION	500	NA	345.2083333			350.75		-0.22	349.65	
L & S	500 FEET STATION	1000	NA	344.1666667			349.708333		-0.22	348.55	
L & S	500 FEET STATION	1500	NA	343.125			348.666667		-0.22	347.45	
L & S	500 FEET STATION	2000	NA	342.0833333			347.625		-0.22	346.35	
L & S	500 FEET STATION	2500	NA	341.0416667			346.583333		-0.22	345.25	
L & S	500 FEET STATION	3000	NA	340			345.541667		-1	340.25	3.9
L & S	GRADE XING	3181	336.5	336.5	323.6	346.6	341	Should be between 323.6 to 346.6	-1	338.442868	
L & S	500 FEET STATION	3500	NA	332.3492719			344.5		-1	335.25	
L & S	500 FEET STATION	4000	NA	324.8914116			336.849272		-1	330.25	

L & S	500 FEET STATION	4500	NA	318.8897899			329.391412		-1	325.25	
L & S	500 FEET STATION	5000	NA	316.032647			323.38979		-1	320.25	
L & S	500 FEET STATION	5500	NA	316.664686			320.532647		-1	315.25	16.6666667
L & S	500 FEET STATION	6000	NA	319.2715682			321.164686		1	320.25	
L & S	500 FEET STATION	6500	NA	323.6028678			323.771568		1	325.25	
L & S	500 FEET STATION	7000	NA	328.6028678			328.102868		1	330.25	
L & S	500 FEET STATION	7500	NA	336.7818687			333.102868		1	335.25	
L & S	500 FEET STATION	8000	NA	342.1935785			341.281869		1	340.25	
L	500 FEET STATION	8500	NA	344.7741806			346.693579		1	345.25	
L	500 FEET STATION	9000	NA	343.3456092			349.274181		1	350.25	8.85
L	500 FEET STATION	9500	NA	341.9170378			347.845609		-0.77	346.4	
L	500 FEET STATION	10000	NA	340.4884664			346.417038		-0.77	342.55	
L	500 FEET STATION	10500	NA	338.3548161			344.988466		-0.77	338.7	
L & S	GRADE XING	10671	337.5	337.5	327.5	347.5	342	Should be between 327.5 - 347.5	-0.77	337.383583	
L	500 FEET STATION	11000	NA	333.5515587			342.854816		-0.77	334.85	

L	500 FEET STATION	11500	NA	328.4608029			338.051559		-0.77	331	
L	500 FEET STATION	12000	NA	324.6889408			332.960803		-0.77	327.15	
L	500 FEET STATION	12500	NA	320.9170788			329.188941		-0.77	323.3	
L	500 FEET STATION	13000	NA	317.773932			325.417079		-0.77	319.45	
L	500 FEET STATION	13500	NA	314.8327555			322.273932		-0.77	315.6	
L	500 FEET STATION	14000	NA	311.8915791			319.332756		-0.77	311.75	
L	500 FEET STATION	14500	NA	307.6209125			316.391579		-0.77	307.9	
L	500 FEET STATION	15000	NA	300.9542459			312.120913		-0.77	304.05	
L	500 FEET STATION	15500	NA	296.1917195			305.454246		-0.77	300.2	
L	500 FEET STATION	16000	NA	291.747275			300.691719		-0.77	296.35	
L	500 FEET STATION	16500	NA	286.641347			296.247275		-0.77	292.5	
L	500 FEET STATION	17000	NA	281.1068979			291.141347		-0.77	288.65	
L	500 FEET STATION	17500	NA	282.1344678			285.606898		-0.1	288.15	5.58333333
L	500 FEET STATION	18000	NA	284.8025575			286.634468		-0.1	287.65	
L	500 FEET STATION	18500	NA	284.0252647			289.302557		-0.1	287.15	
L	500 FEET STATION	19000	NA	282.9726331			288.525265		-0.1	286.65	
L	500 FEET STATION	19500	NA	281.9200015			287.472633		-0.1	286.15	

L	500 FEET STATION	20000	NA	280.86737			286.420002		-0.1	285.65	
L	500 FEET STATION	20500	NA	279.8147384			285.36737		-0.1	285.15	
L	500 FEET STATION	21000	NA	278.7621068			284.314738		-0.1	284.65	
L	500 FEET STATION	21500	NA	277.7094752			283.262107		-0.1	284.15	
L	500 FEET STATION	22000	NA	276.6568436			282.209475		-0.1	283.65	
L	500 FEET STATION	22500	NA	275.6042121			281.156844		-0.1	283.15	
L	500 FEET STATION	23000	NA	274.5515805			280.104212		-0.1	282.65	
L	500 FEET STATION	23500	NA	273.4989489			279.05158		-0.1	282.15	
L	500 FEET STATION	24000	NA	272.4463173			277.998949		-0.1	281.65	
L	500 FEET STATION	24500	NA	271.3936858			276.946317		-0.1	281.15	
L	500 FEET STATION	25000	NA	270.3410542			275.893686		-0.1	280.65	
L	500 FEET STATION	25500	NA	271.5905848			274.841054		-0.1	280.15	
L	500 FEET STATION	26000	NA	273.943526			276.090585		-0.1	279.65	
L	500 FEET STATION	26500	NA	276.2964671			278.443526		0.25	280.9	2.91666667
L	500 FEET STATION	27000	NA	278.6494083			280.796467		0.25	282.15	
L	500 FEET STATION	27500	NA	284.1089407			283.149408		0.25	283.4	
L	500 FEET STATION	28000	NA	288.802343			288.608941		0.25	284.65	
L	500 FEET STATION	28500	NA	285.7254199			293.302343		0.25	285.9	
L	500 FEET STATION	29000	NA	282.6484968			290.22542		0.25	287.15	
L	500 FEET STATION	29500	NA	280.8354312			287.148497		0.25	288.4	
L	GRADE XING	29875	284.5	284.5	274.5	294.5	289	Should be between 274.5 - 294.5	0.25	289.3375	

L	500 FEET STATION	30000	NA	284.8425299			285.335431		0.25	289.65	
L	500 FEET STATION	30500	NA	285.7225299			289.34253		0.25	290.9	
L	500 FEET STATION	31000	NA	286.6025299			290.22253		0.25	292.15	
L	500 FEET STATION	31500	NA	287.4825299			291.10253		0.25	293.4	
L	500 FEET STATION	32000	NA	288.3625299			291.98253		0.25	294.65	
L	500 FEET STATION	32500	NA	289.2425299			292.86253		0.25	295.9	
L	500 FEET STATION	33000	NA	290.5813718			293.74253		0.25	297.15	
L	500 FEET STATION	33500	NA	294.7567371			295.081372		0.25	298.4	
L	500 FEET STATION	34000	NA	298.9321025			299.256737		0.25	299.65	
L	500 FEET STATION	34500	NA	300			303.432102		0.25	300.9	
L	500 FEET STATION	35000	NA	298.8076146			304.5		0.25	302.15	
L	500 FEET STATION	35500	NA	290			303.307615		0.25	303.4	
L	500 FEET STATION	36000	NA	290			294.5		0.25	304.65	
L	500 FEET STATION	36500	NA	290			294.5		0.25	305.9	
L	500 FEET STATION	37000	NA	290			294.5		0.25	307.15	
L	500 FEET STATION	37500	NA	292.8211017			294.5		0.25	308.4	
L	500 FEET STATION	38000	NA	299.4427599			297.321102		0.25	309.65	
L	TIE-IN B	38174	301.75	301.75			303.94276		0.25	310.085548	

Appendix D: Earthwork Calculations for Alternative S

Span	Stationing	Cut Volume (yd^3)	Fill Volume (yd^3)
L & S	0	276	688
L & S	500	300	653
L & S	1000	325	618
L & S	1500	350	583
L & S	2000	376	548
L & S	2500	2472	265
L & S	3000	1258	0
L & S	3181	1177	0
L & S	3500	641	629
L & S	4000	0	1268
L & S	4500	253	832
L & S	5000	253	2104
L & S	5500	0	5020
L & S	6000	0	6593
L & S	6500	0	6966
L & S	7000	0	5340
L & S	7500	0	3531
L & S	8000	0	4514
S	8500	0	4341
S	9000	68	1958
S	9500	1229	457
S	10000	3678	0
S	10500	1862	0
L & S	10671	3341	0
L & S	11000	3294	0

L & S	11500	1554	34
S	12000	1028	34
S	12500	2161	0
S	13000	4083	0
S	13500	6180	0
S	14000	7278	0
S	14500	7205	0
S	15000	6754	0
S	15500	5854	0
S	16000	4526	0
S	16500	2822	0
S	17000	960	1483
S	17500	0	8030
S	18000	0	24273
S	18500	0	39542
S	19000	0	30721
S	19500	56	9384
S	20000	1023	479
S	20500	1867	0
S	21000	1758	0
S	21500	2129	0
S	22000	2974	0
S	22500	3855	0
S	23000	2623	0
S	23287	2146	0
S	23500	5389	0
S	24000	5423	0
S	24500	5192	0
S	25000	3865	0
S	25500	1533	250

S	26000	207	1315
S	26500	0	3166
S	27000	0	5885
S	27500	102	1127
S	27646	0	0
TOTAL CUT & FILL VOLUMES		111699	189894
EXTRA MATERIAL REQ FOR CONSTRUCTION			78195

Appendix E: Earthwork Calculations for Alternative L

Span	Stationing	Cut Volume (yd^3)	Fill Volume (yd^3)
L & S	0	276	688
L & S	500	300	653
L & S	1000	325	618
L & S	1500	350	583
L & S	2000	376	548
L & S	2500	2472	265
L & S	3000	1258	0
L & S	3181	1177	0
L & S	3500	641	629
L & S	4000	0	1615
L & S	4500	192	1254
L & S	5000	3631	268
L & S	5500	5241	0
L & S	6000	3184	0
L & S	6500	2765	0
L & S	7000	4907	0
L & S	7500	7354	0
L & S	8000	5957	0
L	8500	2128	1195
L	9000	135	1543
L	9500	1266	348
L	10000	3345	0
L	10500	1620	0
L & S	10671	2714	0
L	11000	2448	0
L	11500	1743	0

L	12000	1834	0
L	12500	2305	0
L	13000	3303	0
L	13500	4480	0
L	14000	4800	0
L	14500	2789	0
L	15000	772	207
L	15500	352	592
L	16000	111	1187
L	16500	0	2257
L	17000	0	2313
L	17500	671	859
L	18000	1185	0
L	18500	839	114
L	19000	514	386
L	19500	267	713
L	20000	77	1062
L	20500	0	1434
L	21000	0	1828
L	21500	0	2246
L	22000	0	2685
L	22500	0	3148
L	23000	0	3633
L	23500	0	4140
L	24000	0	4671
L	24500	0	5224
L	25000	0	4651
L	25500	0	2647
L	26000	111	1133
L	26500	484	451

L	27000	3307	66
L	27500	8506	0
L	28000	7900	0
L	28500	2460	353
L	29000	132	1817
L	29500	51	1441
L	29875	35	227
L	30000	84	1017
L	30500	11	1262
L	31000	0	1517
L	31500	0	1782
L	32000	0	2057
L	32500	0	2163
L	33000	334	1169
L	33500	2304	105
L	34000	3822	0
L	34500	2270	24
L	35000	417	4563
L	35500	0	9902
L	36000	0	11605
L	36500	0	13425
L	37000	0	13193
L	37500	0	8711
L	38000	0	1567
L	38174	0	0
TOTAL CUT & FILL VOLUMES		112333	149327
EXTRA MATERIAL REQ FOR CONSTRUCTION			36995

Appendix F: Operating Cost for Alternative S

Item	Quantity	Units	Source
Gross Railcar Load	286000	lb/car	Project Spec
Empty Tare Weight	57300	lb/car	Project Spec
Number of Cars	44	cars	Project Spec
Operating Days	6	days/week	Project Spec
Operating Weeks	52	weeks/year	Project Spec
	0.007553	MGT/day	Calculation
	2.356411	MGT/year	Calculation
Hypothetical Length	4	miles	Project Spec
Alt S Length	5.75943	miles	Geometry
delta d	1.75943	miles	Calculation
Hypothetical MGTM	**9.425645**	MGTM	Calculation
FROM A1.a	13512.47		A1.a
Annual operating cost straight-line	**0.127364**	$M/year	Calculation
Distance Factor (1-10 miles)	37.11	%	Project Spec
ED	**0.02079**	$M/year	Calculation
Curve Resistance	0.8	lb/ton/deg of curve	Assummtion
Average Resistance	5	lb/ton	Assummtion
Equivalent curve	6.25	degrees	Calculation
Equivalent central angle	330	degrees	Calculation
Sum of central angles	314.795	degrees	Geometry
Equivalent curve miles	**0.953924**	miles	Calculation
Curve Factor	25.59	%	Project Spec
EC	**0.007773**	$M/year	Calculation
Grade Resistance	20	lb/ton/% grade	Assummtion
Equivalent grade	0.25	% grade	Calculation

Equivalent grade mile	13.2	feet	Calculation
Rise and Fall	239.32	feet	Geometry
Equivalent grade miles	**18.1303**	miles	Calculation
Grade Factor (Class C)	19.09	%	Project Spec
ER&F	**0.110204**		Calculation
Additional operating cost	0.138766	$M/year	Calculation
Annual operating cost Route S	**0.26613**	$M/year	Calculation

Appendix G: Operating Cost for Alternative L

Item	Quantity	Units	Source
Gross Railcar Load	286000	lb/car	Project Spec
Empty Tare Weight	57300	lb/car	Project Spec
Number of Cars	44	cars	Project Spec
Operating Days	6	days/week	Project Spec
Operating Weeks	52	weeks/year	Project Spec
	0.007553	MGT/day	Calculation
	2.356411	MGT/year	Calculation
Hypothetical Length	4	miles	Project Spec
Alt S Length	9.03689	miles	Geometry
delta d	5.03689	miles	Calculation
Hypothetical MGTM	**9.425645**	MGTM	Calculation
FROM A1.a	13512.47		A1.a
Annual operating cost straight-line	**0.127364**	$M/year	Calculation
Distance Factor (1-10 miles)	37.11	%	Project Spec
ED	**0.059517**	$M/year	Calculation
Curve Resistance	0.8	lb/ton/deg of curve	Assummtion
Average Resistance	5	lb/ton	Assummtion
Equivalent curve	6.25	degrees	Calculation
Equivalent central angle	330	degrees	Calculation
Sum of central angles	398.795	degrees	Geometry
Equivalent curve miles	**1.20847**	miles	Calculation
Curve Factor	25.59	%	Project Spec
EC	**0.009847**	$M/year	Calculation
Grade Resistance	20	lb/ton/% grade	Assummtion
Equivalent grade	0.25	% grade	Calculation

Equivalent grade mile	13.2	feet	Calculation
Rise and Fall	188.79	feet	Geometry
Equivalent grade miles	**14.30227**	miles	Calculation
Grade Factor (Class C)	19.09	%	Project Spec
ER&F	**0.086935**		Calculation
Additional operating cost	0.156299	$M/year	Calculation
Annual operating cost Route L	**0.283663**	$M/year	Calculation

Appendix H: Acceleration from STA 00+00 (Alternative L)

Time (s)	Position (ft)	Speed (mph)	Tractive Effort (lbs)	Grade	Curve	Loco Resistance (lbs)	Car Resistance (lbs)	Drawbar Pull (lbs)	Accel Force (lbs)
0	0.00	0.00	141570	-0.22	0	-3140	-20390	144710	165100
5	0.18	0.24	141570	-0.22	0	-3138	-20374	144708	165083
10	0.71	0.48	141570	-0.22	0	-3136	-20359	144706	165065
15	1.59	0.72	141570	-0.22	0	-3134	-20344	144704	165048
20	2.83	0.97	141570	-0.22	0	-3132	-20329	144702	165031
25	4.42	1.21	141570	-0.22	0	-3130	-20314	144700	165013
30	6.37	1.45	141570	-0.22	0	-3128	-20298	144698	164996
35	8.66	1.69	141570	-0.22	0	-3126	-20283	144696	164979
40	11.32	1.93	141570	-0.22	0	-3124	-20268	144694	164961
45	14.32	2.17	141570	-0.22	0	-3121	-20253	144691	164944
50	17.68	2.41	141570	-0.22	0	-3119	-20237	144689	164927
55	21.39	2.66	141570	-0.22	0	-3117	-20222	144687	164909
60	25.46	2.90	141570	-0.22	0	-3115	-20207	144685	164892
65	29.88	3.14	141570	-0.22	0	-3113	-20191	144683	164874
70	34.65	3.38	141570	-0.22	0	-3111	-20176	144681	164857
75	39.77	3.62	141570	-0.22	0	-3108	-20161	144678	164839
80	45.25	3.86	141570	-0.22	0	-3106	-20146	144676	164822
85	51.08	4.10	141570	-0.22	0	-3104	-20130	144674	164804
90	57.27	4.34	141570	-0.22	0	-3102	-20115	144672	164787
95	63.81	4.58	141570	-0.22	0	-3100	-20100	144670	164769
100	70.70	4.83	141570	-0.22	0	-3097	-20084	144667	164752
105	77.94	5.07	141570	-0.22	0	-3095	-20069	144665	164734
110	85.54	5.31	141570	-0.22	0	-3093	-20054	144663	164717
115	93.49	5.55	141570	-0.22	0	-3091	-20038	144661	164699
120	101.79	5.79	141570	-0.22	0	-3088	-20023	144658	164681
125	110.44	6.03	141570	-0.22	0	-3086	-20008	144656	164664
130	119.45	6.27	141570	-0.22	0	-3084	-19992	144654	164646
135	128.81	6.51	141570	-0.22	0	-3082	-19977	144652	164628
140	138.53	6.75	141570	-0.22	0	-3079	-19961	144649	164611
145	148.59	6.99	141570	-0.22	0	-3077	-19946	144647	164593
150	159.01	7.24	141570	-0.22	0	-3075	-19931	144645	164575
155	169.78	7.48	141570	-0.22	0	-3072	-19915	144642	164558
160	180.91	7.72	141570	-0.22	0	-3070	-19900	144640	164540
165	192.38	7.96	141570	-0.22	0	-3068	-19884	144638	164522
170	204.21	8.20	141570	-0.22	0	-3065	-19869	144635	164504
175	216.40	8.44	141570	-0.22	0	-3063	-19854	144633	164487
180	228.93	8.68	141570	-0.22	0	-3061	-19838	144631	164469
185	241.82	8.92	141570	-0.22	0	-3058	-19823	144628	164451
190	255.05	9.16	141570	-0.22	0	-3056	-19807	144626	164433
195	268.65	9.40	141570	-0.22	0	-3054	-19792	144624	164415
200	282.59	9.64	140558.42	-0.22	0	-3051	-19776	143610	163386
205	296.88	9.88	137158.05	-0.22	0	-3049	-19761	140207	159968
210	311.52	10.11	133984.53	-0.22	0	-3046	-19746	137031	156777
215	326.50	10.34	131013.64	-0.22	0	-3044	-19731	134058	153789
220	341.82	10.57	128224.65	-0.22	0	-3042	-19717	131267	150983
225	357.46	10.79	125599.7	-0.22	0	-3040	-19703	128639	148342
230	373.42	11.01	123123.27	-0.22	0	-3037	-19689	126161	145849
235	389.69	11.22	120781.86	-0.22	0	-3035	-19675	123817	143492
240	406.28	11.43	118563.59	-0.22	0	-3033	-19661	121597	141258
245	423.17	11.64	116458.04	-0.22	0	-3031	-19648	119489	139137

250	440.36	11.84	114455.95	-0.22	0	-3029	-19635	117485	137120
255	457.84	12.04	112549.11	-0.22	0	-3027	-19622	115576	135198
260	475.62	12.24	110730.2	-0.22	0	-3025	-19609	113755	133364
265	493.69	12.43	108992.66	-0.22	0	-3023	-19596	112016	131612
270	512.04	12.63	107330.59	-0.22	0	-3021	-19584	110352	129935
275	530.67	12.82	105738.69	-0.22	0	-3019	-19572	108758	128329
280	549.57	13.00	104212.14	-0.22	0	-3017	-19560	107229	126789
285	568.75	13.19	102746.59	-0.22	0	-3015	-19548	105762	125309
290	588.20	13.37	101338.1	-0.22	0	-3013	-19536	104351	123887
295	607.92	13.55	99983.042	-0.22	0	-3011	-19524	102994	122518
300	627.90	13.73	98678.132	-0.22	0	-3009	-19512	101687	121200
305	648.14	13.91	97420.351	-0.22	3	-948	-4400	98369	102769
310	668.62	14.06	96378.696	-0.22	3	-947	-4390	97325	101716
315	689.32	14.21	95369.418	-0.22	3	-945	-4381	96315	100695
320	710.24	14.36	94390.874	-0.22	3	-944	-4371	95334	99705
325	731.37	14.50	93441.535	-0.22	3	-942	-4362	94384	98745
330	752.72	14.65	92519.974	-0.22	3	-941	-4352	93460	97813
335	774.27	14.79	91624.864	-0.22	3	-939	-4343	92564	96907
340	796.04	14.93	90754.963	-0.22	3	-937	-4334	91692	96026
345	818.01	15.07	89909.108	-0.22	3	-936	-4325	90845	95170
350	840.18	15.21	89086.212	-0.22	3	-934	-4315	90021	94336
355	862.56	15.35	88285.254	-0.22	3	-933	-4306	89218	93525
360	885.14	15.49	87505.278	-0.22	3	-932	-4298	88437	92734
365	907.92	15.62	86745.382	-0.22	3	-930	-4289	87675	91964
370	930.90	15.76	86004.72	-0.22	3	-929	-4280	86933	91213
375	954.07	15.89	85282.494	-0.22	3	-927	-4271	86210	90481
380	977.44	16.02	84577.952	-0.22	3	-926	-4263	85504	89766
385	1001.00	16.15	83890.384	-0.22	3	-924	-4254	84815	89069
390	1024.75	16.28	83219.12	-0.22	3	-923	-4246	84142	88388
395	1048.69	16.41	82563.525	-0.22	3	-922	-4237	83485	87722
400	1072.83	16.54	81922.999	-0.22	3	-920	-4229	82843	87072
405	1097.14	16.67	81296.975	-0.22	3	-919	-4220	82216	86436
410	1121.65	16.80	80684.914	-0.22	3	-917	-4212	81602	85814
415	1146.34	16.92	80086.304	-0.22	3	-916	-4204	81002	85206
420	1171.21	17.05	79500.66	-0.22	3	-915	-4196	80415	84611
425	1196.26	17.17	78927.522	-0.22	3	-913	-4188	79841	84029
430	1221.50	17.29	78366.45	-0.22	3	-912	-4180	79278	83458
435	1246.91	17.42	77817.028	-0.22	3	-911	-4172	78728	82899
440	1272.50	17.54	77278.859	-0.22	3	-909	-4164	78188	82352
445	1298.27	17.66	76751.563	-0.22	3	-908	-4156	77659	81815
450	1324.22	17.78	76234.779	-0.22	3	-907	-4148	77141	81290
455	1350.34	17.90	75728.165	-0.22	3	-905	-4140	76633	80774
460	1376.63	18.01	75231.39	-0.22	3	-904	-4133	76135	80268
465	1403.10	18.13	74744.141	-0.22	3	-903	-4125	75647	79772
470	1429.73	18.25	74266.117	-0.22	3	-901	-4117	75167	79285
475	1456.54	18.36	73797.031	-0.22	3	-900	-4110	74697	78807
480	1483.52	18.48	73336.609	-0.22	3	-899	-4102	74235	78338
485	1510.67	18.59	72884.588	-0.22	3	-897	-4095	73782	77877
490	1537.98	18.71	72440.714	-0.22	3	-896	-4087	73337	77424
495	1565.46	18.82	72004.748	-0.22	3	-895	-4080	72900	76979
500	1593.10	18.93	71576.457	-0.22	3	-894	-4072	72470	76543
505	1620.91	19.05	71155.62	-0.22	3	-892	-4065	72048	76113
510	1648.88	19.16	70742.021	-0.22	3	-891	-4058	71633	75691
515	1677.02	19.27	70335.458	-0.22	3	-890	-4050	71225	75276
520	1705.32	19.38	69935.733	-0.22	3	-889	-4043	70824	74868
525	1733.77	19.49	69542.656	-0.22	3	-887	-4036	70430	74466
530	1762.39	19.60	69156.046	-0.22	3	-886	-4029	70042	74071
535	1791.17	19.70	68775.728	-0.22	3	-885	-4022	69661	73682

540	1820.10	19.81	68401.533	-0.22	3	-884	-4015	69285	73300
545	1849.20	19.92	68033.299	-0.22	3	-883	-4008	68916	72923
550	1878.44	20.03	67670.869	-0.22	3	-881	-4001	68552	72553
555	1907.85	20.13	67314.094	-0.22	3	-880	-3994	68194	72188
560	1937.41	20.24	66962.827	-0.22	3	-879	-3987	67842	71828
565	1967.12	20.34	66616.93	-0.22	3	-878	-3980	67495	71474
570	1996.99	20.45	66276.266	-0.22	3	-876	-3973	67153	71126
575	2027.01	20.55	65940.705	-0.22	3	-875	-3966	66816	70782
580	2057.18	20.66	65610.122	-0.22	3	-874	-3959	66484	70444
585	2087.51	20.76	65284.395	-0.22	3	-873	-3953	66157	70110
590	2117.98	20.86	64963.406	-0.22	3	-872	-3946	65835	69781
595	2148.61	20.96	64647.042	-0.22	3	-871	-3939	65518	69457
600	2179.38	21.06	64335.194	-0.22	3	-869	-3932	65205	69137
605	2210.30	21.17	64027.754	-0.22	3	-868	-3926	64896	68822
610	2241.37	21.27	63724.621	-0.22	3	-867	-3919	64592	68511
615	2272.59	21.37	63425.695	-0.22	3	-866	-3912	64292	68204
620	2303.95	21.47	63130.88	-0.22	3	-865	-3906	63996	67902
625	2335.46	21.57	62840.082	-0.22	3	-864	-3899	63704	67603
630	2367.12	21.66	62553.212	-0.22	3	-862	-3893	63416	67308
635	2398.91	21.76	62270.182	-0.22	3	-861	-3886	63131	67018
640	2430.86	21.86	61990.908	-0.22	3	-860	-3880	62851	66731
645	2462.94	21.96	61715.307	-0.22	3	-859	-3873	62574	66448
650	2495.17	22.06	61443.3	-0.22	3	-858	-3867	62301	66168
655	2527.54	22.15	61174.809	-0.22	3	-857	-3861	62032	65892
660	2560.05	22.25	60909.76	-0.22	3	-856	-3854	61765	65620
665	2592.71	22.35	60648.081	-0.22	3	-855	-3848	61503	65350
670	2625.50	22.44	60389.699	-0.22	3	-853	-3842	61243	65085
675	2658.43	22.54	60134.547	-0.22	3	-852	-3835	60987	64822
680	2691.51	22.63	59882.559	-0.22	3	-851	-3829	60734	64563
685	2724.72	22.73	59633.67	-0.22	3	-850	-3823	60484	64307
690	2758.07	22.82	59387.816	-0.22	3	-849	-3817	60237	64053
695	2791.55	22.91	59144.938	-0.22	3	-848	-3810	59993	63803
700	2825.17	23.01	58904.975	-0.22	3	-847	-3804	59752	63556
705	2858.93	23.10	58667.869	-0.22	3	-846	-3798	59514	63312
710	2892.83	23.19	58433.566	-0.22	3	-845	-3792	59278	63070
715	2926.86	23.28	58202.01	-0.22	3	-843	-3786	59045	62831
720	2961.03	23.38	57973.148	-0.22	3	-842	-3780	58816	62595
725	2995.33	23.47	57746.929	-0.22	3	-841	-3774	58588	62362
730	3029.76	23.56	57523.302	-1	3	-14225	-101923	71748	173671
735	3064.45	23.81	56909.555	-1	3	-14222	-101906	71132	173038
740	3099.51	24.07	56310.936	-1	3	-14219	-101889	70530	172419
745	3134.93	24.32	55726.852	-1	3	-14216	-101872	69943	171815
750	3170.73	24.57	55156.743	-1	3	-14213	-101856	69370	171225
755	3206.90	24.82	54600.079	-1	3	-14210	-101839	68810	170649
760	3243.43	25.07	54056.357	-1	3	-14207	-101823	68263	170086
765	3280.32	25.32	53525.1	-1	3	-14204	-101806	67729	169535
770	3317.58	25.57	53005.853	-1	3	-14201	-101790	67207	168996
775	3355.20	25.81	52498.187	-1	3	-14198	-101773	66696	168469
780	3393.19	26.06	52001.692	-1	3	-14195	-101757	66197	167953
785	3431.53	26.31	51515.978	-1	3	-14192	-101740	65708	167448
790	3470.24	26.55	51040.674	-1	3	-14189	-101724	65230	166954
795	3509.30	26.80	50575.427	-1	3	-14186	-101708	64761	166469
800	3548.72	27.04	50119.898	-1	3	-14183	-101692	64303	165994
805	3588.49	27.28	49673.766	-1	3	-14180	-101675	63854	165529
810	3628.62	27.52	49236.725	-1	3	-14177	-101659	63414	165073
815	3669.11	27.77	48808.48	-1	3	-14174	-101643	62982	164625
820	3709.94	28.01	48388.751	-1	3	-14171	-101627	62560	164186
825	3751.13	28.25	47977.269	-1	3	-14168	-101611	62145	163756

830	3792.67	28.49	47573.779	-1	3	-14165	-101595	61739	163333
835	3834.56	28.73	47178.035	-1	3	-14162	-101579	61340	162919
840	3876.81	28.96	46789.8	-1	3	-14159	-101563	60949	162511
845	3919.39	29.20	46408.849	-1	3	-14156	-101547	60565	162112
850	3962.33	29.44	46034.967	-1	3	-14153	-101531	60188	161719
855	4005.62	29.68	45667.944	-1	3	-14150	-101515	59818	161333
860	4049.25	29.91	45307.583	-1	3	-14147	-101499	59454	160954
865	4093.22	30.15	44953.692	-1	3	-14144	-101484	59097	160581