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Heber Light & Power

Underground Transmission Cost/Feasibility Study

Prepared by

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Rev	Date	Eng	Appvd.	Description
0	03/20/2018	Carson Bates	Clifton Oertli	Preliminary Issue
1	04/09/2018	Carson Bates	Clifton Oertli	Added sample segment & various minor updates
2	04/24/2018	Carson Bates	Clifton Oertli	Final Issue

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Executive Summary

Cost of underground transmission is approximately four to five times the cost of overhead transmission. However, there are other considerations besides cost for underground versus overhead transmission. This report focuses on cost but provides a short description of other considerations. Estimated costs have been provided by various entities and have been compiled to determine the cost per segment based on the segment map provided by Heber Light & Power (see Appendix A for segment map). The purpose of this study is to provide an estimated cost within 30% of the actual value. This study is meant to be a cost feasibility analysis. It is not intended to be a ready for construction design estimate. The table below summarizes the underground transmission project costs and comparable overhead transmission project.

Table 1 Underground versus Overhead Cost Estimates

Seg.	Length (mile)	OH 138kV & 46kV Shared Structure ($M)	UG 138kV & 46kV Separate Trench ($M)	UG/OH
1	1.8	$2.00	$8.79	4.4
2	2.7	$3.00	$12.67	4.2
3	1.4	$1.53	$6.69	4.4
4	2.5	$2.75	$11.81	4.3
5	1.2	$1.32	$6.06	4.6
6	0.6	$0.64	$3.50	5.5
7	0.9	$0.96	$4.59	4.8
8	1.3	$1.40	$6.38	4.6
9	1.2	$1.31	$5.40	4.1
Hwy 40 to Midway	7.1	$7.77	$32.16	4.1

Figure 1 Partial Segment Map (refer to Appendix A for entire map)

Underground Transmission Cost/Feasibility Study

1) Introduction

NEI Electric Power Engineering (NEI) has been contracted by Heber Light & Power (Heber) to provide, "the cost requirements of undergrounding roughly 8 miles of dual circuit 138 KV 46 KV transmission. The study will need to address the cost of this underground transmission project to within +/- 30%. Heber Light & Power has identified various segments of the transmission line and the respondent should identify each segments cost and feasibility. There are two separate utilities, Heber and Rocky Mountain Power (RMP), that are a part of this project, so the costs should be separated by segment and by 138KV (RMP) cost and 46KV (Heber) cost. For employee safety, system reliability, and operational flexibility, each circuit cannot share the same vault. Both utility's underground specifications are included in this bid packet"[1].

Undergrounding transmission lines may provide benefits compared to overhead transmission. Aesthetics is likely the most common reason, but other benefits include less frequent, short duration electrical faults due to trees or pests, and increased safety for overhead line contact. Shock from underground cable is less common since the conductor is shielded with a grounded wire. Beyond this, technological advances have increased reliability, reduced cost, and eased installation difficulties. Some cities are considering underground cables for power delivery for these reasons and more.

There are disadvantages for moving towards underground transmission including increase in cost and/or complexity. While not complete and generic, some disadvantages include: installation method changes, less frequent/longer duration outages due to faults, no automatic reclosing, modified relay protection, right-of-way changes, land use changes, less familiarity with underground cables, different operational requirements for monitoring electrical system, different maintenance schedules, and different spare parts. Underground transmission should be evaluated in a broad context rather than only considering cost or aesthetics.

A simple pros and cons of underground transmission when compared to overhead transmission summarizes the preceding paragraph:

Table 2 Pros and Cons of Underground versus Overhead Transmission

Pros	**Cons**
Not generally observable (better aesthetics)	Higher Cost
Less frequent transient faults (trees birds)	More difficult and expensive to find and repair a fault; typically, longer outages
Different land use (no overhead lines over roads)	Restricts other construction within right of way, i.e. no building foundations over cables and restricted agricultural use.
Less maintenance	More expensive testing and diagnostics

[1] RFP Cost-feasibility study transmission.pdf provided by Heber Light & Power

2) Proposed Design

Heber provided the proposed underground segments during the proposal stage of the project, which is included in Appendix A. The underground design consists of 9 segments that connect several substations within Heber's electrical infrastructure. The lengths and routing were detailed in the provided map and descriptions. NEI reviewed the provided segment map and added detail to consider the required cable riser structures and directional boring locations. Several assumptions were required. Some assumptions are inherent to the design while others can be defined explicitly. The explicit numerical assumptions are shown in Table 3 Numerical Design Assumptions.

Table 3 Numerical Design Assumptions

Voltage (kV)	**Min. Ampacity (A)**	**Power (MVA)**	**1-Circuit, Size (kcmil), Cu**	**1-Circuit, Size (kcmil), Al**	**2-Circuit, Size (kcmil), Cu**	**2-Circuit, Size (kcmil), Al**
46	873	70	1000	1500	N/A	N/A
138	898	215	1250	2000	750	1000
Max Section Length (ft)	2100	Based on max cable per reel (2100ft), shield voltage (120V)				
Directional Boring						
Roadway Bore (ft)	75	crossings of major roadways, boring length for this type is typically 30 to 40 feet wider than the road right of way.				
Waterway Bore (ft)	150	crossings of all major rivers and wastewater ditches. Boring length for this type can have a large range of variation. This depends on surrounding topography and environmental rights-of-way (potential 300' to 500' bore).				
Constructability Bore (ft)	50	could possibly be avoided with slight routing changes				
Assumes: Driveways can be trenched through, rather than bored. Waterways include all rivers and wastewater streams that are verifiable via Bing maps (ACAD map source).						

In addition to the routing design, Heber and Rocky Mountain Power provided the underground duct bank designs for their respective circuits, which are included in Appendix A. These designs were both similar to each other and to typical transmission duct bank details. It is assumed that these duct banks will be installed parallel to each other and separated by enough distance to allow for separate trenches—about five feet. This limits the mutual heating, allowing for higher ampacity for the same conductor size.

The required minimum ampacity is listed above and was specified separately by Heber and Rocky Mountain Power. Heber provided a draft load forecast, an excerpt of which is included in Appendix A. NEI was instructed to use the larger load forecast for consideration. This is approximately 70MW with a 55% load factor. Rocky Mountain Power specified the ampacity requirement to be similar to ACSR 795 Drake during the kickoff meeting. The ampacity for Drake is approximately 900A based on typical transmission line assumptions (Conductor temperature of 75°C, ambient temperature 25°C, emissivity 0.5, wind 2 ft./sec., in sun.). A load factor was not provided but is assumed to be similar to that provided by Heber: 55%.

The soil thermal resistivity is a critical parameter for specifying the conductor size of an underground cable. This is measured according to IEEE Std. 442 but was not provided for this study since it is a feasibility study rather than a detailed design. Therefore, the conductor sizes were determined based on IEEE Std 835, the standard for cable ampacity. The installation details are similar to those provided by Heber and RMP. Typical engineering assumptions are made including: a conductor temperature of 90°C, ambient soil temperature of 25°C, resistivity of 90°C*cm/W, and load factor of 75%. Since the cable rating will likely be 105°C and the load factor is projected to be about 55%, this provides a reasonable estimate even considering the unknown soil resistivity. In addition to these assumptions, it is assumed the cables will be cross bonded. This provides many benefits as listed in IEEE Std. 575, but the primary consideration for this study is the ampacity benefit—allowing for a smaller, lower cost cable. The calculations for the shield voltage are provided in Appendix B. The maximum cable section length is determined to be 2100 feet based on the shield voltage and the maximum length of cable for a standard reel. A splice is required at each of these sections. This then requires a cable vault and shield voltage limiter at each of these sections. The final design should optimize the major and minor section lengths to minimize shield voltage, but this preliminary design divides the total segment length by the maximum cable section length and rounds up to the nearest integer.

A cable riser is required at the end of each segment. If the segment terminates in a substation, a small riser is required to support the termination. If the segment terminates outside of a substation, a transmission line dead-end structure is required. This larger structure can vary significantly based on the soil properties and line design, so a typical structure is used based on engineering judgment. The assumed cable riser at both ends a segment results in a higher cost if multiple segments remain underground. A riser is not required if the cable can remain underground rather a splice and vault are required in its place. This can be accounted for in cost considerations by subtracting the cost of the riser from each segment that is to remain underground and adding one additional splice, SVL, and vault.

3) Cost Parameters

Estimated costs were solicited from multiple sources.

This cost estimate focuses on installation of the underground transmission. Some costs were not included in this estimate such as:

- Substation or line integration equipment, e.g. circuit breaker, disconnect switch
- Right-of-way purchase/lease
- Operation and maintenance

Most costs are based on a per unit length cost, e.g. "$/ft". Some costs are based on where the cable terminations—either inside or outside of a substation. Others are based on a per unit time, e.g. "$/month". Reasonable assumptions and markups were included to determine a final cost per segment as requested. It is important to understand that changes in the segment length, location, or design details can result in disproportionate cost impacts due to the various cost metrics, so any changes must be reevaluated. The specific cost assumptions are detailed in Appendix C.

The following tables, Table 4 46kV Underground Cable Cost Estimates and Table 5 138kV Underground Cable Cost Estimates, provide the cost estimates for a few key portions of the underground cable project. The full details are provided in Appendix C.

Table 4 46kV Underground Cable Cost Estimates

Seg.	Design	Cable & Ductbank	Terminations, Splices & Vaults	Cable Risers	Installation	Total[1]
1	$73,935	$2,232,465	$207,010	$126,813	$276,010	$4,188,078
2	$110,811	$3,345,908	$275,990	$126,813	$363,955	$6,063,538
3	$56,726	$1,712,828	$172,520	$63,275	$228,835	$3,209,130
4	$101,471	$3,063,885	$275,990	$126,813	$363,890	$5,647,296
5	$48,833	$1,474,515	$172,520	$126,813	$181,710	$2,881,072
6	$23,493	$709,358	$103,540	$190,350	$97,255	$1,615,889
7	$35,374	$1,068,105	$138,030	$126,813	$142,970	$2,172,661
8	$51,559	$1,556,820	$172,520	$126,813	$201,480	$3,030,940
9	$48,356	$1,460,100	$138,030	$0	$157,400	$2,589,534

Note 1: Includes contractor markup of 25% and 15% contingency

Table 5 138kV Underground Cable Cost Estimates

Seg.	Design	Cable & Ductbank	Terminations, Splices & Vaults	Cable Risers	Installation	Total[1]
1	$91,219	$2,412,503	$233,200	$179,200	$288,010	$4,596,964
2	$136,715	$3,615,739	$303,200	$179,200	$373,955	$6,610,006
3	$69,987	$1,850,959	$198,200	$67,700	$240,835	$3,483,469
4	$125,191	$3,310,973	$303,200	$179,200	$375,390	$6,160,716
5	$60,249	$1,593,428	$198,200	$179,200	$183,210	$3,179,515
6	$28,985	$766,564	$128,200	$290,700	$99,755	$1,887,734
7	$43,643	$1,154,243	$163,200	$179,200	$145,970	$2,421,795
8	$63,612	$1,682,370	$198,200	$179,200	$207,480	$3,346,126
9	$59,660	$1,577,850	$163,200	$0	$161,900	$2,814,450

Note 1: Includes contractor markup of 25% and 15% contingency

Figure 2 Segment 1 Cost Proportions provides the cost proportions for segment 1-138kV, which is similar for the other segments.

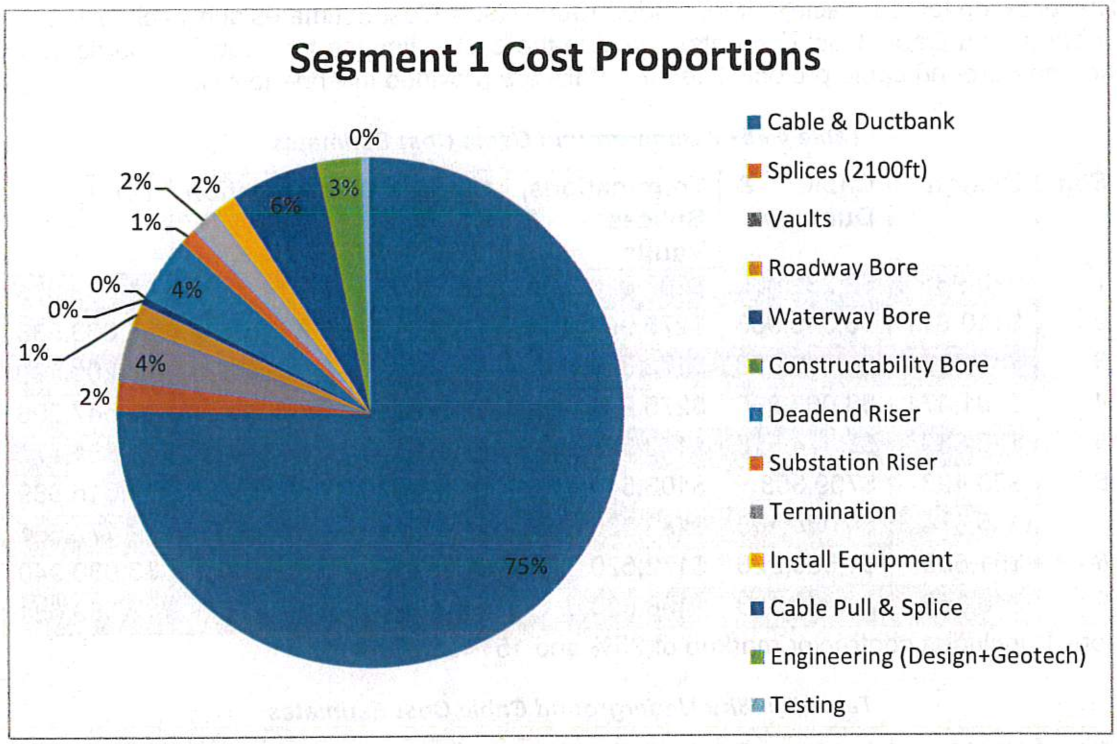


Figure 2 Segment 1 Cost Proportions

A sample cost for undergrounding the transmission from Highway 40 to Midway for both 46kV and 138kV is provided for ease of reference. This considers segments 2, 4, 6, and 8 as one installation. By combining these segments, five dead-end risers are not required and there is corresponding cost savings.

Hwy 40 to Midway	**Design**	**Cable & Ductbank**	**Terms, Splices & Vaults**	**Cable Risers**	**Installation**	**Total**[1]
46kV	$287,333	$8,675,970	$655,380	$190,088	$954,580	$15,451,808
138kV	$354,502	$9,375,645	$688,200	$246,900	$984,580	$16,706,807
Both	$641,835	$18,051,615	$1,343,580	$436,988	$1,939,160	$32,158,615

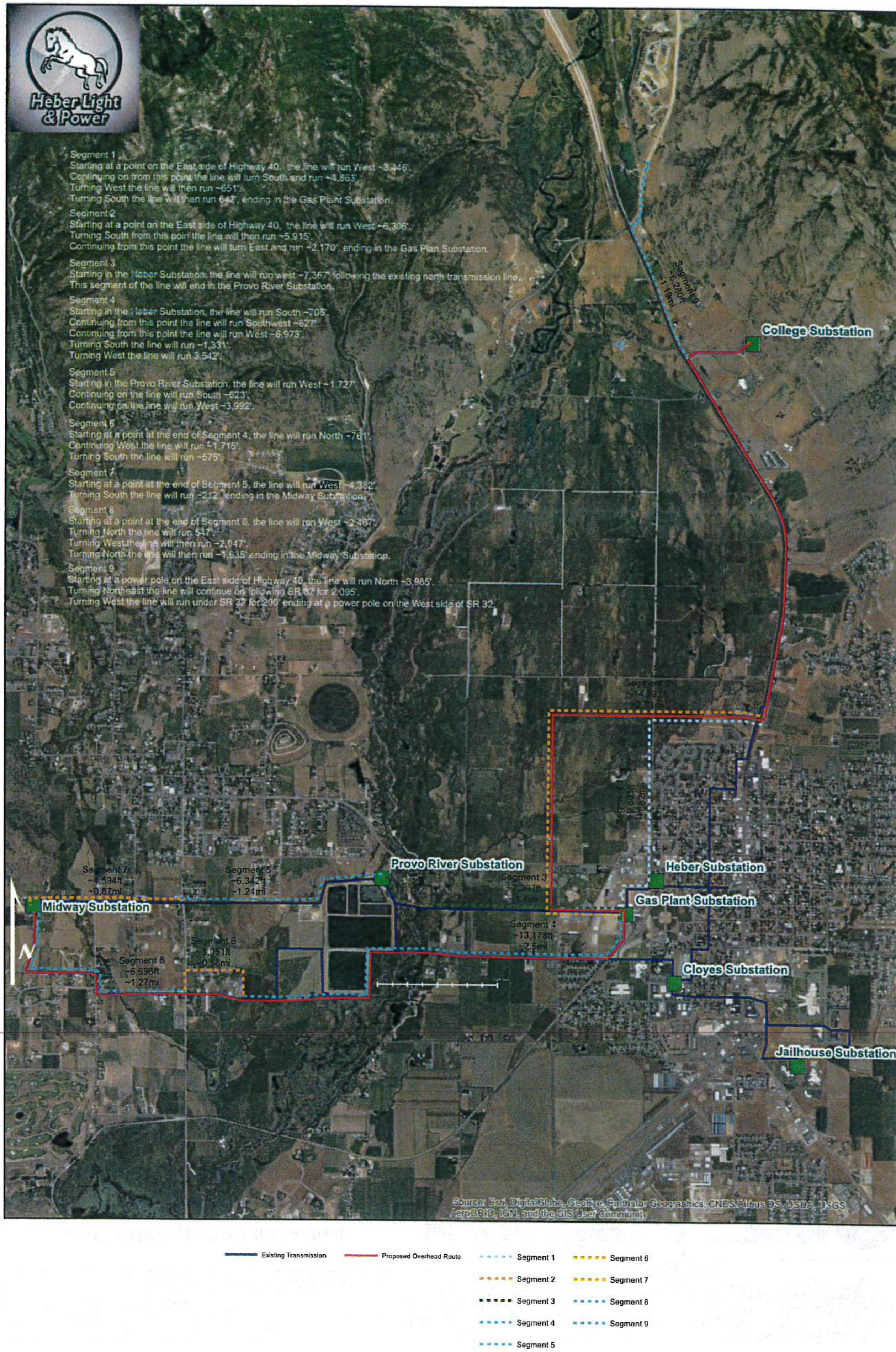
4) Equivalent Overhead Cost Comparison

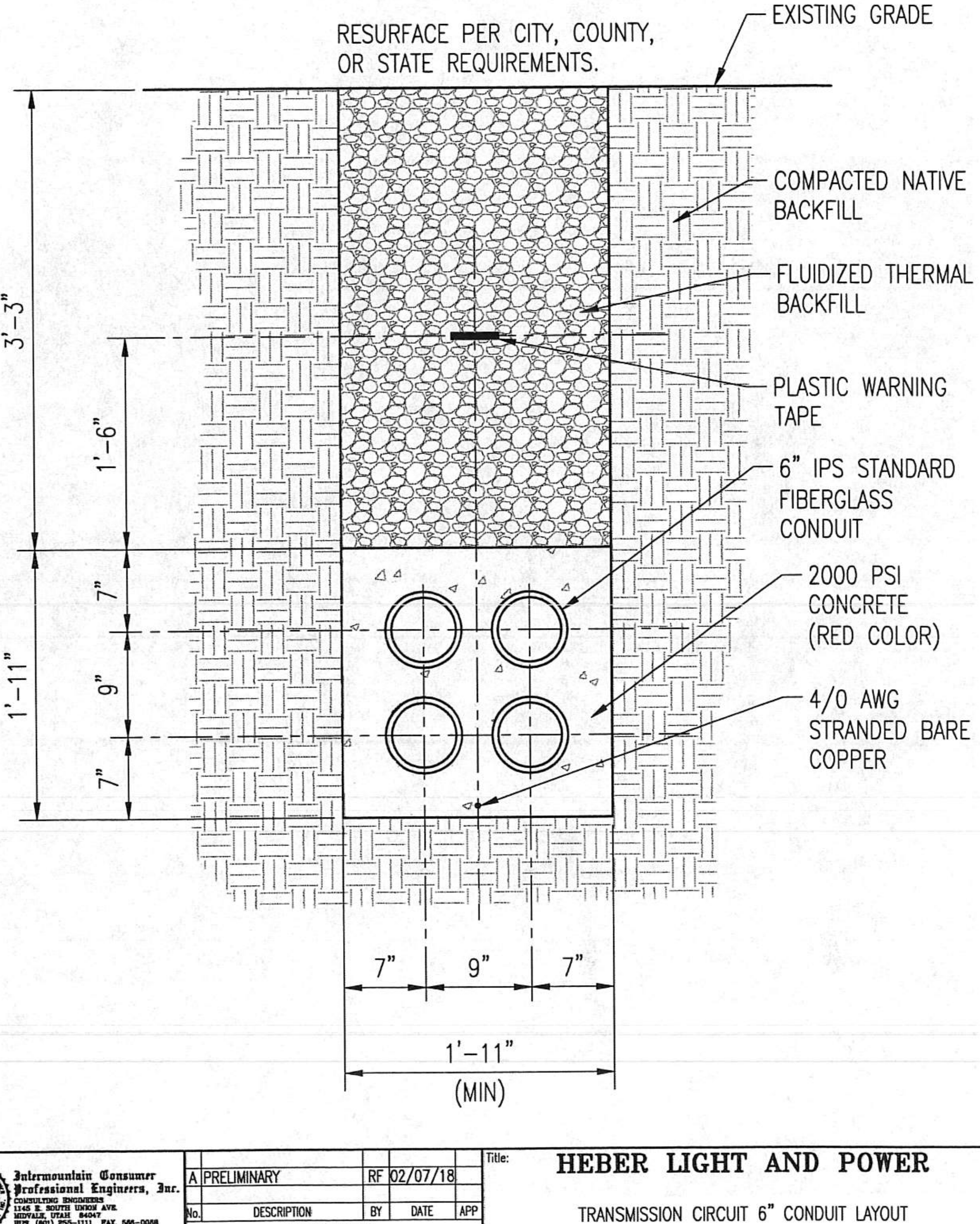
The overhead equivalent cost comparison with the underground segments has been made based on the cost data supplied by Heber Light & Power for two recent one-mile-long segments. This indicates an approximate cost of $1.1M per mile. For this study, a value of $1.1M per mile is used for the double circuit 138kV and 46kV overhead construction, including material such as steel structures. It is worth noting that this value is above typical values for a single circuit line, likely due to the short length and the double circuit structure. A typical number for single circuit 138kV is $0.4M per mile and 46kV is $0.28M per mile, so using $1.1M per mile is conservative. The overhead would likely be a lower cost considering that steel poles were used for the previous overhead construction. However, the goal of this report is to provide a comparison for nearly equivalent functionality, i.e. similar load capability and similar segment routing. The cables cannot be installed as a double circuit without impacting ampacity, so the underground cost is the sum of both 138kV and 46kV circuits. While it is not possible to directly compare a final design due to varying requirements between overhead and underground, Table 6 Overhead versus Underground Costs is provided for comparison.

Table 6 Overhead versus Underground Costs

Seg.	**Length (mile)**	**OH 138kV & 46kV Shared Structure ($M)**	**UG 138kV & 46kV Separate Trench ($M)**	**UG/OH**
1	1.8	$2.00	$8.79	4.4
2	2.7	$3.00	$12.67	4.2
3	1.4	$1.53	$6.69	4.4
4	2.5	$2.75	$11.81	4.3
5	1.2	$1.32	$6.06	4.6
6	0.6	$0.64	$3.50	5.5
7	0.9	$0.96	$4.59	4.8
8	1.3	$1.40	$6.38	4.6
9	1.2	$1.31	$5.40	4.1
Hwy 40 to Midway	7.1	$7.77	$32.16	4.1

Appendix A Data Provided by Heber and RMP


Heber Light & Power
Segment 1
Starting at a point on the East side of Highway 40, the line will run West ~3,446'.
Continuing on from this point the line will turn South and run ~4,863'.
Turning West the line will then run ~651'.
Turning South the line will then run 642', ending in the Gas Plant Substation.
Segment 2
Starting at a point on the East side of Highway 40, the line will run West ~6,306'.
Turning South from this poin the line will then run ~5,915'.
Continuing from this point the line will turn East and run ~2,170', ending in the Gas Plan Substation.
Segment 3
Starting in the Heber Substation, the line will run west ~7,367' following the existing north transmission line.
This segment of the line will end in the Provo River Substation.
Segment 4
Starting in the Heber Substation, the line will run South ~705'.
Continuing from this point the line will run Southwest ~627'.
Continuing from this point the line will run West ~6,973'.
Turning South the line will run ~1,331'.
Turning West the line will run 3,542'.
Segment 5
Starting in the Provo River Substation, the line will run West ~1,727'.
Continuing on the line will run South ~623'.
Continuing on the line will run West ~3,992'.
Segment 6
Starting at a point at the end of Segment 4, the line will run North ~761'.
Continuing West the line will run ~1,715'.
Turning South the line will run ~575'.
Segment 7
Starting at a point at the end of Segment 5, the line will run West ~4,382'.
Turning South the line will run ~212' ending in the Midway Substation.
Segment 8
Starting at a point at the end of Segment 6, the line will run West ~2,467'.
Turning North the line will run 517'.
Turning West the line will then run ~2,047'.
Turning North the line will then run ~1,635' ending in the Midway Substation.
Segment 9
Starting at a power pole on the East side of Highway 40, the line will run North ~3,985'.
Turning Northeast the line will continue on following SR 32 for 2,095'.
Turning West the line will run under SR 32 for 200' ending at a power pole on the West side of SR 32.
College Substation
Provo River Substation
Heber Substation
Gas Plant Substation
Midway Substation
Cloyes Substation
Jailhouse Substation
Segment 7 ~4,594ft ~0.87mi
Segment 5 ~6,342ft ~1.24mi
Segment 3 ~7,367ft
Segment 4 ~13,178ft ~2.5mi
Segment 6 ~3,051ft ~0.58mi
Segment 8 ~6,696ft ~1.27mi
N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Existing Transmission
Proposed Overhead Route
Segment 1
Segment 2
Segment 3
Segment 4
Segment 5
Segment 6
Segment 7
Segment 8
Segment 9



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CONSULTING ENGINEERS
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No.	DESCRIPTION	BY	DATE	APP
A	PRELIMINARY	RF	02/07/18	

REVISIONS

CONFIDENTIAL

Title:

HEBER LIGHT AND POWER

TRANSMISSION CIRCUIT 6" CONDUIT LAYOUT

Dwn.	RF	Date 02/07/18	Engr.	LB	Date 02/07/18	Drawing No.	Rev.
Chk.		Date	App.	LB	Date 02/07/18	E03	A
Proj. No.		–	Scale		NTS		

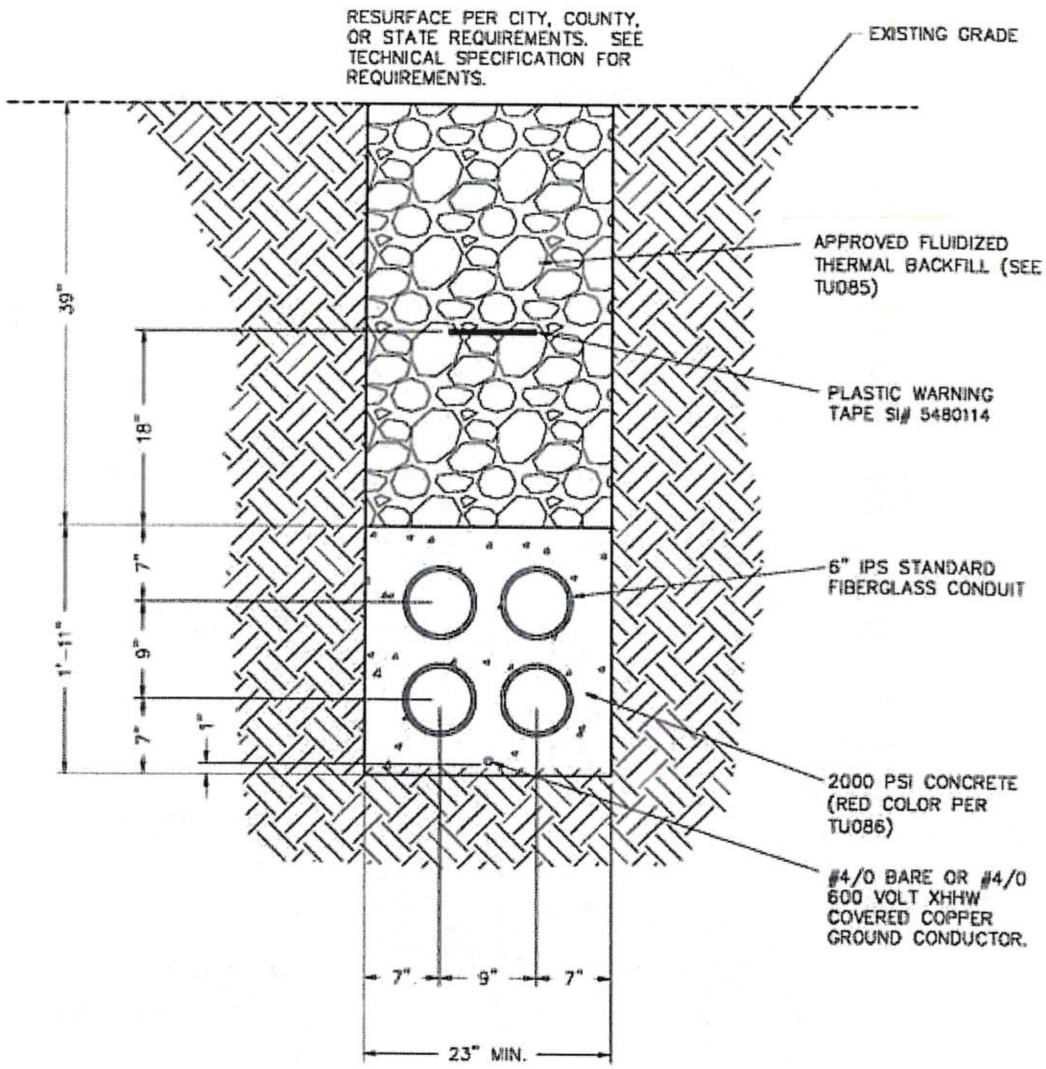


Figure 1—Typical Single-Circuit Conduit Layout

The trench shall be kept free of water until the backfilling has been completed. Dewatering methods shall comply with federal, state, county, and city ordinances and regulations concerning the discharge from dewatering system and site drainage.

Excavated material not used shall be disposed of in accordance with all federal, state, county, and city ordinances and regulations. Since these may be different for each entity it is up to the local construction personnel to determine how to dispose of this material. Temporary placement and removal of excavated material shall not restrict access to public or private property.

Conduits shall be buried to depths as shown in Table 2 and as shown in Figure 1 and Figure 2. Reduced burial depths are not allowed unless prior written approval has been received from the company. All reduced burial depth installations shall be built in accordance with Item 2 of the *Burial Depth* section of this standard.

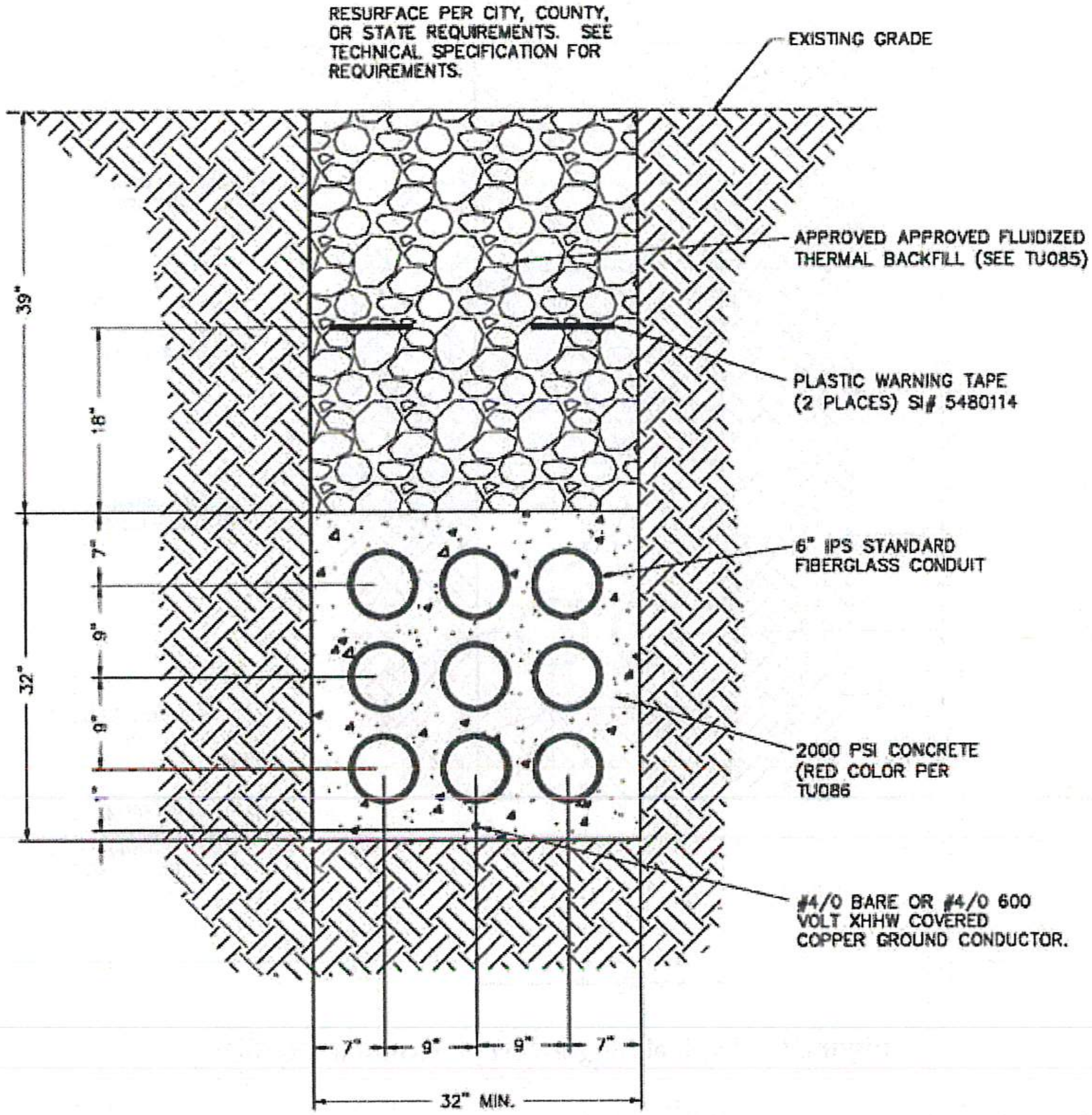
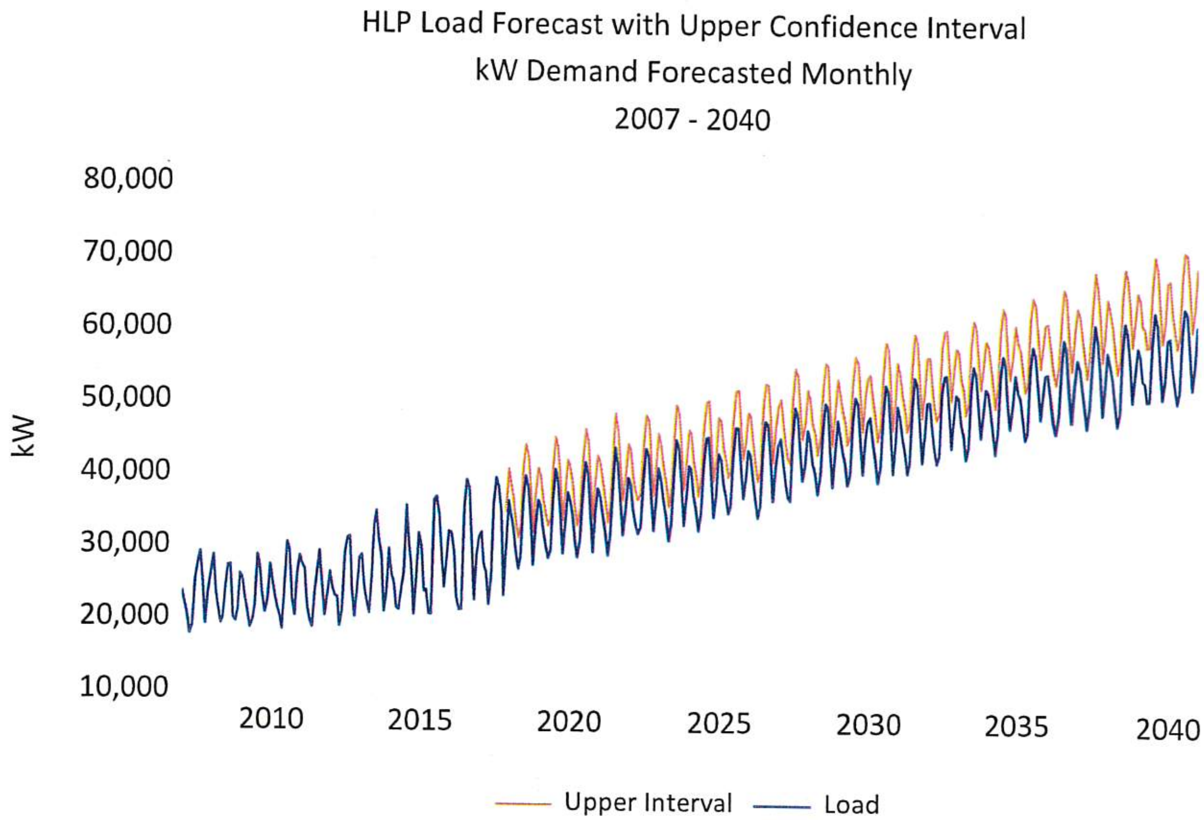


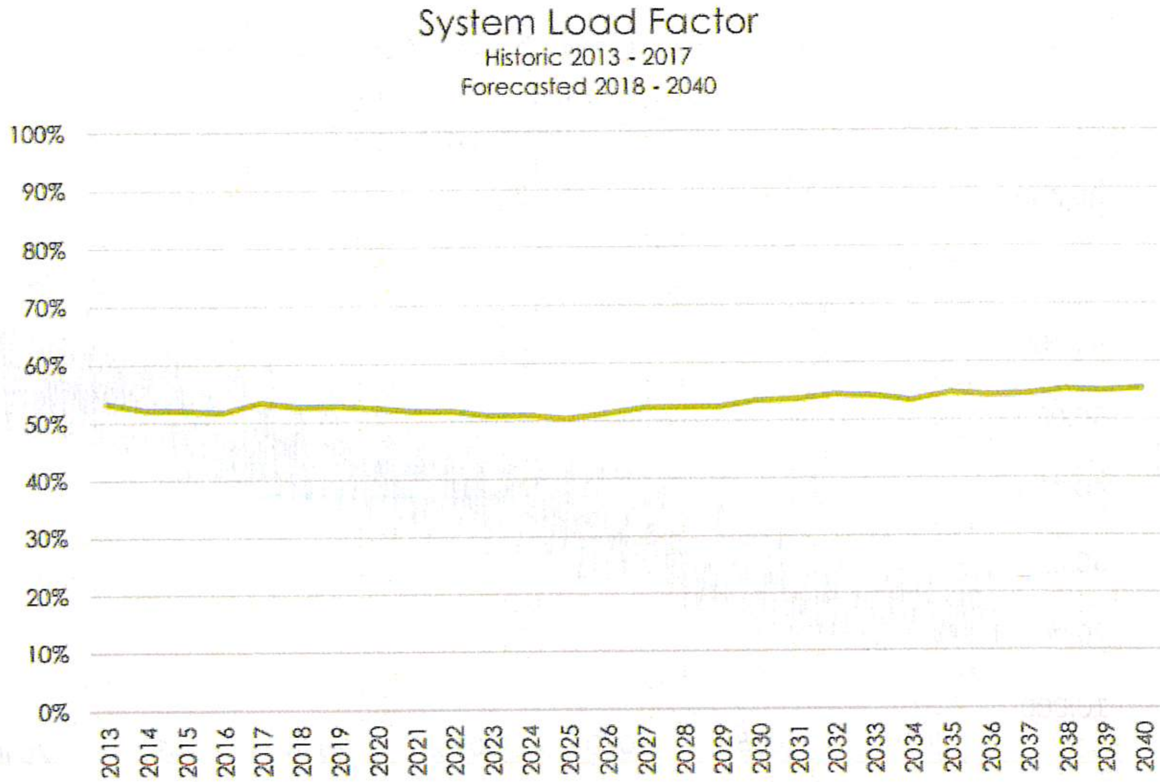
Figure 2—Typical Double-Circuit Conduit Layout

In no case will the company allow a trench less than 23″ wide for single-circuit and 32″ for double-circuit lines. See typical duct bank dimensions and conduit arrangements in Figure 1 and Figure 2.

Load Forecast from HLP 3/29/2018



Load Factor from Heber Light and Power 3/13/2018



Appendix B Calculations and Boring Locations

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Project:	**Heber City 46kV & RMP 138kV Cable**		
Document:	**Cable Shield Voltage Calculation**		
3/15/18 - Preliminary Calcs	Carson Bates		

Circuit Loading Calculation

System Rating	180	MW	
Power Factor	0.9		
System Voltage	138	kV	
Voltage	0.95	pu	
Current per Circuit	881	A	
Max Cable Loading	100%		

Conductor Short Circuit Withstand

Standard	*ICEA P-32-382-2007*		
Conductor Material	*Cu*		
T1 Operating Temp	70	°C	
T2 Max Short Circuit Temp	250	°C	*for Aluminum*
Max Short Circuit Time	10	cycles	
	0.167	sec	
Short Circuit Time (with Bkr Fail)	24	cycles	
	0.4	sec	
Lamda	228	°C	
K	0.00257		

Shield Short Circuit Withstand

Standard	*ICEA P-45-482*		
Conductor Material	*CU*		
T1 Operating Temp	60	°C	
T2 Max Allowable Temp	350	°C	*Allowable jacket temp (per mfgr)*
T0 Arbitrary Temperature	20	°C	*Typical value*
Split Factor	1.0		*Conservative Value*
Max Short Circuit Time	10	cycles	
	0.1667	sec	
SG	8.93		*Table 2 for Copper*
SH	0.092		*Table 2 for Copper*
Po	1.72	µΩ-cm	*Table 2 for Copper*
Lamda	234	°C	*Table 2 for Copper*
K	0.030		*Eq (2) and Table2*
M	0.095		*Eq (5)*

Shield Voltage

Cable Spacing C-C, S	12	in
Shield Diameter, d_s	3.127	in
Shield Resistivity	30	Ω-cmil/ft

Shield thickness, t	0.005	in
Shield resistance, Rs	480	μΩ/ft
Cond-Shield Mutual Reactance, Xm	46.85	μΩ/ft
Y	44.28	
Shield Voltage - Flat, Edge Cables	0.036	V/ft
Shield Voltage - Flat, Center Cable	0.048	V/ft
Max Permissible Shield Voltage	120	V
Max Section Length	**4971**	ft
Access Location Length	**1657**	ft
Access Location Voltage	80	V

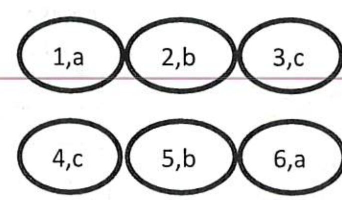
From IEEE 575 D.2.3

Ea	0.050	V/ft
Eb	0.041	V/ft
Max Permissible Shield Voltage	120	V
Max Section Length	**2411**	ft

Charging Current

Insulation Diameter (under screen)	3.025	in
Conductor Diameter (over screen)	1.325	in
Dielectric Constant	2.6	EPR=2.5~3.5,2.9 | XLPE=2.3~6.0,2.4
Calculated Capacitance (1 cond)	53	pF
Cable Capacitance	53	pF
Section Length	4,971	ft
Cable Capacitance	0.27	μF
Capacitive Reactance	-1.00E+04	Ω
Charging current:	8.0	A
Section Charging Voltage	19	V
Total Length	12,000	ft
Cable Capacitance	0.64	μF
Capacitive Reactance	-4.14E+03	Ω
Charging current:	19.2	A
Reactive Power:	4.60	MVAR

Conduit Size	6	in
Conduit O.D.	6.625	in
Conduit E-E	3	in
Conduit C-C	9.625	in
Conduit C-C	0.2445	m



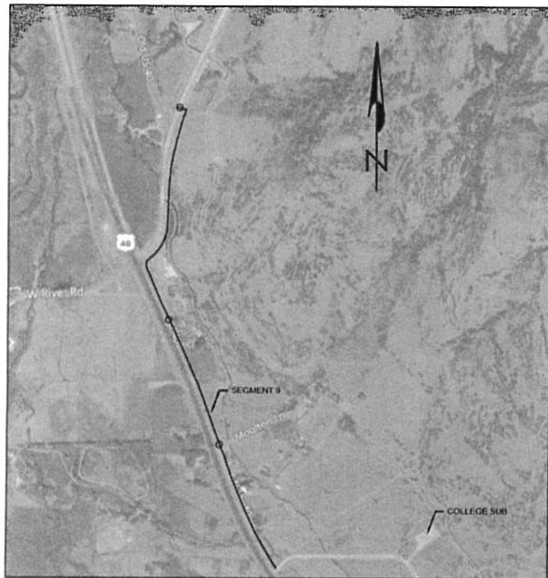
Parallel Circuit	1a,2b,3c,4a,5b,6c		1a,2b,3c,4c,5b,6a	
r_sm, mean shield diameter	0.0397	m	0.0397	m
S_12	0.2445	m	0.2445	m
S_13	0.4890	m	0.4890	m
S_14	0.2445	m	0.2445	m
S_15	0.3457	m	0.3457	m
S_16	0.5467	m	0.5467	m

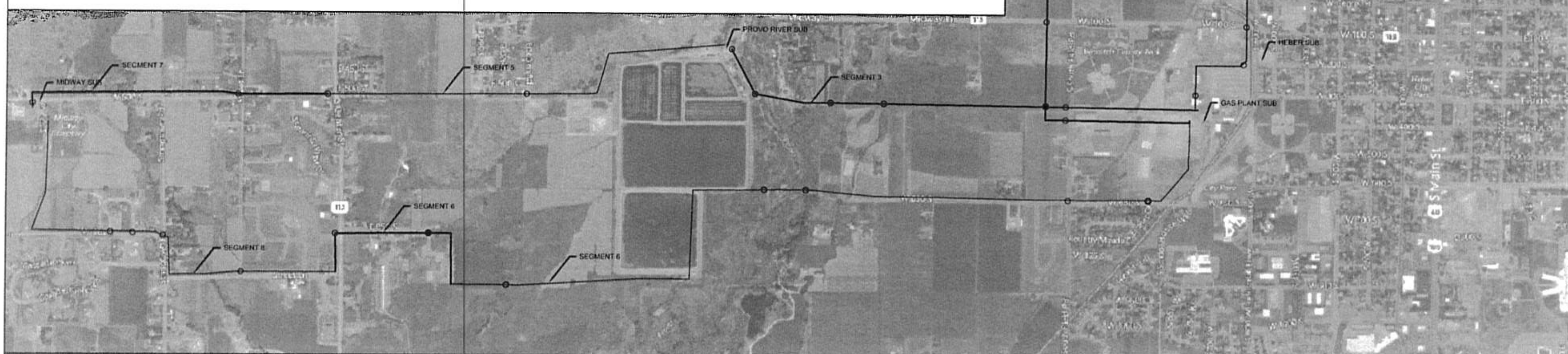
S_23	0.2445	m		0.2445	m		
S_24	0.3457	m		0.3457	m		
S_25	0.2445	m		0.2445	m		
S_26	0.3457	m		0.3457	m		
S_34	0.5467	m		0.5467	m		
S_35	0.3457	m		0.3457	m		
S_36	0.2445	m		0.2445	m		
S_45	0.2445	m		0.2445	m		
S_46	0.4890	m		0.4890	m		
S_56	0.2445	m		0.2445	m		
k	7.540E-05			7.540E-05			
Xaa	3.49E-04	0.0003494		2.89E-04	0.000288775383374467j		
Xab	1.86E-04	0.0001862		1.86E-04	0.000186287210032381j		
Xac	9.95E-05	0.0000994		1.60E-04	0.000160156176948737j		
Xbb	3.49E-04	0.0003494		3.49E-04	0.00034944976323981j		
Xbc	1.86E-04	0.0001862		1.86E-04	0.000186287210032381j		
Xcc	3.49E-04	0.0003494		2.89E-04	0.000288775383374467j		
Ia	-440.389221349829+762.			-440.389221			
Ib	880.778442699658			880.7784426			
Ic	-440.389221349829-762.7			-440.389221			
Ea0	-0.1906696919	0.19361		-0.09810770	0.1037	V/m	
Eb0	0.1437100595	0.14371		0.143710059	0.1437	V/m	
Ec0	0.1906696919	0.19361		0.098107708	0.1037	V/m	
Max Permissible Shield Voltage	120	V		120	V		
Max Section Length	2033	ft		2740	ft		

Transient Shield Voltage

I fault - 3 Phase	4000	A	
Section Length	2100	ft	
Ia	-2000+3464.10		
Ib	4000		
Ic	-2000-3464.10		
Ea0	0.47469111018	0.677	V/m
Eb0	0.54812608049	0.548	V/m
Ec0	-0.4746911101	0.677	V/m
Transient Shield Voltage	434	V	
Ratio S/d	4.122		
Est. Voltage Gradient	180	V/km/kA	
Est. Transient Shield Voltage	462	V	

PRELIMINARY
NOT FOR CONSTRUCTION
FOR REVIEW & APPROVAL ONLY






○ ▪ BORE LOCATION

NO.	DATE	DWN	CHK	REVISIONS
A	03/16/18	SAB	NCB	ISSUED FOR REVIEW
-	-	-	-	
-	-	-	-	
-	-	-	-	
-	-	-	-	
-	-	-	-	

HEBER LIGHT AND POWER
WASATCH COUNTY, UTAH

HEBER UNDERGROUND BORING PROPOSAL

PREPARED BY:
electric power engineering incorporated
P.O. Box 1265 Arvada, CO 80001
(303) 431-7895 www.nseng.com

DATE 03/16/18	SCALE NTS
JOB NO 3116.001	

C0-01

Appendix C Cost Details

nei incorporated electric power engineering

Project:	Heber Underground Cost Estimate					
By:	Carson Bates					
Date:	9-Apr-18					
Voltage (kV)	Min. Ampacity (A)	Power (MVA)	1-Circuit, Size (kcmil), Cu	1-Circuit, Size (kcmil), Al	2-Circuit, Size (kcmil), Cu	2-Circuit, Size (kcmil), Al
46	873	70	1000	1500	N/A	N/A
138	898	215	1250	2000	750	1000
Max Section Length (ft)	2100	Based on max cable per reel (2100ft), shield voltage (120V)				
		Directional Boring				
Roadway Bore (ft)	75	crossings of major roadways, boring length for this type is typically 30 to 40 feet wider than the road right of way.				
Waterway Bore (ft)	150	crossings of all major rivers and wastewater ditches. Boring length for this type can have a large range of variation. This depends on surrounding topography and environmental rights-of-way (potential 300' to 500' bore).				
Constructability Bore (ft)	50	could possibly be avoided with slight routing changes				

Assumes: Driveways can be trenched through, rather than bored. Waterways include all rivers and wastewater streams that are

Item	Unit Cost	Unit	Notes
138kV Bore	$100	$/ft	18" bore = $80~$125/ft per local REA
138kV Cable	$40	$/ft/phase	Per IEC
138kV Dead End Riser	$100,350	$/riser	Steel=29,250 lb@$2.20/lb+Concrete=6'x28'@$1200/yd
138kV Ductbank	$44	$/ft	Per IEC
138kV Splice	$4,000	$/splice/phas	Per TE Connectivity
138kV Substation Riser	$8,850	$/riser	Steel=2,200 lb@$1.75/lb+Concrete=2.5'x10'@$1200/yd
138kV SVL	$2,400	$/SVL (3ϕ)	Per TE Connectivity
138kV Termination	$5,800	$/term/phas	Per TE Connectivity
46kV Bore	$80	$/ft	18" bore = $80~$125/ft per local REA
46kV Cable	$40	$/ft/phase	Assumed equivalent to 138kV
46kV Dead End Riser	$50,175	$/riser	50% of 138kV
46kV Ductbank	$38	$/ft	Per IEC
46kV Splice	$3,830	$/splice/phas	Per TE Connectivity
46kV Substation Riser	$6,638	$/riser	75% of 138kV
46kV SVL	$2,800	$/SVL (3ϕ)	Per TE Connectivity
46kV Termination	$1,460	$/term/phas	Per TE Connectivity
Cable Vault	$23,000	$/vault	Per IEC
Cable Pulling	$10,500	$/pull/phase	Per IEC
Cable Splicing	$1,500	$/splice/phas	Per IEC
Install Equipment	$50,000	$/month	excavator, puller, reel trailer, telehandler per IEC
Dead End Setting and Dres	$45,000	$/riser	Setting $30k+Dress Out $15k
Substation Riser Setting an	$25,000	$/riser	Setting $10k+Dress Out $15k
Testing Cable	$3,000	$/section	Estimated

Segment	Length (ft)	Splices (2100ft)	Vaults	Roadway Bore	Waterway Bore	Constructability Bore	Deadend Riser	Substation Riser
1	9,602	5	5	6	1	0	1	1
2	14,391	7	7	4	1	1	1	1
3	7,367	4	4	2	3	0	0	2
4	13,178	7	7	1	3	1	1	1
5	6,342	4	4	1	0	0	1	1
6	3,051	2	2	1	0	1	2	0
7	4,594	3	3	2	0	0	1	1
8	6,696	4	4	4	0	0	1	1
9	6,280	3	3	3	0	0	0	0
Hwy 40 to Midway	37,316	18	18	10	4	3	1	3

Segment	Cable & Ductbank	Splices (2100ft)	Vaults	Roadway Bore	Waterway Bore	Constructability Bore	Deadend Riser	Substation Riser	Termination	Install Equipment	Cable Pull & Splice
1	$2,412,503	$60,000	$115,000	$45,000	$15,000	$0	$145,350	$33,850	$58,200	$48,010	$180,000
2	$3,615,739	$84,000	$161,000	$30,000	$15,000	$5,000	$145,350	$33,850	$58,200	$71,955	$252,000
3	$1,850,959	$48,000	$92,000	$15,000	$45,000	$0	$0	$67,700	$58,200	$36,835	$144,000
4	$3,310,973	$84,000	$161,000	$7,500	$45,000	$5,000	$145,350	$33,850	$58,200	$65,890	$252,000
5	$1,593,428	$48,000	$92,000	$7,500	$0	$0	$145,350	$33,850	$58,200	$31,710	$144,000
6	$766,564	$24,000	$46,000	$7,500	$0	$5,000	$290,700	$0	$58,200	$15,255	$72,000
7	$1,154,243	$36,000	$69,000	$15,000	$0	$0	$145,350	$33,850	$58,200	$22,970	$108,000
8	$1,682,370	$48,000	$92,000	$30,000	$0	$0	$145,350	$33,850	$58,200	$33,480	$144,000
9	$1,577,850	$36,000	$69,000	$22,500	$0	$0	$0	$0	$58,200	$31,400	$108,000
Hwy 40 to	$9,375,645	$216,000	$414,000	$75,000	$60,000	$15,000	$145,350	$101,550	$58,200	$186,580	$648,000

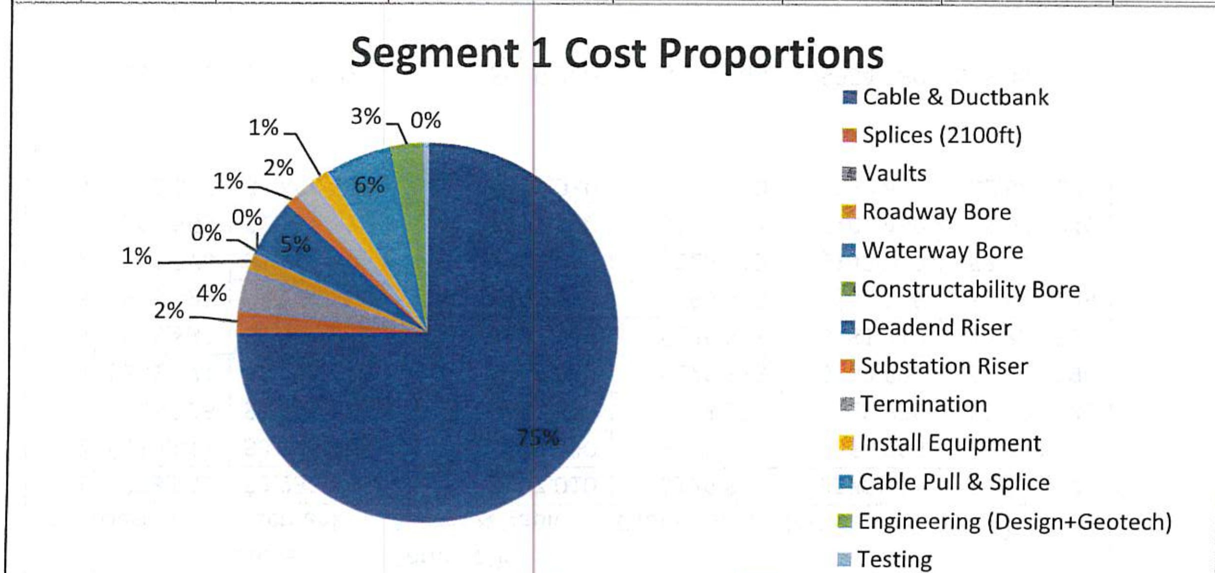
Total (+25% Contractor)	Engineering (Design+Geotech)	Testing	Total (+15% Contingency)	Spare (splice, SVL, term, 2100ft cable)
$3,891,141	$91,219	$15,000	$4,596,964	$96,200
$5,590,117	$136,715	$21,000	$6,610,006	$96,200
$2,947,117	$69,987	$12,000	$3,483,469	$96,200
$5,210,953	$125,191	$21,000	$6,160,716	$96,200
$2,692,547	$60,249	$12,000	$3,179,515	$96,200
$1,606,523	$28,985	$6,000	$1,887,734	$96,200
$2,053,266	$43,643	$9,000	$2,421,795	$96,200
$2,834,063	$63,612	$12,000	$3,346,126	$96,200
$2,378,688	$59,660	$9,000	$2,814,450	$96,200
$14,119,156	$354,502	$54,000	$16,706,807	$96,200

Segment	Cable & Ductbank	Splices (2100ft)	Vaults	Roadway Bore	Waterway Bore	Constructability Bore	Deadend Riser	Substation Riser	Termination	Install Equipment	Cable Pull & Splice
1	$2,232,465	$57,450	$115,000	$36,000	$12,000	$0	$95,175	$31,638	$34,560	$48,010	$180,000
2	$3,345,908	$80,430	$161,000	$24,000	$12,000	$4,000	$95,175	$31,638	$34,560	$71,955	$252,000
3	$1,712,828	$45,960	$92,000	$12,000	$36,000	$0	$0	$63,275	$34,560	$36,835	$144,000
4	$3,063,885	$80,430	$161,000	$6,000	$36,000	$4,000	$95,175	$31,638	$34,560	$65,890	$252,000
5	$1,474,515	$45,960	$92,000	$6,000	$0	$0	$95,175	$31,638	$34,560	$31,710	$144,000
6	$709,358	$22,980	$46,000	$6,000	$0	$4,000	$190,350	$0	$34,560	$15,255	$72,000
7	$1,068,105	$34,470	$69,000	$12,000	$0	$0	$95,175	$31,638	$34,560	$22,970	$108,000
8	$1,556,820	$45,960	$92,000	$24,000	$0	$0	$95,175	$31,638	$34,560	$33,480	$144,000
9	$1,460,100	$34,470	$69,000	$18,000	$0	$0	$0	$0	$34,560	$31,400	$108,000
Hwy 40 to	$8,675,970	$206,820	$414,000	$60,000	$48,000	$12,000	$95,175	$94,913	$34,560	$186,580	$648,000

Total (+25% Contractor)	Engineering (Design+Geotech)	Testing	Total (+15% Contingency)	Spare (splice, SVL, term, 2100ft cable)
$3,552,872	$73,935	$15,000	$4,188,078	$92,090
$5,140,831	$110,811	$21,000	$6,063,538	$92,090
$2,721,822	$56,726	$12,000	$3,209,130	$92,090
$4,788,222	$101,471	$21,000	$5,647,296	$92,090
$2,444,447	$48,833	$12,000	$2,881,072	$92,090
$1,375,628	$23,493	$6,000	$1,615,889	$92,090
$1,844,897	$35,374	$9,000	$2,172,661	$92,090
$2,572,041	$51,559	$12,000	$3,030,940	$92,090
$2,194,413	$48,356	$9,000	$2,589,534	$92,090
$13,095,022	$287,333	$54,000	$15,451,808	$92,090

Seg.	Length (mile)	OH 138kV & 46kV Shared Structure ($M)	UG 138kV & 46kV Separate Trench ($M)	UG/OH
1	1.8	$2.00	$8.79	4.4
2	2.7	$3.00	$12.67	4.2
3	1.4	$1.53	$6.69	4.4
4	2.5	$2.75	$11.81	4.3
5	1.2	$1.32	$6.06	4.6
6	0.6	$0.64	$3.50	5.5
7	0.9	$0.96	$4.59	4.8
8	1.3	$1.40	$6.38	4.6
9	1.2	$1.31	$5.40	4.1
Hwy 40 to Midway	7.1	$7.77	$32.16	4.1

For 138kV						
Seg.	Design	Cable & Ductbank	Terminations, Splices & Vaults	Cable Risers	Installation	Total[1]
1	$91,219	$2,412,503	$233,200	$179,200	$288,010	$4,596,964
2	$136,715	$3,615,739	$303,200	$179,200	$373,955	$6,610,006
3	$69,987	$1,850,959	$198,200	$67,700	$240,835	$3,483,469
4	$125,191	$3,310,973	$303,200	$179,200	$375,390	$6,160,716
5	$60,249	$1,593,428	$198,200	$179,200	$183,210	$3,179,515
6	$28,985	$766,564	$128,200	$290,700	$99,755	$1,887,734
7	$43,643	$1,154,243	$163,200	$179,200	$145,970	$2,421,795
8	$63,612	$1,682,370	$198,200	$179,200	$207,480	$3,346,126
9	$59,660	$1,577,850	$163,200	$0	$161,900	$2,814,450
Hwy 40 to Mid way	$354,502	$9,375,645	$688,200	$246,900	$984,580	$16,706,807
Both	$641,835	$18,051,615	$1,343,580	$436,988	$1,939,160	$32,158,615



For 46kV

Seg.	Design	Cable & Ductbank	Terminations, Splices & Vaults	Cable Risers	Installation	Total[1]
1	$73,935	$2,232,465	$207,010	$126,813	$276,010	$4,188,078
2	$110,811	$3,345,908	$275,990	$126,813	$363,955	$6,063,538
3	$56,726	$1,712,828	$172,520	$63,275	$228,835	$3,209,130
4	$101,471	$3,063,885	$275,990	$126,813	$363,890	$5,647,296
5	$48,833	$1,474,515	$172,520	$126,813	$181,710	$2,881,072
6	$23,493	$709,358	$103,540	$190,350	$97,255	$1,615,889
7	$35,374	$1,068,105	$138,030	$126,813	$142,970	$2,172,661
8	$51,559	$1,556,820	$172,520	$126,813	$201,480	$3,030,940
9	$48,356	$1,460,100	$138,030	$0	$157,400	$2,589,534
Hwy 40 to Mid way	$287,333	$8,675,970	$655,380	$190,088	$954,580	$15,451,808