APPENDIX J: TRAIN ENERGY CALCULATIONS

Calculations of train energy for the Pt. MacKenzie Rail Extension alternatives were prepared as an input to the evaluation matrix, presented in Chapter 5. The values obtained, in units of horsepower-hours, are approximations intended for comparison of the alternatives and not absolute values of energy consumption.

J.1 Assumptions for Calculations

The train energy calculations were based on the following basic assumptions:

- A design train of 100 cars, each weighing 125 tons. This results in a design train weight of 12,500 tons. It was assumed that the weight of the locomotives would be balanced by a fewer number of cars or lighter loadings in certain cars.
- Resistance forces considered were internal train resistance, grade resistance, and curvature resistance.
- Atmospheric resistance and wind were not considered.
- The resistance of the entire train was calculated based on the grade and curvature over a distance of alignment where these two values were constant. No attempt was made to account for the variation in curvature or grade that would typically be found within the length of the design train. This assumption is appropriate for values intended solely for comparison and not to determine absolute values.
- The Combined Resistance values were not permitted to be less than zero. While a train descending a grade will have a negative resistance and thus accelerate, the energy produced by internal combustion locomotives cannot be less than zero. Again, this is an appropriate for values intended solely for comparison and not to determine absolute values.
- The design velocity of the design train was set at a uniform 60 miles per hour per ARRC standards.

J.2 Calculation Methodology

The calculations found on the following pages were developed with a consistent methodology and resistance factors (Hay, 1982). First, using the conceptual alignments and profiles found in Appendix B and the ARRC track chart for the existing mainline, station limits were established for zones of uniform grade and curvature. The internal train resistance was calculated as a constant value, the product of the design train weight and a resistance factor of 4.5lb/ton of train weight. For each zone, a curve resistance was determined as the product of the design train weight and a curve resistance factor of 0.8 lb/ton of train weight. A zone value for grade resistance was derived from the grade resistance factor of 20 lb/ton multiplied by the train weight. The sum of the three resistances is identified as the Combined Resistance.

The Power Required to move the train within a given zone was calculated as the product of the Combined Resistance and the Design Velocity of 60 mph, with the appropriate factors to produce the results in horsepower. Time Between Stations values were derived from the length of each zone multiplied by the velocity, again adjusting units to seconds. Finally the approximate energy used within each zone was calculated as the product of the Power Required and the Time Between Stations, including a factor to convert the time component from seconds to hours, to produce a result in horsepower-hours.

The calculations are presented on the following pages. Table J-1 is a summary of the energy values for each alignment segment, along with the combination of these segmental values into an overall value for each alignment option between Port MacKenzie and Milepost 188.9 just north of Willow. Once the total energy was determined for each alignment, a determination was made of the median value, the middle value of the set of values for the eight alignments. The difference between each alignment's energy value and the median value was calculated and is displayed at the bottom of the table for comparison.

The subsequent pages are the calculations of energy for each alignment segment.

J.3 References

Hay, William Walter. 1982. *Railroad Engineering* (2nd ed.). John Wiley & Sons, Inc.: New York.

Table J-1: Train Energy Summary - Northbound

	Estimated Required Energy, Horsepower-Hours							
Alignment Segments	Mac West, Connection 1, Willow	Mac West, Connection 1, Houston, Houston North	Mac West, Connection 1, Houston, Houston South	Mac West, Connection 2, Big Lake	Mac East, Connection 3, Willow	Mac East, Connection 3, Houston, Houston North	Mac East, Connection 3, Houston, Houston South	Mac East, Big Lake
Mac West	1744.0	1744.0	1744.0	1744.0				
Mac East					2666.7	2666.7	2666.7	2666.7
Connection 1	621.4	621.4	621.4					
Connection 2				1595.8				
Connection 3					291.2	291.2	291.2	
Willow	5702.0				5702.0			
Houston		2560.2	2560.2			2560.2	2560.2	
Houston North		1741.5				1741.5		
Houston South			1917.7				1917.7	
Big Lake				4646.0				4646.0
Existing Mainline								
MP 170.3-188.9				3624.7				3624.7
MP 174.0-188.9			2654.4				2654.4	
MP 179.3-188.9		1864.6				1864.6		
Total	8067.4	8531.7	9497.7	11610.5	8659.9	9124.2	10090.2	10937.4
Median Value	9311.0							
Departure from Median	-13%	-8%	2%	25%	-7%	-2%	8%	17%

Prepared by: TNH-Hanson, LLC
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Table J-2: Mac West Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
12+56	56250	5	50000	0.00	0	106250	60	17000	14.3	67.5
23+46	56250	0	0	0.00	0	56250	60	9000	12.4	31.0
25+00	56250	4	40000	0.00	0	96250	60	15400	1.8	7.7
31+63	56250	4	40000	-0.50	-125000	0	60	0	7.5	0.0
37+83	56250	0	0	-0.50	-125000	0	60	0	7.0	0.0
44+63	56250	4	40000	-0.50	-125000	0	60	0	7.7	0.0
45+00	56250	4	40000	-0.50	-125000	0	60	0	0.4	0.0
63+14	56250	0	0	-0.10	-25000	31250	60	5000	20.6	28.6
80+21	56250	2	20000	-0.10	-25000	51250	60	8200	19.4	44.2
106+54	56250	0	0	-0.10	-25000	31250	60	5000	29.9	41.5
142+63	56250	0.83	8300	-0.10	-25000	39550	60	6328	41.0	72.1
150+00	56250	0.83	8300	-0.10	-25000	39550	60	6328	8.4	14.8
200+00	56250	0.83	8300	0.08	20000	84550	60	13528	56.8	213.4
247+21	56250	0	0	-0.24	-60000	0	60	0	53.6	0.0
264+17	56250	1	10000	-0.24	-60000	6250	60	1000	19.3	5.4
299+11	56250	0	0	-0.24	-60000	0	60	0	39.7	0.0
300+00	56250	0	0	-0.24	-60000	0	60	0	1.0	0.0
323+26	56250	2	20000	0.00	0	76250	60	12200	26.4	89.5
360+00	56250	2	20000	0.00	0	76250	60	12200	41.8	141.7
381+06	56250	0	0	0.20	50000	106250	60	17000	23.9	112.9
430+03	56250	1	10000	0.20	50000	116250	60	18600	55.6	287.3
440+00	56250	1	10000	0.20	50000	116250	60	18600	11.3	58.4
502+30	56250	0	0	-0.12	-30000	26250	60	4200	70.8	82.6
520+00	56250	0	0	-0.12	-30000	26250	60	4200	20.1	23.5
547+46	56250	1	10000	0.00	0	66250	60	10600	31.2	91.9
663+59	56250	0	0	0.00	0	56250	60	9000	132.0	330.0
										1744.0

Prepared by: TNH-Hanson, LLC
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Table J-3: Mac East Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
12+56	56250	5	50000	0.00	0	106250	60	17000	14.3	67.5
23+46	56250	0	0	0.00	0	56250	60	9000	12.4	31.0
25+00	56250	4	40000	0.00	0	96250	60	15400	1.8	7.7
31+63	56250	4	40000	-0.50	-125000	0	60	0	7.5	0.0
37+83	56250	0	0	-0.50	-125000	0	60	0	7.0	0.0
44+63	56250	4	40000	-0.50	-125000	0	60	0	7.7	0.0
45+00	56250	0	0	-0.50	-125000	0	60	0	0.4	0.0
63+14	56250	0	0	-0.10	-25000	31250	60	5000	20.6	28.6
80+21	56250	2	20000	-0.10	-25000	51250	60	8200	19.4	44.2
95+00	56250	0	0	-0.10	-25000	31250	60	5000	16.8	23.3
106+54	56250	0	0	0.00	0	56250	60	9000	13.1	32.8
150+00	56250	0.83	8300	0.00	0	64550	60	10328	49.4	141.7
172+84	56250	0.83	8300	0.20	50000	114550	60	18328	26.0	132.4
215+59	56250	0	0	0.20	50000	106250	60	17000	48.6	229.5
282+88	56250	1	10000	0.20	50000	116250	60	18600	76.5	395.3
300+00	56250	0	0	0.20	50000	106250	60	17000	19.5	92.1
361+75	56250	0	0	0.00	0	56250	60	9000	70.2	175.5
377+32	56250	2	20000	0.00	0	76250	60	12200	17.7	60.0
390+00	56250	0	0	0.00	0	56250	60	9000	14.4	36.0
418+19	56250	0	0	0.50	125000	181250	60	29000	32.0	257.8
434+55	56250	2	20000	0.50	125000	201250	60	32200	18.6	166.4
460+00	56250	0	0	0.50	125000	181250	60	29000	28.9	232.8
463+31	56250	0	0	0.12	30000	86250	60	13800	3.8	14.6
477+57	56250	2	20000	0.12	30000	106250	60	17000	16.2	76.5
516+22	56250	0	0	0.12	30000	86250	60	13800	43.9	168.3
523+59	56250	2	20000	0.12	30000	106250	60	17000	8.4	39.7
550+00	56250	0	0	0.12	30000	86250	60	13800	30.0	115.0
561+22	56250	0	0	-0.28	-70000	0	60	0	12.8	0.0
587+07	56250	1	10000	-0.28	-70000	0	60	0	29.4	0.0
615+00	56250	0	0	-0.28	-70000	0	60	0	31.7	0.0
649+49	56250	0	0	0.00	0	56250	60	9000	39.2	98.0
										2666.7

Prepared by: TNH-Hanson, LLC
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Table J-4: Connection 1 Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
0+40	56250	0	0	0.00	0	56250	60	9000	0.5	1.3
139+44	56250	0	0	-0.12	-30000	26250	60	4200	158.0	184.3
159+03	56250	1	10000	-0.12	-30000	36250	60	5800	22.3	35.9
160+00	56250	0	0	-0.12	-30000	26250	60	4200	1.1	1.3
207+00	56250	0	0	0.40	100000	156250	60	25000	53.4	370.8
216+75	56250	0	0	0.00	0	56250	60	9000	11.1	27.8
										621.4

Table J-5: Connection 2 Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
30+00	56250	2	20000	0.00	0	76250	60	12200	34.1	115.6
45+01	56250	2	20000	0.48	120000	196250	60	31400	17.1	149.2
161+02	56250	0	0	0.48	120000	176250	60	28200	131.8	1032.4
182+11	56250	2	20000	0.48	120000	196250	60	31400	24.0	209.3
190+00	56250	0	0	0.48	120000	176250	60	28200	9.0	70.5
196+57	56250	0	0	0.00	0	56250	60	9000	7.5	18.8
										1595.8

Table J-6: Connection 3 Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
23+00	56250	0	0	0.00	0	56250	60	9000	26.1	65.3
42+15	56250	0	0	-0.50	-125000	0	60	0	21.8	0.0
65+99	56250	2	20000	-0.50	-125000	0	60	0	27.1	0.0
136+13	56250	0	0	-0.50	-125000	0	60	0	79.7	0.0
158+32	56250	2	20000	-0.50	-125000	0	60	0	25.2	0.0
166+00	56250	0	0	-0.50	-125000	0	60	0	8.7	0.0
182+52	56250	0	0	0.00	0	56250	60	9000	18.8	47.0
199+44	56250	2	20000	0.00	0	76250	60	12200	19.2	65.1
239+44	56250	0	0	0.00	0	56250	60	9000	45.5	113.8
										291.2

Table J-7: Willow Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
10+00	56250	0	0	0.00	0	56250	60	9000	11.4	28.5
60+00	56250	0	0	-0.32	-80000	0	60	0	56.8	0.0
68+92	56250	0	0	0.50	125000	181250	60	29000	10.1	81.4
82+54	56250	2	0	0.50	125000	181250	60	29000	15.5	124.9
240+00	56250	0	0	0.50	125000	181250	60	29000	178.9	1441.1
252+31	56250	0	20000	0.28	70000	146250	60	23400	14.0	91.0
267+73	56250	2	0	0.28	70000	126250	60	20200	17.5	98.2
380+00	56250	0	0	0.28	70000	126250	60	20200	127.6	716.0
408+30	56250	0	20000	0.00	0	76250	60	12200	32.2	109.1
423+34	56250	2	0	0.00	0	56250	60	9000	17.1	42.8
480+00	56250	0	0	0.00	0	56250	60	9000	64.4	161.0
542+81	56250	0	20000	-0.32	-80000	0	60	0	71.4	0.0
560+00	56250	2	0	-0.32	-80000	0	60	0	19.5	0.0
564+58	56250	2	0	0.32	80000	136250	60	21800	5.2	31.5
646+45	56250	0	20000	0.32	80000	156250	60	25000	93.0	645.8
650+51	56250	2	20000	0.32	80000	156250	60	25000	4.6	31.9
690+00	56250	0	0	0.32	80000	136250	60	21800	44.9	271.9
770+00	56250	0	20000	-0.40	-100000	0	60	0	90.9	0.0
782+33	56250	0	0	-0.50	-125000	0	60	0	14.0	0.0
799+86	56250	2	0	-0.50	-125000	0	60	0	19.9	0.0
860+00	56250	0	0	-0.50	-125000	0	60	0	68.3	0.0
898+44	56250	0	20000	0.20	50000	126250	60	20200	43.7	245.2
926+11	56250	2	0	0.20	50000	106250	60	17000	31.4	148.3
980+00	56250	0	0	0.20	50000	106250	60	17000	61.2	289.0
1018+80	56250	0	20000	-0.12	-30000	46250	60	7400	44.1	90.7
1036+44	56250	2	0	-0.12	-30000	26250	60	4200	20.0	23.3
1045+56	56250	0	0	-0.12	-30000	26250	60	4200	10.4	12.1
1060+00	56250	1	20000	-0.12	-30000	46250	60	7400	16.4	33.7
1069+64	56250	1	0	-0.24	-60000	0	60	0	11.0	0.0
1189+82	56250	0	10000	-0.24	-60000	6250	60	1000	136.6	37.9
1200+00	56250	2	10000	-0.24	-60000	6250	60	1000	11.6	3.2
1204+16	56250	2	0	0.00	0	56250	60	9000	4.7	11.8
1252+92	56250	0	20000	0.00	0	76250	60	12200	55.4	187.7
1256+94	56250	2	20000	0.00	0	76250	60	12200	4.6	15.6
1285+81	56250	0	0	0.00	0	56250	60	9000	32.8	82.0
1300+00	56250	2	20000	0.00	0	76250	60	12200	16.1	54.6
1316+94	56250	2	0	0.20	50000	106250	60	17000	19.3	91.1
1357+27	56250	0	20000	0.20	50000	126250	60	20200	45.8	257.0
1365+18	56250	3	20000	0.20	50000	126250	60	20200	9.0	50.5
1369+91	56250	0	0	0.20	50000	106250	60	17000	5.4	25.5
1394+31	56250	3	30000	0.20	50000	136250	60	21800	27.7	167.7
										5702.0

Prepared by: TNH-Hanson, LLC
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Table J-8: Houston Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
29+64	56250	0	0	-0.08	-20000	36250	60	5800	33.7	54.3
36+82	56250	2	20000	-0.08	-20000	56250	60	9000	8.2	20.5
47+84	56250	0	0	-0.08	-20000	36250	60	5800	12.5	20.1
57+68	56250	1	10000	-0.08	-20000	46250	60	7400	11.2	23.0
76+07	56250	0	0	-0.08	-20000	36250	60	5800	20.9	33.7
91+00	56250	0.5	5000	-0.08	-20000	41250	60	6600	17.0	31.2
94+31	56250	0.5	5000	0.32	80000	141250	60	22600	3.8	23.9
108+22	56250	0	0	0.32	80000	136250	60	21800	15.8	95.7
108+74	56250	1	10000	0.32	80000	146250	60	23400	0.6	3.9
144+87	56250	0	0	0.32	80000	136250	60	21800	41.1	248.9
162+46	56250	2	20000	0.32	80000	156250	60	25000	20.0	138.9
220+79	56250	0	0	0.32	80000	136250	60	21800	66.3	401.5
249+99	56250	1	10000	0.32	80000	146250	60	23400	33.2	215.8
277+00	56250	0	0	0.32	80000	136250	60	21800	30.7	185.9
306+47	56250	0	0	-0.36	-90000	0	60	0	33.5	0.0
321+22	56250	1	10000	-0.36	-90000	0	60	0	16.8	0.0
349+00	56250	0	0	-0.36	-90000	0	60	0	31.6	0.0
414+26	56250	0	0	0.32	80000	136250	60	21800	74.2	449.3
440+00	56250	0.5	5000	0.32	80000	141250	60	22600	29.3	183.9
444+31	56250	0.5	5000	0.08	20000	81250	60	13000	4.9	17.7
519+58	56250	0	0	0.08	20000	76250	60	12200	85.5	289.8
534+19	56250	2	20000	0.08	20000	96250	60	15400	16.6	71.0
547+47	56250	0	0	0.08	20000	76250	60	12200	15.1	51.2
										2560.2

Table J-9: Houston North Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
21+39	56250	2	20000	0.40	100000	176250	60	28200	24.3	190.4
86+93	56250	0	0	0.40	100000	156250	60	25000	74.5	517.4
100+00	56250	1	10000	0.40	100000	166250	60	26600	14.9	110.1
119+14	56250	1	10000	0.12	30000	96250	60	15400	21.8	93.3
133+98	56250	0	0	0.12	30000	86250	60	13800	16.9	64.8
148+72	56250	2	20000	0.12	30000	106250	60	17000	16.8	79.3
160+00	56250	0	0	0.12	30000	86250	60	13800	12.8	49.1
225+00	56250	0	0	0.50	125000	181250	60	29000	73.9	595.3
232+67	56250	0	0	-0.40	-100000	0	60	0	8.7	0.0
241+42	56250	2	20000	-0.40	-100000	0	60	0	9.9	0.0
276+42	56250	0	0	-0.40	-100000	0	60	0	39.8	0.0
300+00	56250	3	30000	-0.40	-100000	0	60	0	26.8	0.0
309+63	56250	3	30000	0.00	0	86250	60	13800	10.9	41.8
										1741.5

Table J-10: Houston South Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
51+79	56250	0	0	0.20	50000	106250	60	17000	58.9	278.1
83+25	56250	1	10000	0.20	50000	116250	60	18600	35.8	185.0
100+00	56250	0	0	0.20	50000	106250	60	17000	19.0	89.7
184+09	56250	0	0	0.50	125000	181250	60	29000	95.6	770.1
200+00	56250	2	20000	0.50	125000	201250	60	32200	18.1	161.9
204+26	56250	2	20000	0.20	50000	126250	60	20200	4.8	26.9
226+47	56250	0	0	0.20	50000	106250	60	17000	25.2	119.0
243+24	56250	2	20000	0.20	50000	126250	60	20200	19.1	107.2
260+00	56250	0	0	0.20	50000	106250	60	17000	19.0	89.7
260+04	56250	0	0	-0.40	-100000	0	60	0	0.0	0.0
281+25	56250	2	20000	-0.40	-100000	0	60	0	24.1	0.0
305+07	56250	0	0	-0.40	-100000	0	60	0	27.1	0.0
310+00	56250	3	30000	-0.40	-100000	0	60	0	5.6	0.0
330+72	56250	3	30000	0.00	0	86250	60	13800	23.5	90.1
										1917.7

Prepared by: TNH-Hanson, LLC
January 2008

Table J-11: Big Lake Alignment, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

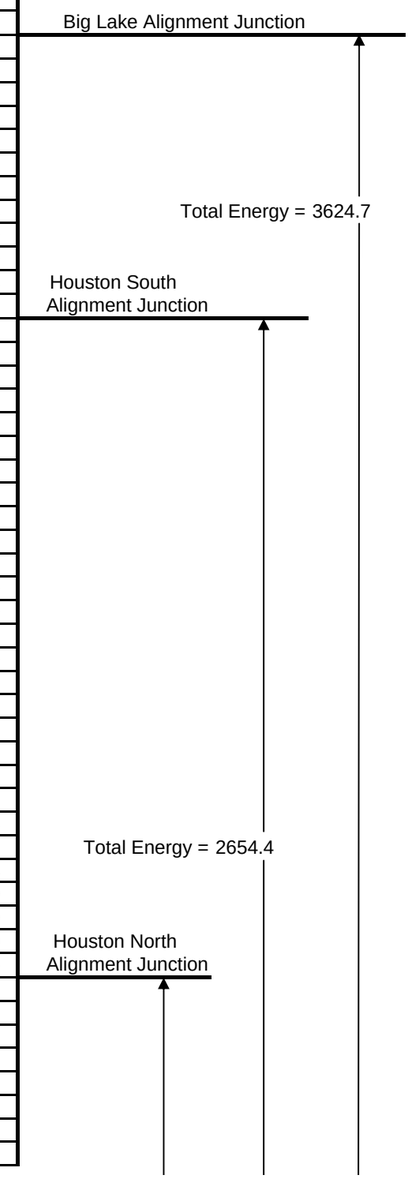
Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
		Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
0+00										
60+00	56250	0	0	0.36	90000	146250	60	23400	68.2	443.3
66+28	56250	0	0	0.00	0	56250	60	9000	7.1	17.8
85+41	56250	2	20000	0.00	0	76250	60	12200	21.7	73.5
99+37	56250	0	0	0.00	0	56250	60	9000	15.9	39.8
123+69	56250	1.5	15000	0.00	0	71250	60	11400	27.6	87.4
130+00	56250	0	0	0.00	0	56250	60	9000	7.2	18.0
145+92	56250	0	0	0.40	100000	156250	60	25000	18.1	125.7
167+78	56250	0.5	5000	0.40	100000	161250	60	25800	24.8	177.7
180+00	56250	0	0	0.40	100000	156250	60	25000	13.9	96.5
194+77	56250	0	0	-0.50	-125000	0	60	0	16.8	0.0
206+93	56250	0.5	5000	-0.50	-125000	0	60	0	13.8	0.0
234+16	56250	0	0	-0.50	-125000	0	60	0	30.9	0.0
292+99	56250	0.75	7500	-0.50	-125000	0	60	0	66.9	0.0
300+11	56250	0	0	-0.50	-125000	0	60	0	8.1	0.0
329+65	56250	1	10000	-0.50	-125000	0	60	0	33.6	0.0
342+15	56250	0	0	-0.50	-125000	0	60	0	14.2	0.0
355+00	56250	1.25	12500	-0.50	-125000	0	60	0	14.6	0.0
388+38	56250	1.25	12500	0.20	50000	118750	60	19000	37.9	200.0
430+00	56250	0	0	0.20	50000	106250	60	17000	47.3	223.4
454+21	56250	0	0	-0.50	-125000	0	60	0	27.5	0.0
462+65	56250	1	10000	-0.50	-125000	0	60	0	9.6	0.0
500+00	56250	0	0	-0.50	-125000	0	60	0	42.4	0.0
529+57	56250	0	0	0.50	125000	181250	60	29000	33.6	270.7
538+32	56250	1	10000	0.50	125000	191250	60	30600	9.9	84.2
568+27	56250	0	0	0.50	125000	181250	60	29000	34.0	273.9
577+01	56250	1	10000	0.50	125000	191250	60	30600	9.9	84.2
600+00	56250	0	0	0.50	125000	181250	60	29000	26.1	210.3
650+77	56250	0	0	0.32	80000	136250	60	21800	57.7	349.4
682+95	56250	1	10000	0.32	80000	146250	60	23400	36.6	237.9
725+27	56250	0	0	0.32	80000	136250	60	21800	48.1	291.3
732+22	56250	2	20000	0.32	80000	156250	60	25000	7.9	54.9
739+77	56250	0	0	0.32	80000	136250	60	21800	8.6	52.1
740+00	56250	2	20000	0.32	80000	156250	60	25000	0.3	2.1
744+19	56250	2	20000	-0.40	-100000	0	60	0	4.8	0.0
766+50	56250	0	0	-0.40	-100000	0	60	0	25.4	0.0
772+00	56250	2	20000	-0.40	-100000	0	60	0	6.3	0.0
810+00	56250	0	0	-0.40	-100000	0	60	0	43.2	0.0
848+78	56250	0	0	0.50	125000	181250	60	29000	44.1	355.3
853+43	56250	2	20000	0.50	125000	201250	60	32200	5.3	47.4
881+28	56250	0	0	0.50	125000	181250	60	29000	31.6	254.6
893+35	56250	3	30000	0.50	125000	211250	60	33800	13.7	128.6
899+54	56250	0	0	0.50	125000	181250	60	29000	7.0	56.4
936+06	56250	3	30000	0.50	125000	211250	60	33800	41.5	389.6
										4646.0

Prepared by: TNH-Hanson, LLC
January 2008

Table J-12: Existing ARRC Mainline, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

ARRC Milepost	Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
			Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
170.30	0+00										
170.86	29+57	56250	3	30000	0.71	177500	263750	60	42200	33.6	393.9
171.20	47+52	56250	0	0	0.71	177500	233750	60	37400	20.4	211.9
171.33	54+38	56250	2.46	24600	0.71	177500	258350	60	41336	7.8	89.6
171.70	73+92	56250	2.46	24600	-0.34	-85000	0	60	0	22.2	0.0
171.85	81+84	56250	2.46	24600	0.15	37500	118350	60	18936	9.0	47.3
171.92	85+54	56250	0	0	0.15	37500	93750	60	15000	4.2	17.5
172.20	100+32	56250	0	0	-0.30	-75000	0	60	0	16.8	0.0
172.54	118+27	56250	0	0	0.54	135000	191250	60	30600	20.4	173.4
173.20	153+12	56250	0	0	-0.82	-205000	0	60	0	39.6	0.0
173.72	180+58	56250	0.75	7500	-0.82	-205000	0	60	0	31.2	0.0
173.78	183+75	56250	0.75	7500	-0.02	-5000	58750	60	9400	3.6	9.4
173.98	194+31	56250	0	0	-0.02	-5000	51250	60	8200	12.0	27.3
174.26	209+09	56250	0	0	0.17	42500	98750	60	15800	16.8	73.7
174.49	221+23	56250	0	0	-0.44	-110000	0	60	0	13.8	0.0
174.60	227+04	56250	1.02	10200	-0.44	-110000	0	60	0	6.6	0.0
174.69	231+79	56250	1.02	10200	-0.13	-32500	33950	60	5432	5.4	8.1
174.94	244+99	56250	0	0	-0.13	-32500	23750	60	3800	15.0	15.8
175.07	251+85	56250	0.92	9200	-0.13	-32500	32950	60	5272	7.8	11.4
175.14	255+55	56250	0	0	-0.13	-32500	23750	60	3800	4.2	4.4
175.40	269+28	56250	0	0	0.05	12500	68750	60	11000	15.6	47.7
175.65	282+48	56250	0	0	-0.10	-25000	31250	60	5000	15.0	20.8
175.94	297+79	56250	0	0	-0.18	-45000	11250	60	1800	17.4	8.7
176.10	306+24	56250	0	0	0.23	57500	113750	60	18200	9.6	48.5
176.19	310+99	56250	0	0	-0.31	-77500	0	60	0	5.4	0.0
176.44	324+19	56250	0.92	9200	-0.31	-77500	0	60	0	15.0	0.0
176.47	325+77	56250	0.92	9200	0.00	0	65450	60	10472	1.8	5.2
176.69	337+39	56250	0	0	0.00	0	56250	60	9000	13.2	33.0
177.04	355+87	56250	0.97	9700	0.00	0	65950	60	10552	21.0	61.6
177.09	358+51	56250	0.97	9700	-0.15	-37500	28450	60	4552	3.0	3.8
177.16	362+21	56250	0	0	-0.15	-37500	18750	60	3000	4.2	3.5
177.35	372+24	56250	0	0	0.08	20000	76250	60	12200	11.4	38.6
177.54	382+27	56250	0	0	-0.06	-15000	41250	60	6600	11.4	20.9
177.90	401+28	56250	1.97	19700	-0.06	-15000	60950	60	9752	21.6	58.5
177.97	404+98	56250	1.97	19700	0.24	60000	135950	60	21752	4.2	25.4
178.29	421+88	56250	0	0	0.24	60000	116250	60	18600	19.2	99.2
178.55	435+61	56250	0	0	0.66	165000	221250	60	35400	15.6	153.4
178.64	440+36	56250	0	0	-0.49	-122500	0	60	0	5.4	0.0
178.78	447+75	56250	0.43	4300	-0.49	-122500	0	60	0	8.4	0.0
178.98	458+31	56250	0	0	-0.49	-122500	0	60	0	12.0	0.0
179.26	473+09	56250	0	0	0.03	7500	63750	60	10200	16.8	47.6
179.41	481+01	56250	0	0	-0.03	-7500	48750	60	7800	9.0	19.5
179.48	484+71	56250	1.5	15000	-0.03	-7500	63750	60	10200	4.2	11.9
179.68	495+27	56250	1.5	15000	0.39	97500	168750	60	27000	12.0	90.0
179.82	502+66	56250	0	0	-0.14	-35000	21250	60	3400	8.4	7.9
180.01	512+69	56250	0	0	-0.68	-170000	0	60	0	11.4	0.0
180.20	522+72	56250	0	0	0.48	120000	176250	60	28200	11.4	89.3
180.45	535+92	56250	0	0	0.72	180000	236250	60	37800	15.0	157.5
180.52	539+62	56250	0.9	9000	0.72	180000	245250	60	39240	4.2	45.8



Prepared by: TNH-Hanson, LLC
January 2008

Table J-12: Existing ARRC Mainline, Northbound - Train Energy Calculations

Design Train is 100 cars @ 125 tons/car = 12,500 tons

ARRC Milepost	Station	Train Resistance (4.5lb/ton) (lb)	Curve Component		Grade Component		Combined Resistance R (>0) (lb)	Design Velocity V (mph)	Power Required P=R*V (hp)	Time Between Stations (sec)	Energy E=P*T (hp-hour)
			Curvature D (degrees)	Resistance D(0.8lb/ton) (lb)	Gradient G (%)	Resistance G*(20lb/ton) (lb)					
180.68	548+07	56250	0.9	9000	0.11	27500	92750	60	14840	9.6	39.6
180.73	550+71	56250	0.9	9000	-0.01	-2500	62750	60	10040	3.0	8.4
180.95	562+33	56250	0	0	-0.01	-2500	53750	60	8600	13.2	31.5
181.02	566+03	56250	0	0	-0.78	-195000	0	60	0	4.2	0.0
181.24	577+65	56250	1.7	17000	-0.78	-195000	0	60	0	13.2	0.0
181.34	582+93	56250	0	0	-0.78	-195000	0	60	0	6.0	0.0
181.40	586+10	56250	0	0	-0.01	-2500	53750	60	8600	3.6	8.6
181.56	594+55	56250	2.75	27500	-0.01	-2500	81250	60	13000	9.6	34.7
181.80	607+22	56250	0	0	-0.01	-2500	53750	60	8600	14.4	34.4
182.00	617+78	56250	0	0	-0.09	-22500	33750	60	5400	12.0	18.0
182.02	618+84	56250	0	0	0.47	117500	173750	60	27800	1.2	9.3
182.14	625+18	56250	4.1	41000	0.47	117500	214750	60	34360	7.2	68.7
182.28	632+57	56250	4.1	41000	0.53	132500	229750	60	36760	8.4	85.8
182.52	645+24	56250	0	0	0.53	132500	188750	60	30200	14.4	120.8
182.82	661+08	56250	0	0	1.02	255000	311250	60	49800	18.0	249.0
182.98	669+53	56250	0	0	0.31	77500	133750	60	21400	9.6	57.1
183.07	674+28	56250	0	0	-0.31	-77500	0	60	0	5.4	0.0
183.12	676+92	56250	5.98	59800	-0.31	-77500	38550	60	6168	3.0	5.1
183.23	682+73	56250	5.98	59800	-1.17	-292500	0	60	0	6.6	0.0
183.34	688+54	56250	5.98	59800	-0.25	-62500	53550	60	8568	6.6	15.7
183.58	701+21	56250	5.92	59200	-0.03	-7500	107950	60	17272	14.4	69.1
183.70	707+55	56250	0	0	-0.03	-7500	48750	60	7800	7.2	15.6
184.09	728+14	56250	0	0	-0.65	-162500	0	60	0	23.4	0.0
184.80	765+63	56250	0	0	-0.36	-90000	0	60	0	42.6	0.0
184.97	774+61	56250	0	0	-0.73	-182500	0	60	0	10.2	0.0
185.12	782+53	56250	0.45	4500	-0.73	-182500	0	60	0	9.0	0.0
185.15	784+11	56250	0.45	4500	-0.03	-7500	53250	60	8520	1.8	4.3
185.40	797+31	56250	0	0	-0.03	-7500	48750	60	7800	15.0	32.5
186.06	832+16	56250	0	0	-0.40	-100000	0	60	0	39.6	0.0
186.11	834+80	56250	0.92	9200	-0.40	-100000	0	60	0	3.0	0.0
186.39	849+58	56250	0.92	9200	-0.96	-240000	0	60	0	16.8	0.0
187.06	884+96	56250	0	0	-0.96	-240000	0	60	0	40.2	0.0
187.28	896+58	56250	1.93	19300	0.00	0	75550	60	12088	13.2	44.3
187.42	903+97	56250	0	0	0.00	0	56250	60	9000	8.4	21.0
187.89	928+79	56250	0	0	1.08	270000	326250	60	52200	28.2	408.9
188.09	939+35	56250	0	0	0.00	0	56250	60	9000	12.0	30.0
188.25	947+80	56250	1.47	14700	0.00	0	70950	60	11352	9.6	30.3
188.41	956+25	56250	1.47	14700	-0.59	-147500	0	60	0	9.6	0.0
188.93	983+71	56250	0	0	-0.59	-147500	0	60	0	31.2	0.0

Total Energy = 1864.6

Willow Alignment Junction

Prepared by: TNH-Hanson, LLC
January 2008

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