PLANNING COMMISSION MEETING STAFF REPORT

DATE OF MEETING: May 14, 2019

NAME OF PROJECT: Transmission Line Rebuild along 970 South, Stringtown Road, and Wards Lane

NAME OF APPLICANT: Rocky Mountain Power and Heber Light and Power

AGENDA ITEM: Conditional Use Permit

LOCATION OF ITEM: 970 South, Stringtown Road, and Wards Lane

ZONING DESIGNATION: R-1-15 & R-1-22

ITEM: 2

Rocky Mountain Power and Heber Light and Power are requesting a Conditional Use Permit to rebuild an existing Heber Light and Power transmission line and install a 138kV line for Rocky Mountain Power that will be located on the Heber Light and Power poles. Heber Light and Power would also have a 46 – 138 KV line on the same pole. The proposal will establish a second transmission interconnection which will strengthen service reliability and increase capacity in Midway and the surrounding area. It also creates a "loop" for RMP increasing their capacity to deliver power to a larger area. The portion in Midway is about one mile in length and will following the existing transmission line along Wards Lane, Stringtown Road, and 970 South. The proposed tangent poles range in height from 70'-85' above ground and the dead end poles and crossing poles range in height from 80' – 110' above ground.

BACKGROUND:

This request for a Conditional Use Permit (CUP) by Rocky Mountain Power and Heber Light and Power to rebuild the existing transmission line and install a 138kV line for Rocky Mountain Power that will be located on the Heber Light and Power poles. As part of the proposal, the distribution and communication lines that currently are located on the transmission line poles will be buried along the route. The proposal will establish a second transmission interconnection which will strengthen service reliability and increase capacity in Midway and the surrounding area. The portion in Midway is about one mile in length and will following the existing transmission line along Wards Lane, Stringtown Road, and 970 South. The proposed poles tangent poles range in height from 70'-85' above ground and the dead-end poles and crossing poles range in height from 80' – 110' above ground.

The plan is to use many of the existing easements, which include prescriptive easements, through property in the city limits. The prescriptive easements are not wide enough for the proposed transmission lines so additional easements will need to be acquired to accommodate the wider easements necessary for the new lines. The proposed poles will be taller than the existing poles along the route in question and will carry considerably more power than what the current transmission lines carry. Heber Light and Power has stated that the main reason for this proposal is to have a second source of power into the Heber Valley. Another reason for the proposal is to increase power capacity for the Heber Valley that is needed because of development and growth. Rocky Mountain Power is an applicant for the conditional use permit because they would like a transmission to connect their areas of service in Summit County and Utah County. Rocky Mountain Power will pay 80% of the cost of the proposed line which will in turn save Heber Light and Power rate payers the cost that would have been required if Heber Light Power were to fix the aforementioned issues on its own. Heber Light and Power rate payers may see an increase in rates though based on the 20% of the transmission line cost that Heber light and Power is paying for the transmission lines.

Midway residents are concerned about how this upgraded and larger line will impact them. Staff has received comments that range from aesthetics, health concerns, property value concerns, and lack of additional options.

The City recently adopted a transmission line code on January 15, 2019 to regulate the processing and requirements regarding new transmission lines and the rebuilding of existing transmission lines. This code is Section 16.13.47 in the Midway City Municipal Code (please see attached to this report).

The applicant has submitted the following studies and reports to the City, two of which are attached to this report. All studies are all available at the Planning Office and on the City's website.

- Underground Transmission Cost/Feasibility Study
- Transmission Lines and Property Values: Review of the Research
- EMF Electric and Magnetic Fields Associated with the Use of Electric Power
- Powering Our Future: Summit Wasatch Electrical Plan Local Planning Handbook

Section 16.13.47 Transmission Line Code Requirements and Comments

Section 16.13.47 (D)(1) prefers that transmission lines follow routes where transmission lines are currently located. The proposal does follow the current location of transmission lines along 970 South, Stringtown Road, and Wards Lane.

Section 16.13.47 (D)(2) prefers the shortest poles allowed by industry standards though all options should be considered for aesthetics and for harmonizing with the vision of Midway City as described in the General Plan. Generally, taller poles will reduce the number of poles and shorter poles will increase the number poles. The proposal is to replace the existing poles that are 55' – 65' in height with new wood tangent poles that are 70'-85' above ground and the dead-end poles and crossing poles range in height from 80' – 110' above ground. The City has not received exact height for the poles but there will be three dead end poles where the transmission lines change direction at the intersection of Stringtown and 970 South, the intersection of Stringtown and Wards Lane, and on Wards Lane where the line heads north to the substation next to the Midway cemetery. Wood poles are will be taller than metal poles even though the same amount of power are carried by both. Wood poles may be preferred though because currently, there are wood poles along this route and second because they don't feel as industrial as metal poles. The height and number of poles is an item the Planning Commission and City Council can determine.

Section 16.13.47 (D)(3) limits the types of poles that are allowed and focusses on the visual impact of the poles and lines. No galvanized poles, or poles with other reflective material can be used. Pole color and material shall be focused on minimizing the visual impact of the transmission line. The City may consider wood poles or metal poles. If metal poles are used, then the City can determine the color that will minimize the visual impact on the community.

Section 16.13.47 (D)(4) allows the City to impose any reasonable restrictions on the conditional use.

Section 16.13.47 (E) allows the City to require the burial of transmission lines and distribution lines that share a transmission line pole. The applicant has stated that distribution and communication lines will be buried. The cost of burying the distribution lines will be paid for by the Heber Light and Power rate payers. The applicants and City will need to work with the communication line companies to have the communication lines buried. Heber Light and Power has offered to install conduit for the communication companies when the conduit for the distribution lines is installed.

The City may, after consideration of cost, require the transmission lines to be buried. Burying the transmission lines will have a positive visual impact on the community by eliminating all current lines and future transmission lines along this specific route. Financially, the difference in cost of above ground lines and buried lines would need to be paid by the City or some other funding source by private individuals. The amount required would need to be paid within 30 days after approval is granted. The limited time allowed to pay for the difference in cost creates complications that would need to be considered.

ANALYSIS:

The comments in italicized represent Planning Staff's comments pertaining to compliance or lack of compliance with the findings. The Planning Commission must make in considering this request. Section 16.26.120 requires specifically the Planning Commission to find that:

1. The proposed use is conditionally permitted within the Land Use Title, and would not impair the integrity and character of the intended purpose of the subject zoning district and complies with all of the applicable provisions of this Code; *planning staff believes that the proposal will have an impact on the properties along the route and on the entire community. There will be a visual impact that will be greater with the new proposal than the existing lines. In one way the impact will be diminished, and this is because of the removal of the distribution and communication lines. This will help the area feel less busy. Some of the other impacts may be on property values and depending on which study is considered, health.*

2. The proposed use is consistent with the General Plan; *the proposed use will create a greater visual presence for the transmission line because of the increased height. The General Plan describes the surrounding zones as an area of relatively large lots in an agricultural setting. The proposed lines will not be in harmony with this description though lines do currently exist along this route and have for several decades.*

3. The approval of the conditional use or special exception permit for the proposed use is in compliance with the requirements of state, federal and Midway City or other local regulations; *the proposal is required to comply with all federal, state and local requirements and staff has not identified any noncompliant issues at this point.*

4. There will be no potential, significant negative effects upon the environmental quality and natural resources that could not be properly mitigated and monitored; *the City may require and environmental impact study for the proposed conditional use per Section 16.13.47 (C)(4). This is a report the City may require if deemed necessary.*

5. The design, location, size, and operating characteristics of the proposed use are compatible with the existing and future land uses with the general area in which the proposed use is to be located and will not create significant noise, traffic, or other conditions or situations that may be objectionable or detrimental to other permitted uses in the vicinity or adverse to the public

interest, health, safety, convenience, or welfare to the City; *the proposed use will supply power to the Heber Valley which is important to all residents. The proposal will also provide redundancy to the power supply so if a fire or some other natural disaster disrupts one of the sources of power to the valley there will be another route for power supply. Regarding health, there are studies that argue that transmission lines have a negative impact on the health of those that live nearby and there are studies that argue that there is no negative health impact on surrounding neighbors. The City may want to consult experts regarding this issue.*

6. The subject site is physically suitable for the type and density/intensity of the proposed use; *the proposed location has had transmission lines for decades. It is debatable if increasing the transmission lines will create an intensity that is unsuitable for the subject site. The City may require additional studies, including an environmental impact study, to help answer this question.*

7. There are adequate provisions for public access, including internal and surrounding traffic flow, water, sanitation, and public utilities, and services to insure that the proposed use would not be detrimental to public health and safety; *The debate of the effects of EMF (electromagnetic field) are strong on both sides. However, the proposal will create more access to power and create a redundancy that will benefit the community which should have a positive impact on the community as a whole.*

POSSIBLE FINDINGS:

- The proposal is an administrative review and approval
- The proposed use is a conditional use and the city may impose reasonable conditions to mitigate identified issues
- The proposal includes taller poles that will be visible to the residents of Midway, visitors of Midway, and the surrounding residents of Wasatch County
- The distribution and communication lines will be buried to help declutter the current transmission line situation, and reduce the weight being carried by the poles, thus reducing poles in the area
- The proposal will create a second point of power access that will benefit the residents of the valley
- The proposal will allow more power to enter the valley that will benefit the entire community by meeting community needs

ALTERNATIVE ACTIONS:

1. Recommendation for approval (conditional). This action can be taken if the Planning Commission feels the application complies with the requirements of the code and any conditions will mitigate identified issues.

    a. Accept staff report
    b. List accepted findings
    c. Place condition(s)

2. Continuance. This action can be taken if the Planning Commission feels that there are unresolved issues.

    a. Accept staff report
    b. List accepted findings
    c. Reasons for continuance
        i. Unresolved issues that must be addressed
    d. Date when the item will be heard again

3. Recommendation of denial. This action can be taken if the Planning Commission feels that the request does not meet the intent of the ordinance.

    a. Accept staff report
    b. List accepted findings
    c. Reasons for denial

PROPOSED CONDITIONS:

As the review process continues, conditions will be created based on public comment, Planning Commission discussion, and City Council discussion.

Section 16.13.47 Transmission Lines

A. Transmission Lines are a conditional use in all zones.

B. The purpose of this section is to regulate all electric transmission lines that exceed 55 feet in pole height above grade. It is not the intent of this section to regulate the replacement or maintenance of existing transmission lines that exceed 55 feet in pole height. Existing transmission poles that currently exist within City boundaries, so long as they are replaced with a pole of identical height, diameter, and material, no permit nor approval shall be required. A proposal to alter the height, diameter, or material of existing transmission lines that exceed 55 feet shall require a conditional use permit under this section.

C. Prior to beginning construction on any new or proposed power transmission line that exceeds 55 feet in pole height above grade within any portion of the Midway City boundaries, a power company shall:

1. Apply for and receive approval of a conditional use permit as set forth in this title.

2. In addition to the information required in the application process as set forth in this title, the applicant shall also provide all information, design criteria, and studies deemed necessary by the City Planner, including, but not limited to:
1) the cost and pole height of standard transmission poles with height included for distribution lines;
2) the cost difference and pole height difference of burying just the distribution lines; 3) the cost difference of burying both the transmission and distribution lines; and
4) alternate routes for the transmission line (if not proposed within an existing and historical easement), including cost differential and studies on which route has the least impact on surrounding areas. Any requested studies shall be thorough and may include environmental impact studies, studies to determine costs of different options, and studies to determine the visual and aesthetic impact of the proposed transmission line project. At the City's sole discretion, the City may require outside third-party providers to conduct some or all of the studies, do independent studies, or to review the studies prepared by the applicant and verify the information contained therein. All reasonable costs incurred by third party studies shall be borne by the applicant.

3. Notice requirements shall comply with Section 16 of the Midway City Code and shall include notice to all property owners within 600' of the proposed route of the transmission line.

D. Preferred Conditions on any above ground transmission power lines located within the boundaries of Midway City:

1. Existing Easement Restrictions: New lines shall be preferred in corridors where existing 46kv lines are already in place.

2. Height and Span Restrictions: There shall be a preference for the shortest poles allowed by industry standards, considering the impact a shorter or longer span between poles may have on the view corridor. All options will be considered for aesthetics and for harmonizing with the vision of Midway City

as described in the General Plan.

3. Aesthetic Restrictions: No galvanized poles, or poles with other reflective materials shall be used. Pole color and material shall be focused on minimizing the visual impact of the transmission line. Wood poles will also be considered.

4. Other restrictions as reasonably imposed by the City.

E. City's option to require burial of transmission lines, or distribution lines that share the transmission line pole.

1. It is Midway City's objective to minimize the visual and aesthetic impact of above ground transmission lines within Midway City.

2. Midway City Council shall have the option of requiring transmission power lines approved under this section to be buried within the Midway City limits. Midway City Council shall also have the option of requiring just the distribution lines that commonly share the poles of transmission lines to be buried, if such a requirement would lower the overall height of the transmission poles.

3. As set forth above, to aid Midway City Council in making its determination, Applicant shall be required to submit studies that establish:
a) the cost and pole height of standard transmission poles with height included for distribution lines;
b) the cost difference and pole height difference of burying just the distribution lines;
c) the cost difference of burying both the transmission and distribution lines; and
d) alternate routes for the transmission line (if not proposed within an existing and historical easement), including cost differential and studies on which route has the least impact on surrounding areas.

4. Prior to making any decision, the City shall carefully review the different costs associated with each option.

5. Any requirements imposed by the City to bury some or all of either the transmission lines or distribution lines shall be subject to then existing law that may require the City to cover some or all of the costs.

6. In making the decision to bury some or all of the transmission or distribution lines, Midway City Council shall be allowed to consider all reasonable information available to it and shall not be limited to just an analysis of cost as the determining factor.

ROCKY MOUNTAIN POWER
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****Due to the size of Exhibit B and C, printed copies are not available in this document.

Please see the electronic version on our website to view these exhibits.****

Jordanelle – Midway Transmission Line

Amended and Supplemented Application for Conditional Use Permit

The Heber Valley and surrounding region have, for some time, experienced growth in demand on the Applicants' electric systems and in the very near future the existing facilities are projected to no longer provide adequate electrical service. To address this growth and to continue providing safe, reliable, cost effective power to customers the Applicants must upgrade existing facilities and build new facilities in the Heber Valley area of Wasatch County. The facilities requested in this application will bring capacity and reliability to the Applicants' customers in Wasatch County.

The project in this application connects the 138kV line along the old Highway 40 south of Jordanelle reservoir to the 138kV substation west of the Midway Cemetery, establishes a second transmission interconnection west of the sewer ponds, and rebuilds the south line that generally follows 650 South from Midway Cemetery to the Gas Plant Substation east of the County Special Events Center and to College Substation north of the Utah Valley University campus. Reference the supplemented and amended application for more detailed routing.

These facilities will provide needed redundancy and capacity to serve the Heber Valley now and into the future. These facilities allow the utility to provide uninterrupted power to the Heber Valley area if an outage occurred on the existing sole transmission interconnect and increases the amount of electricity that can be delivered from the regional transmission system. These facilities will strengthen service reliability and increase capacity in Heber Valley, Wasatch County, and surrounding communities.

The facilities in this application are for Rocky Mountain Power and Heber Light & Power's immediate system needs. Each company will own a transmission circuit that will be on a single set of poles. Siting both utilities' facilities together results in a single pole line. This means fewer facilities and lower construction costs which are ultimately paid in electric rates.

The first phase of the project was approved by the County's Planning Commission and construction was completed in 2014. The second phase was approved by the County's Planning Commission and was completed in early 2018. These two phases run approximately two (2) miles on the east side of Utah State Road 40 from College Substation to approximately 950 North. The rest of the transmission line is targeted for construction from fall 2019 – fall 2020. Design and material procurement needs to begin by early spring 2019 to maintain the project schedule.

This Planning Commission first heard this application in late 2017 where it requested a cost estimate to place these facilities underground and tabled the application. As requested by this Commission, Applicant obtained an estimate of the excess costs to place these facilities underground and has included the results of this study in this supplement.

Also, since the initial hearing, a Planning Commission work session was held where the results of the study were reviewed, Heber Light & Power's Power Board reviewed the facilities a second time,

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and the Heber Light & Power Power Board voted it would not fund the excess costs to place these facilities underground and the line should be constructed overhead.

As discussed at the hearing and the work session, Wasatch County has the right to approve this Conditional Use Application with the condition that the facilities be constructed underground pursuant to Utah Code 54-14-201. Pursuant to Utah Code 54-14-203, the County would have 30 days to pay the estimated additional costs to the Applicant or the condition becomes obsolete.

The Planning Commission should note the Applicants have reduced the number and height of poles by eliminating distribution facilities where not immediately needed. These changes are included in this amended application.

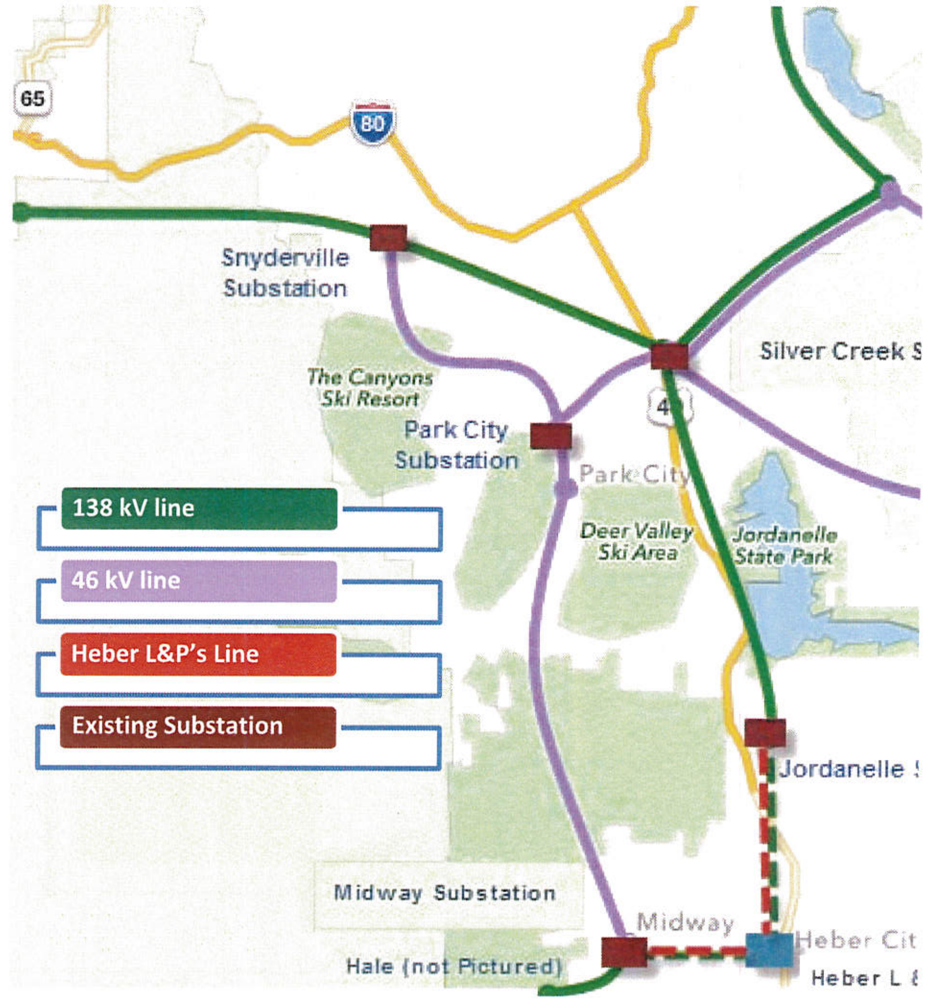
The Applicants have provided the requested studies and Heber Light & Power's Board has approved the facilities in this application for a second time with some facility reductions. This project needs to move forward to complete design, procure equipment, and construct these needed facilities. Applicants hereby respectfully request this application be heard as soon as possible and the Planning Commission approve this amended conditional use permit application.

Sincerely,

Heber Light & Power / Rocky Mountain Power
Joint Transmission project – Wasatch County CUP
Jason Norlen, General Manager HLP
Harold Wilson, Operations Manager HLP
Ben Clegg, Project Manager RMP
Travis Jones, Regional Business Manager

Midway - Jordanelle Project

- Approximatly 10 mile transmission line project. Work includes rebuilding an existing line and building a new line that will share one set of poles.
- The first two miles of the project have been permitted and built.
- The project will follow existing transmission lines, highways and proposed highways.
- Design and material procurement are planned for 2019. Construction is planned for 2020.
- The line will bring added capacity and increased reliability to Wasatch County.
- A substation upgrade will be completed in Midway substation's existing fenceline to accomodate the new 138,000 Volt line.
- A new substation will be the second tranmission point of delivery immediately west of the Sewer Ponds.
- Line routing and substation locations are included in this application.



Jordanelle - Midway
Wasatch County 1 of 3
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Tangent poles 65' – 90' above ground.
Dead-End and crossing poles 80' – 110' above ground.
Four poles and the distribution conductors were removed along highway 40.
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3000 ft
Google earth
©2018 Google


Jordanelle - Midway
Wasatch County 2 of 3
Tangent poles 70' – 85' above ground.
Dead-End and crossing poles 80' – 110' above ground.
Five poles and the distribution conductors were removed in the north fields.
Tangent poles 70' – 85' above ground.
Dead-End and crossing poles 80' – 110' above ground.
New distribution conductors were removed.
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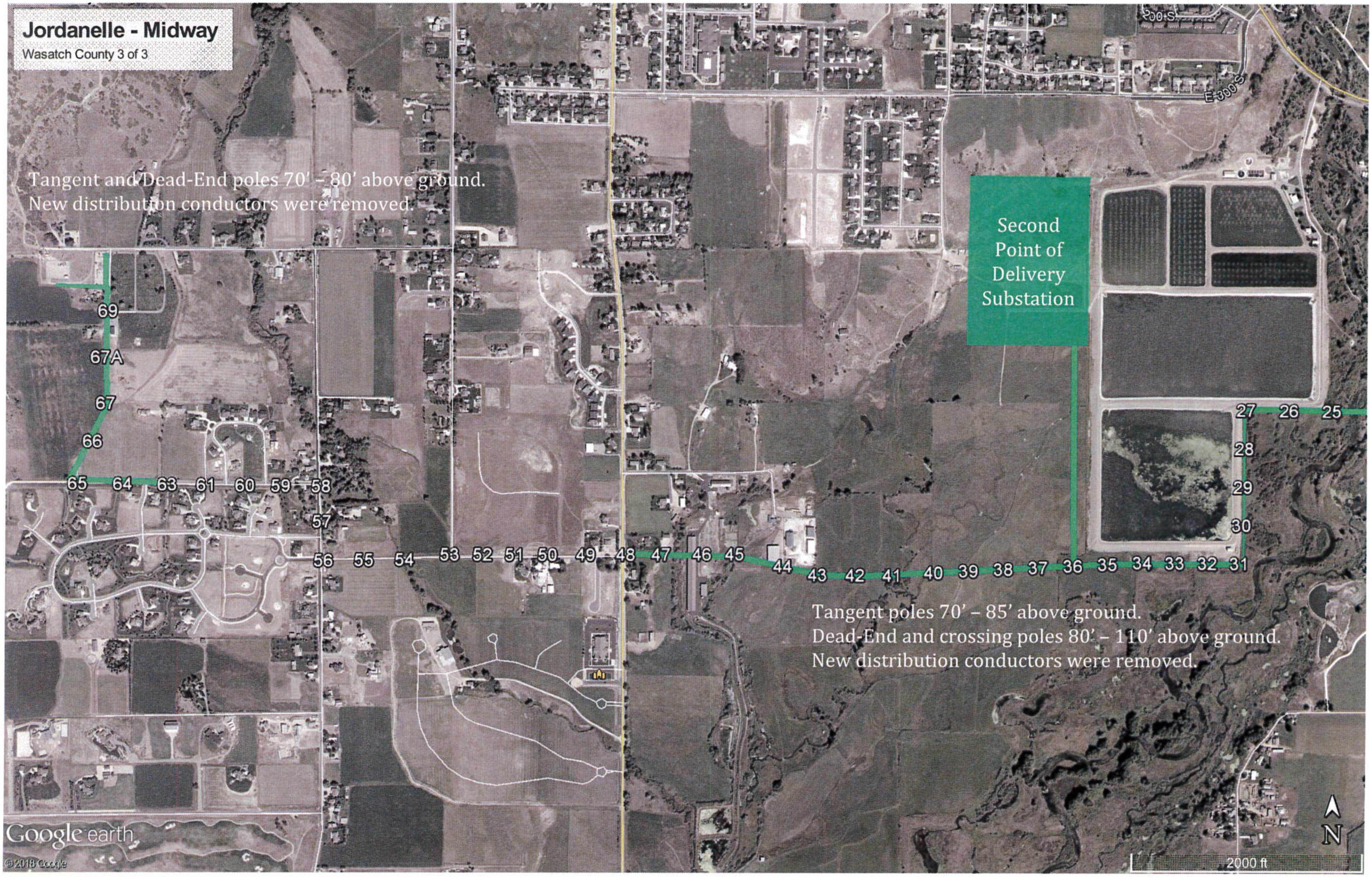
Jordanelle - Midway
Wasatch County 3 of 3
Tangent and Dead-End poles 70' – 80' above ground.
New distribution conductors were removed.
Second Point of Delivery Substation
Tangent poles 70' – 85' above ground.
Dead-End and crossing poles 80' – 110' above ground.
New distribution conductors were removed.
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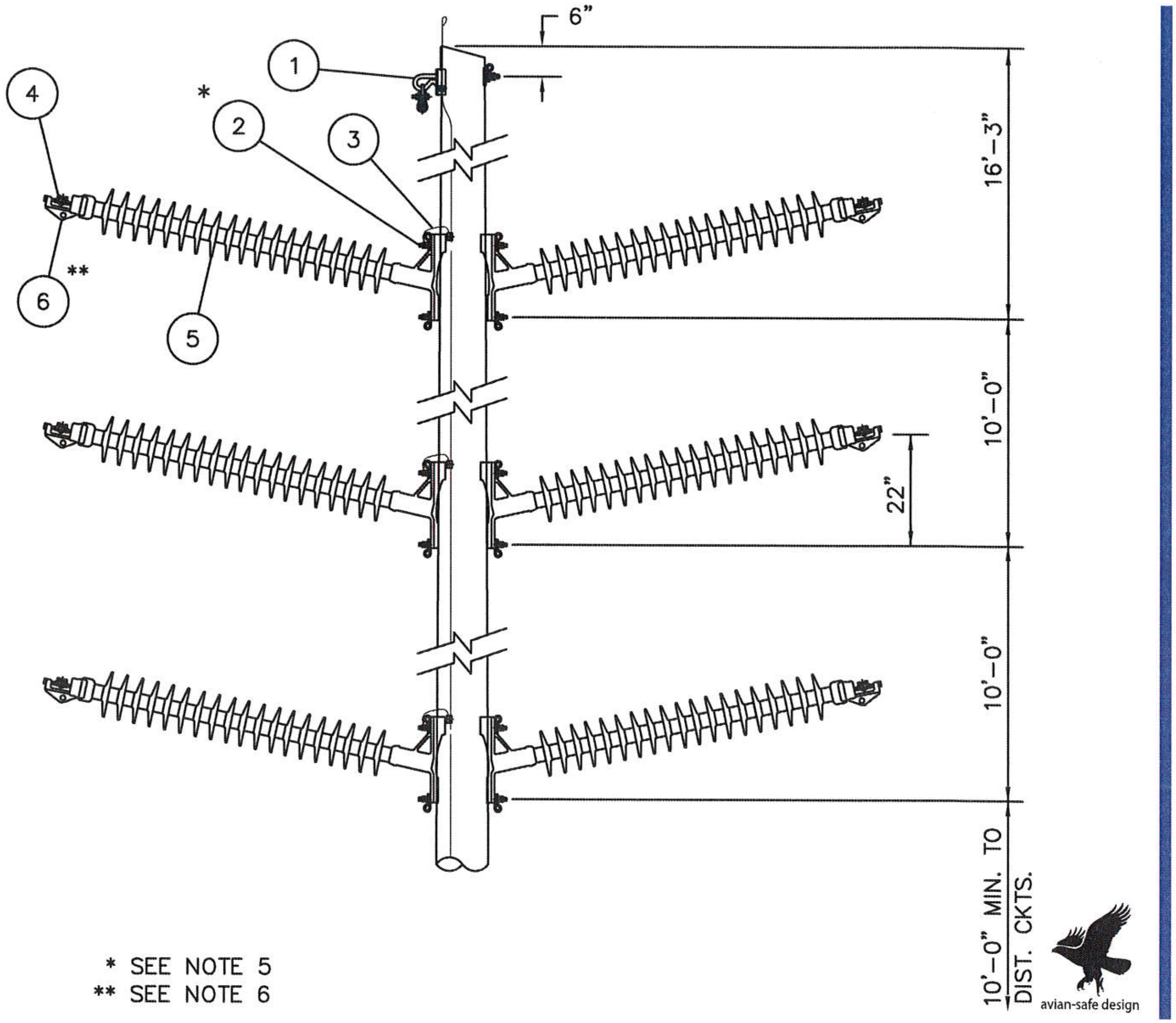
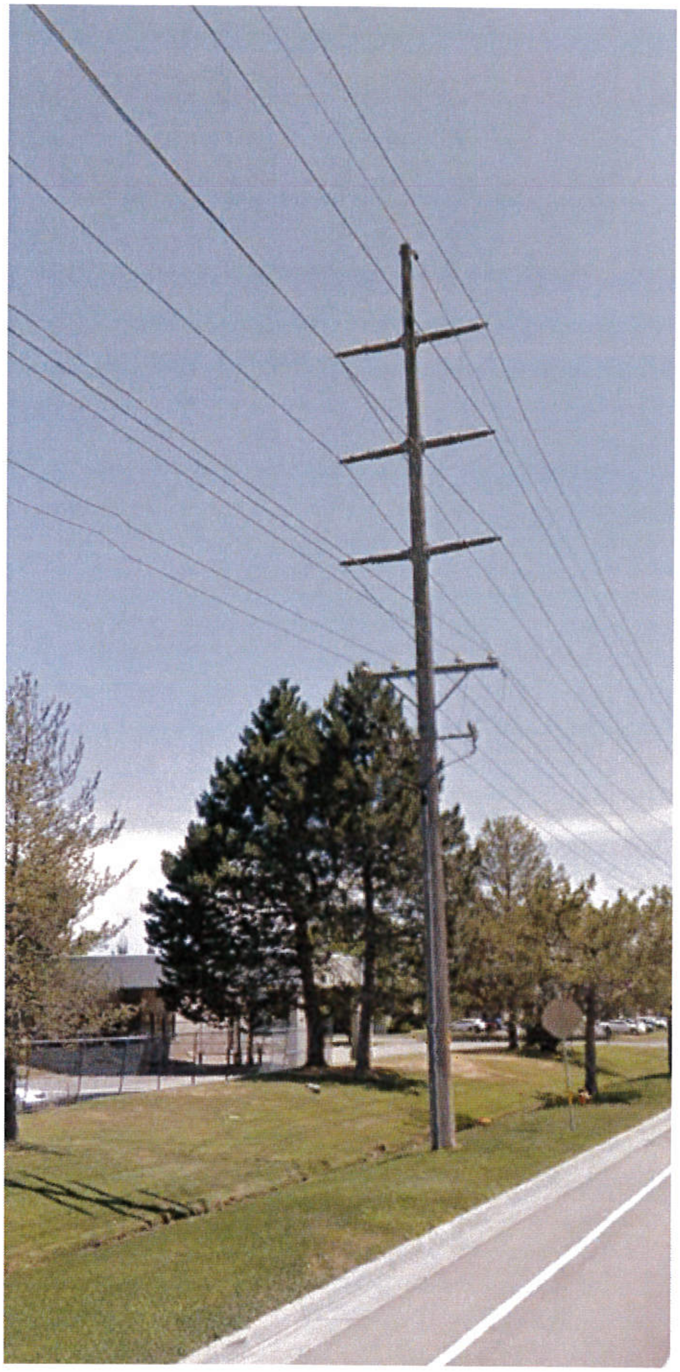
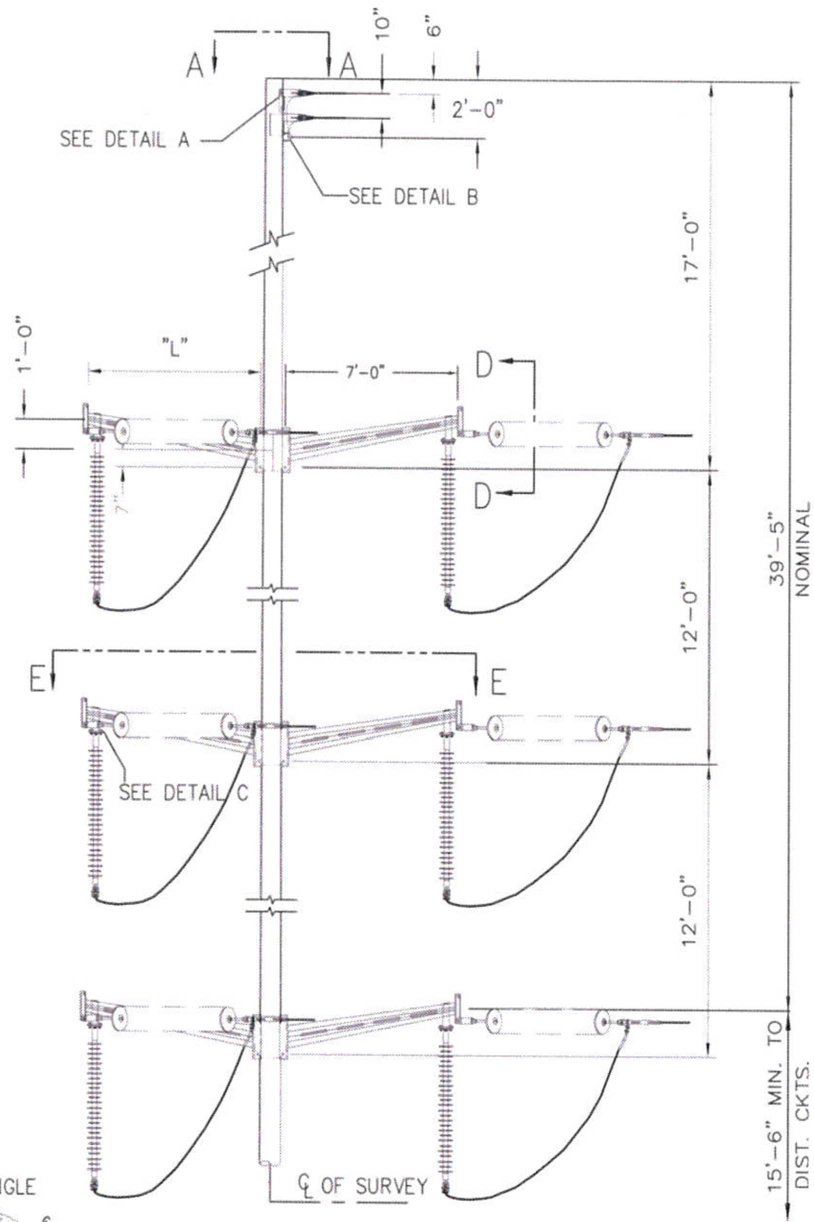
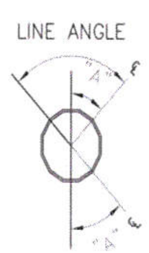


Figure 1—Structure Layout





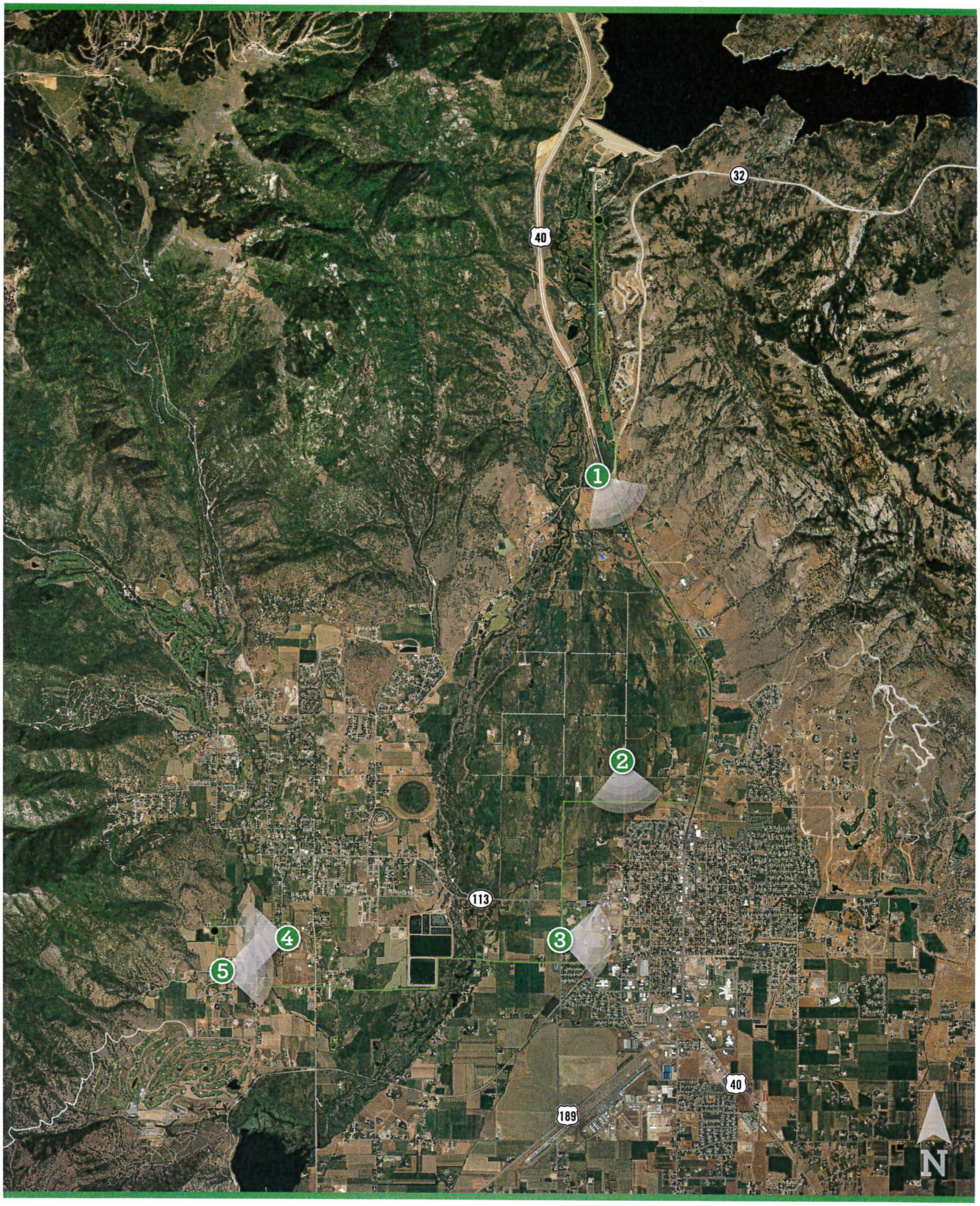


DIMENSION TABLE

LINE ANGLE	"A"	"L"
0°–30°	0°–15°	7'–0"
30°–60°	15°–30°	8'–0"
60°–90°	30°–45°	9'–0"

avian-safe design

Figure 1—Structure Layout



— TRANSMISSION LINE TO BE REBUILT

1 VIEWPOINT LOCATION

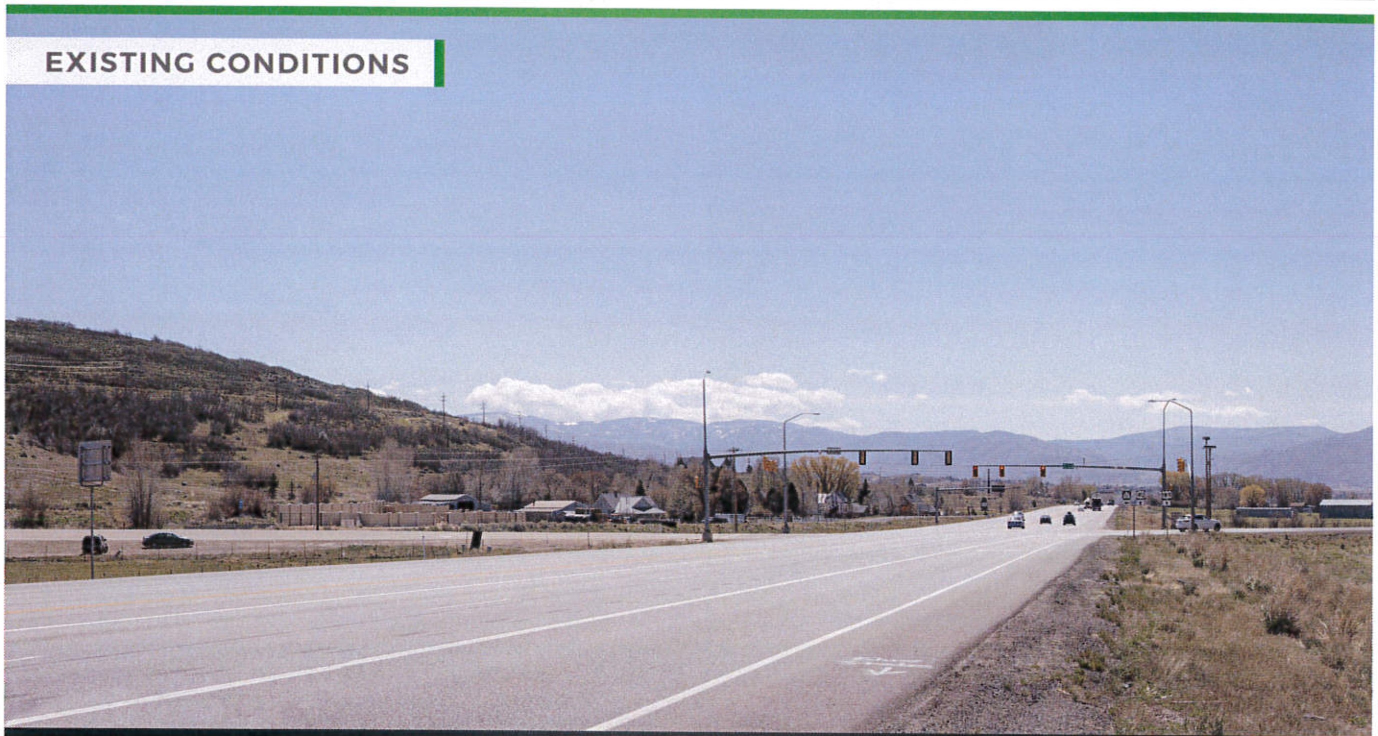
● SUBSTATION

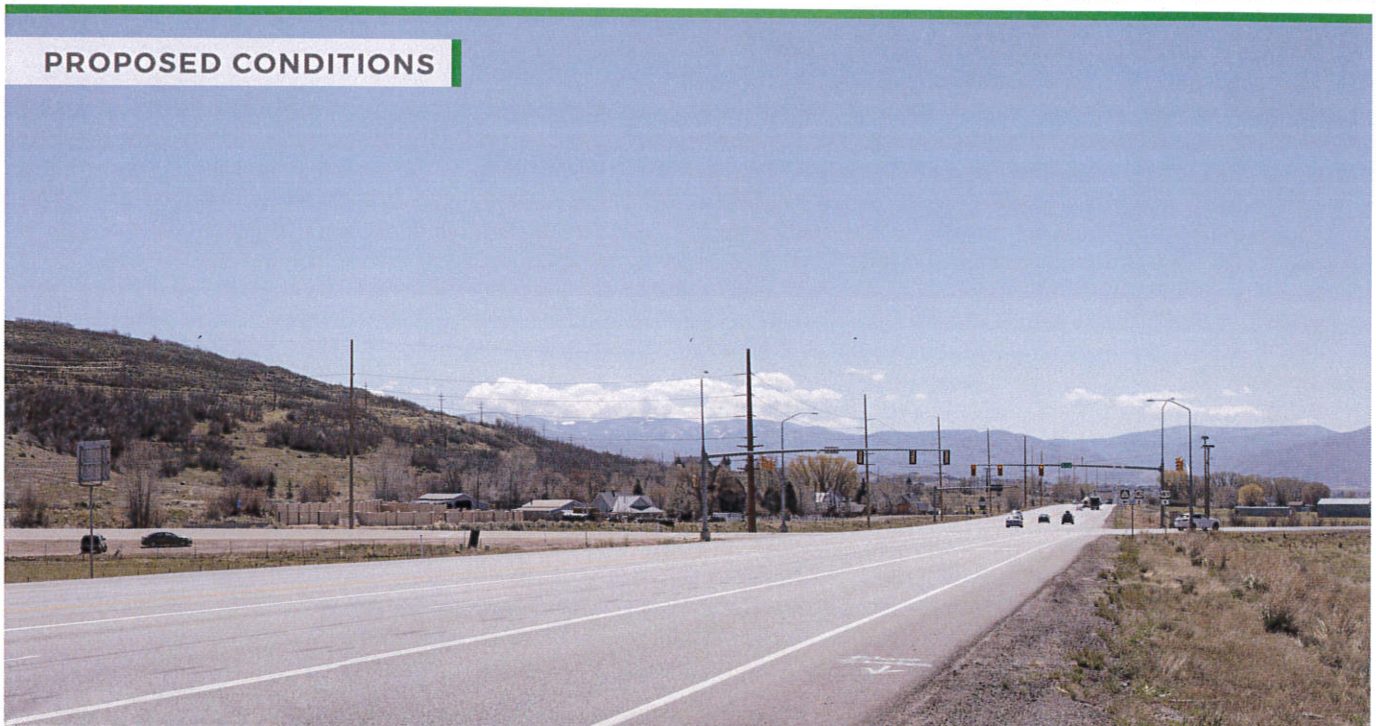
JORDANELLE TO MIDWAY

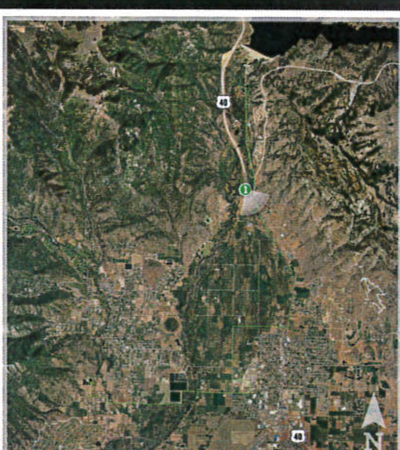
TRANSMISSION LINE UPGRADE PROJECT

Heber Light & Power

PHOTO SIMULATION BY: POWER ENGINEERS







JORDANELLE TO MIDWAY

TRANSMISSION LINE UPGRADE PROJECT

PHOTO SIM VIEWPOINT 1

— TRANSMISSION LINE TO BE REBUILT

① SIMULATION VIEWPOINT LOCATION

PHOTO SIMULATION BY POWER ENGINEERS

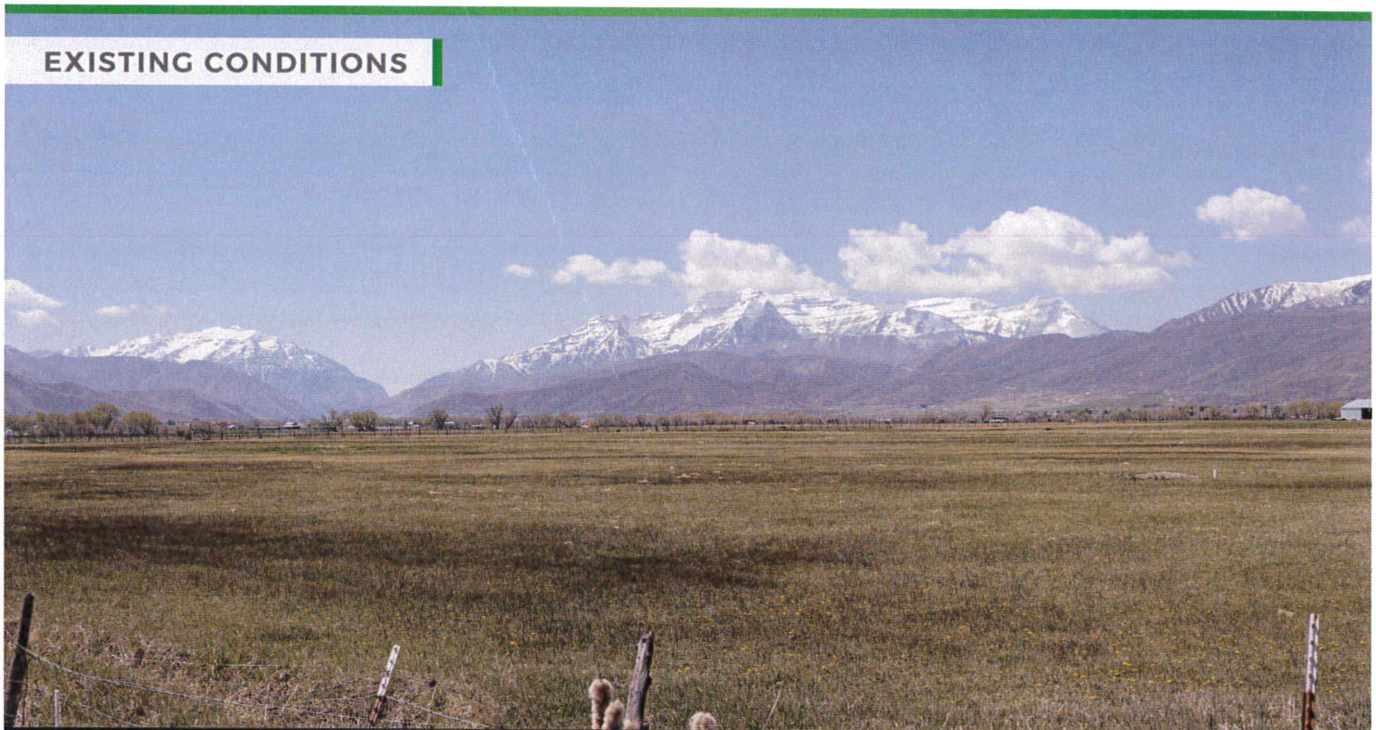
DATE: 04/24/2018

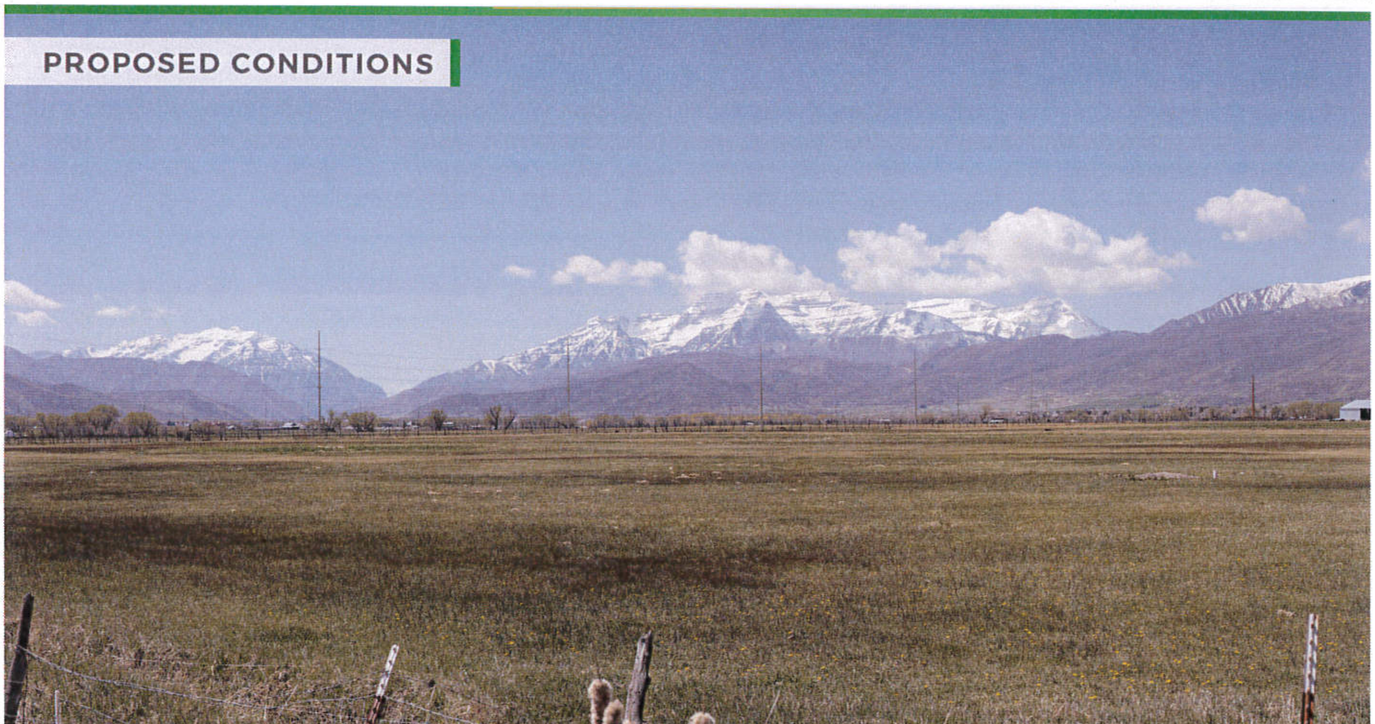
TIME: 11:45 AM

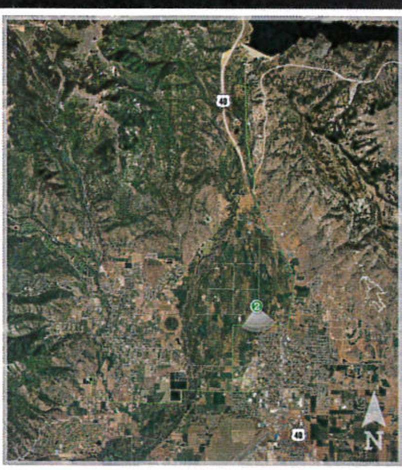
DIRECTION: SOUTHEAST

Heber Light & Power

PHOTO SIMULATION IS FOR DEMONSTRATION PURPOSES ONLY. FINAL DESIGN IS SUBJECT TO CHANGE PENDING PUBLIC, ENGINEERING, AND REGULATORY REVIEW.







JORDANELLE TO MIDWAY

TRANSMISSION LINE UPGRADE PROJECT

PHOTO SIM VIEWPOINT 2

— TRANSMISSION LINE TO BE REBUILT

② SIMULATION VIEWPOINT LOCATION

PHOTO SIMULATION BY POWER ENGINEERS

DATE: 04/24/2018

TIME: 12:26 PM

DIRECTION: SOUTH

Heber Light & Power

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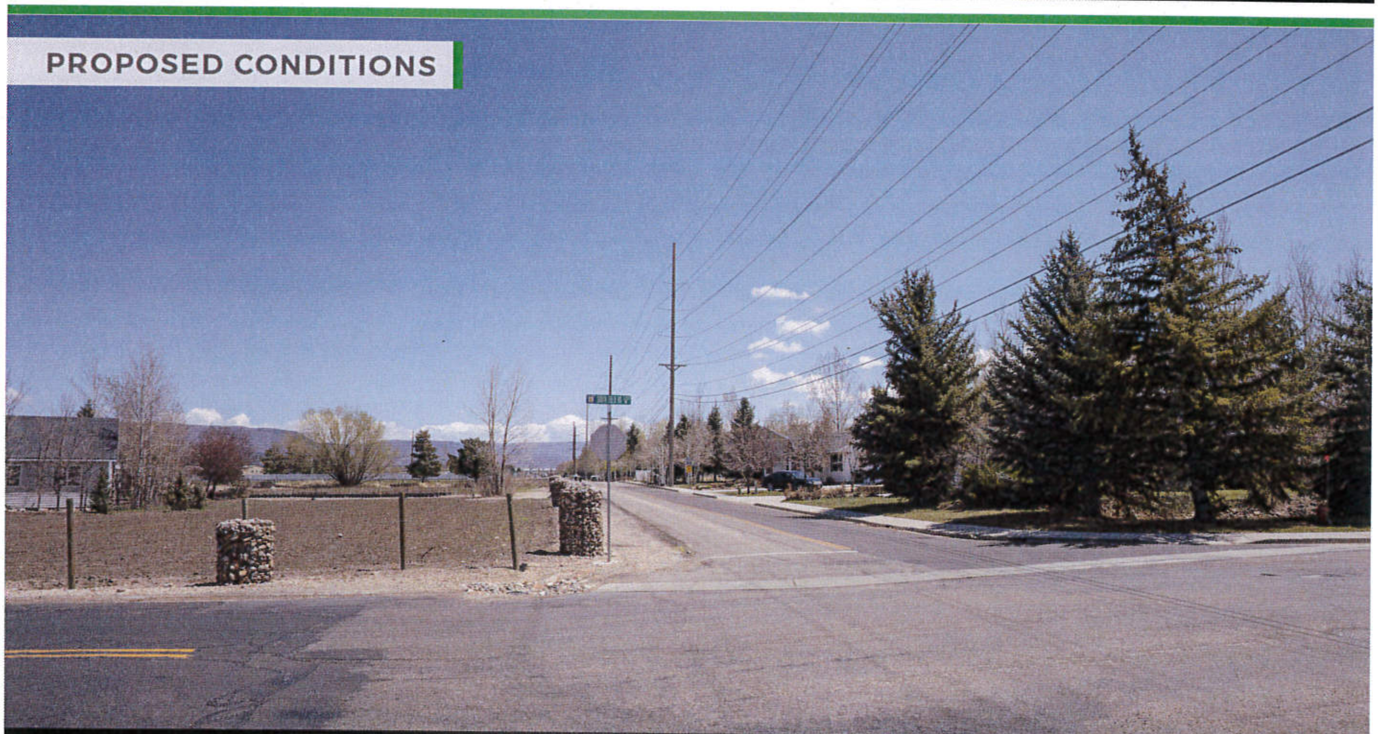

JORDANELLE TO MIDWAY

TRANSMISSION LINE UPGRADE PROJECT

PHOTO SIM VIEWPOINT 3

— TRANSMISSION LINE TO BE REBUILT

③ SIMULATION VIEWPOINT LOCATION

PHOTO SIMULATION BY POWER ENGINEERS

DATE: 04/24/2018

TIME: 1:12 PM

DIRECTION: EAST

Heber Light & Power

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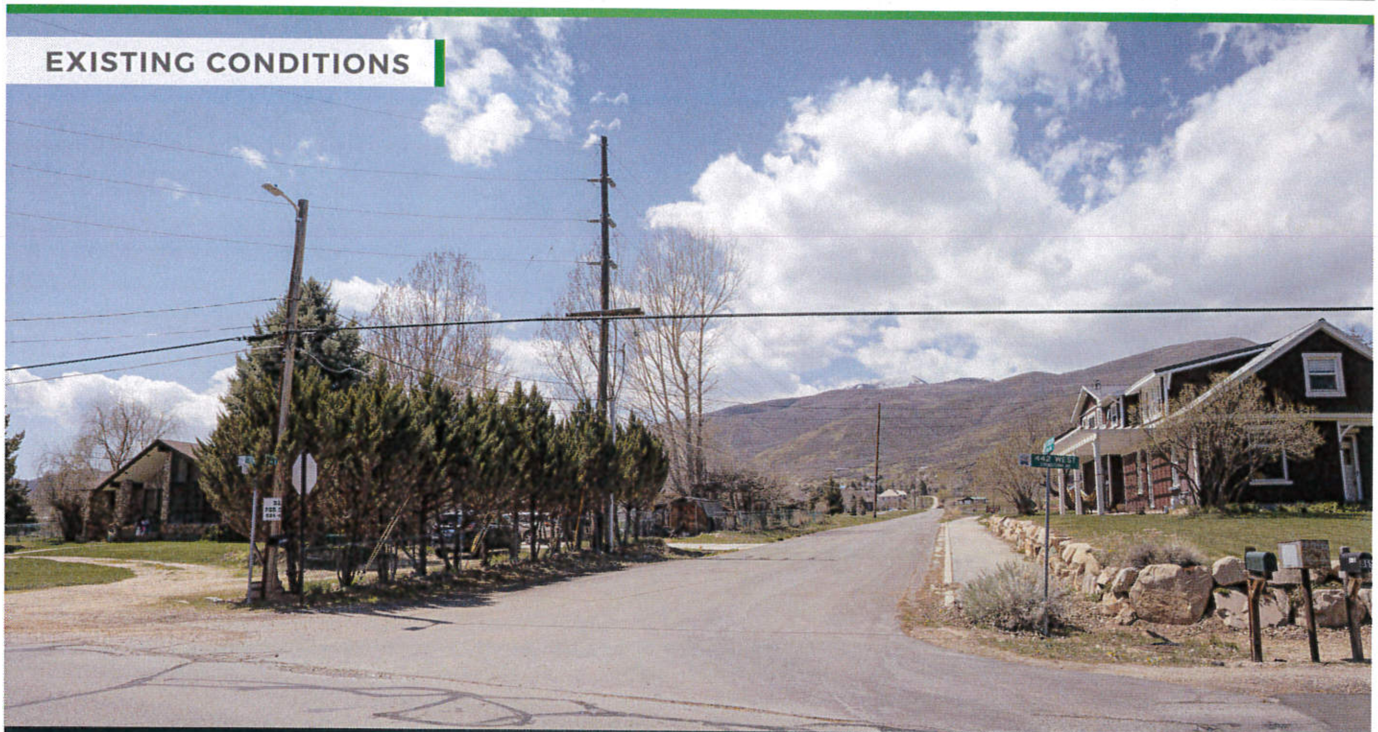


JORDANELLE TO MIDWAY

TRANSMISSION LINE UPGRADE PROJECT

PHOTO SIM VIEWPOINT 4

— TRANSMISSION LINE TO BE REBUILT

4 SIMULATION VIEWPOINT LOCATION

PHOTO SIMULATION BY POWER ENGINEERS

DATE: 04/24/2018

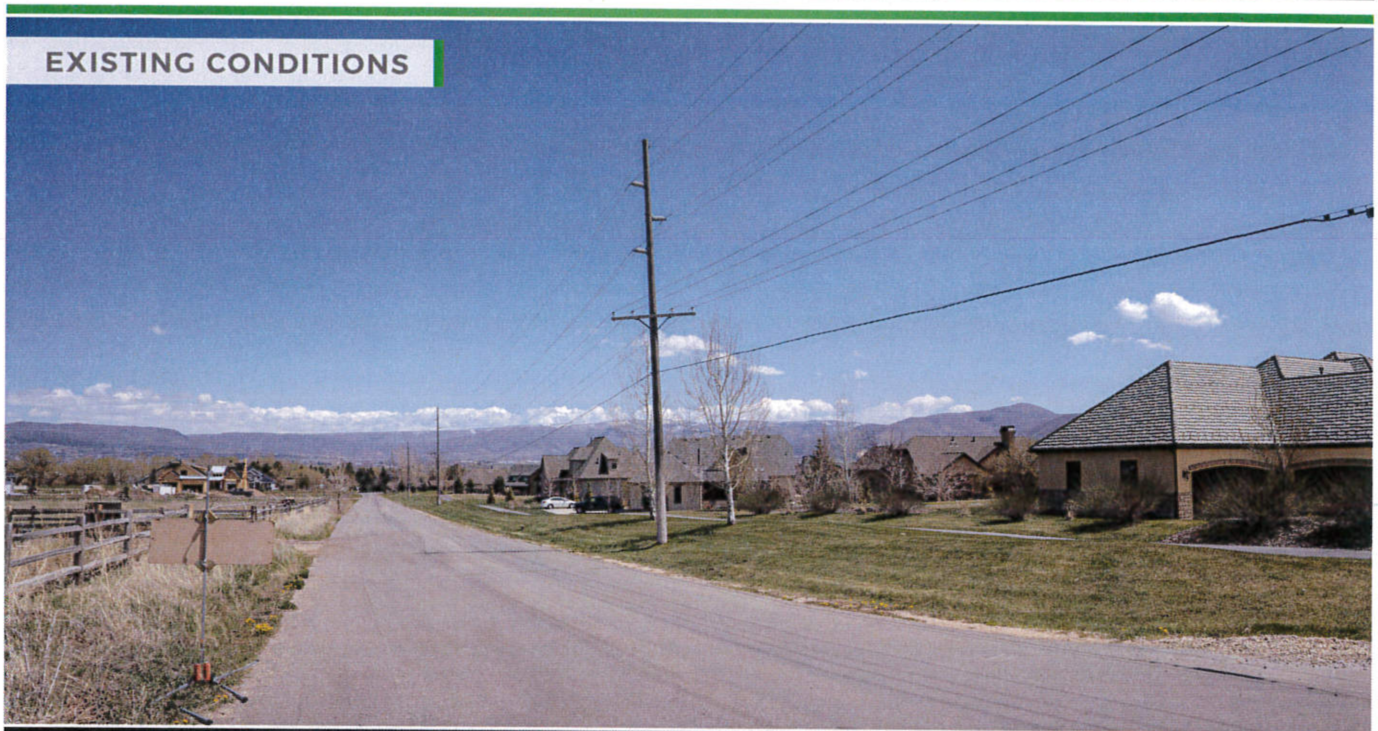
TIME: 1:43 PM

DIRECTION: WEST

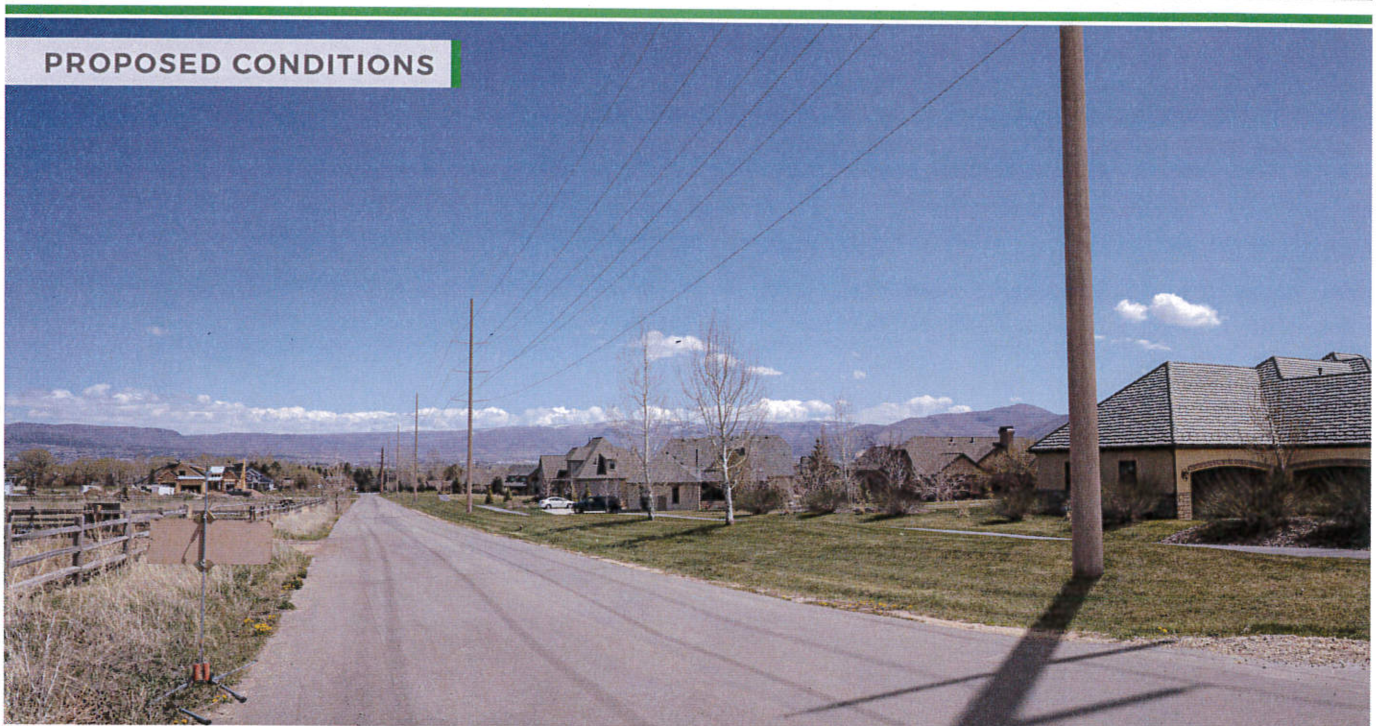
Heber Light & Power

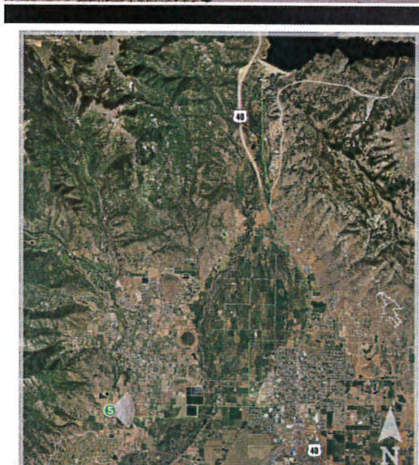
PHOTO SIMULATION IS FOR DEMONSTRATION PURPOSES ONLY. FINAL DESIGN IS SUBJECT TO CHANGE PENDING PUBLIC, ENGINEERING, AND REGULATORY REVIEW.

EXISTING CONDITIONS



PROPOSED CONDITIONS





JORDANELLE TO MIDWAY
TRANSMISSION LINE UPGRADE PROJECT

PHOTO SIM VIEWPOINT 5

— TRANSMISSION LINE TO BE REBUILT

(5) SIMULATION VIEWPOINT LOCATION

PHOTO SIMULATION BY POWER ENGINEERS

DATE: 04/24/2018

TIME: 11:59 AM

DIRECTION: EAST

Heber Light & Power

PHOTO SIMULATION IS FOR DEMONSTRATION PURPOSES ONLY. FINAL DESIGN IS SUBJECT TO CHANGE PENDING PUBLIC, ENGINEERING, AND REGULATORY REVIEW.

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electric power engineering

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Heber Light & Power

Underground Transmission Cost/Feasibility Study

Prepared by

NEI Electric Power Engineering, Inc.

Arvada, Colorado 80001

April 24, 2018

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

Table of Contents

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

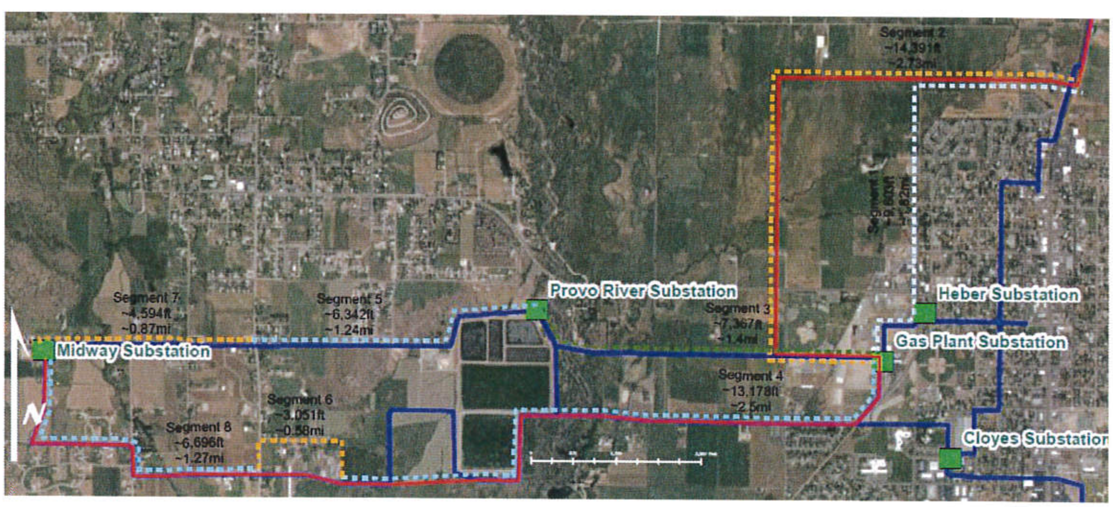


Figure 1 Partial Segment Map (refer to Appendix A for entire map)

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)				
<u>Directional Boring</u>						
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.

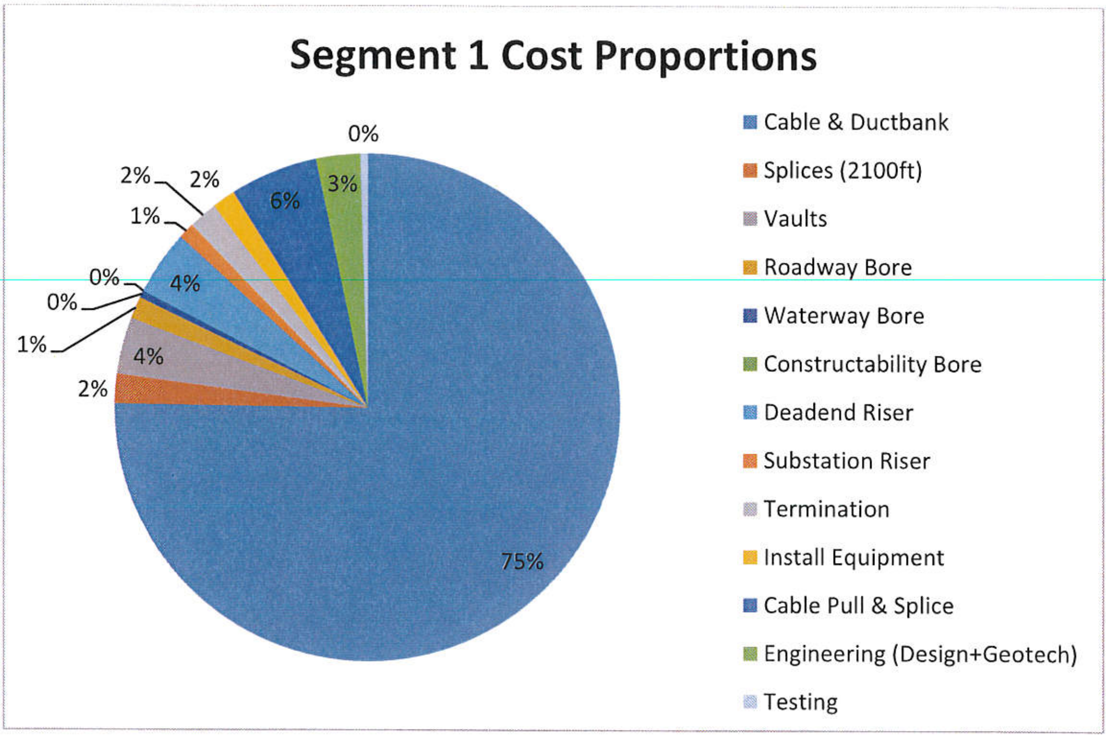


Figure 2 Segment 1 Cost Proportions

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

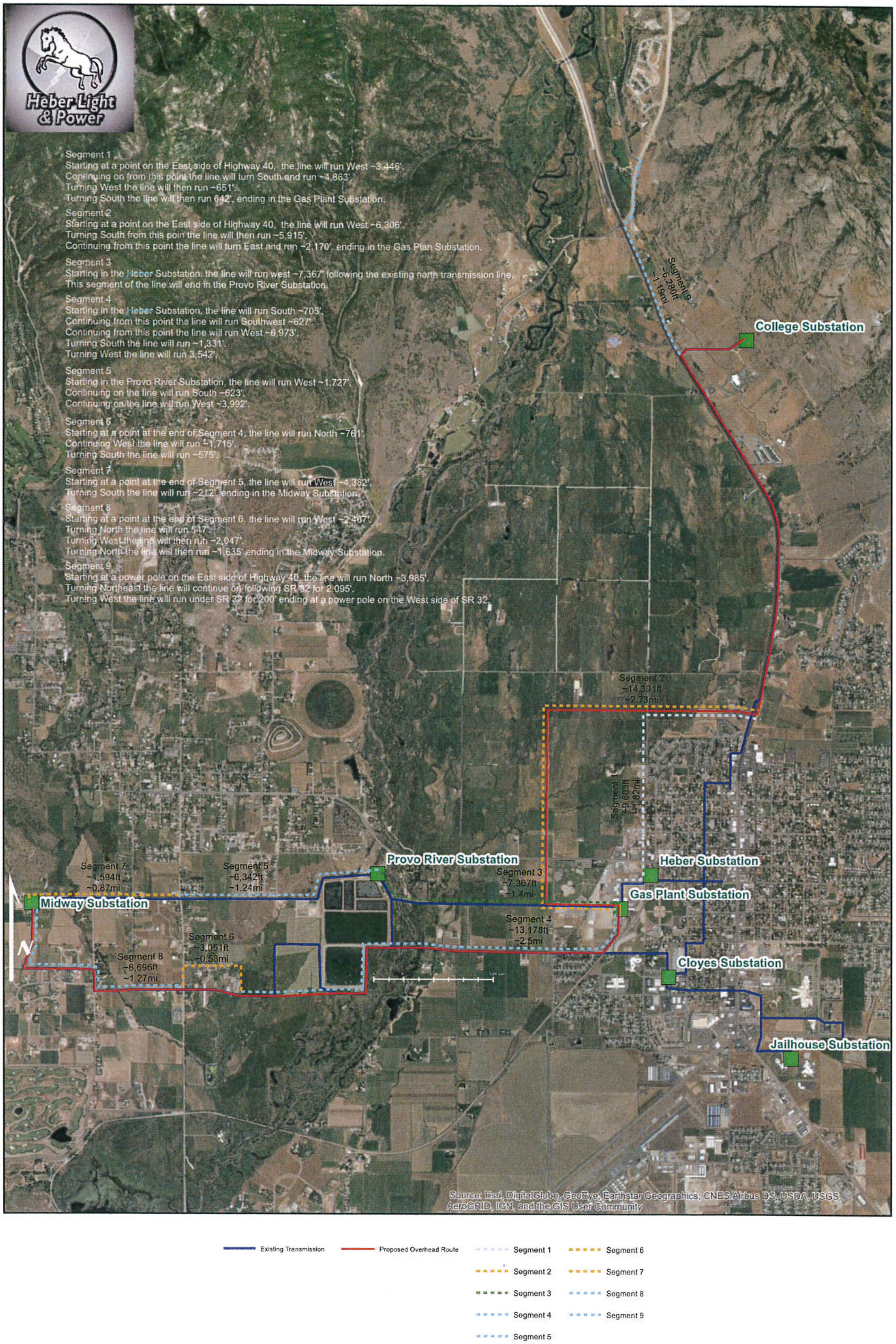
4) Equivalent Overhead Cost Comparison

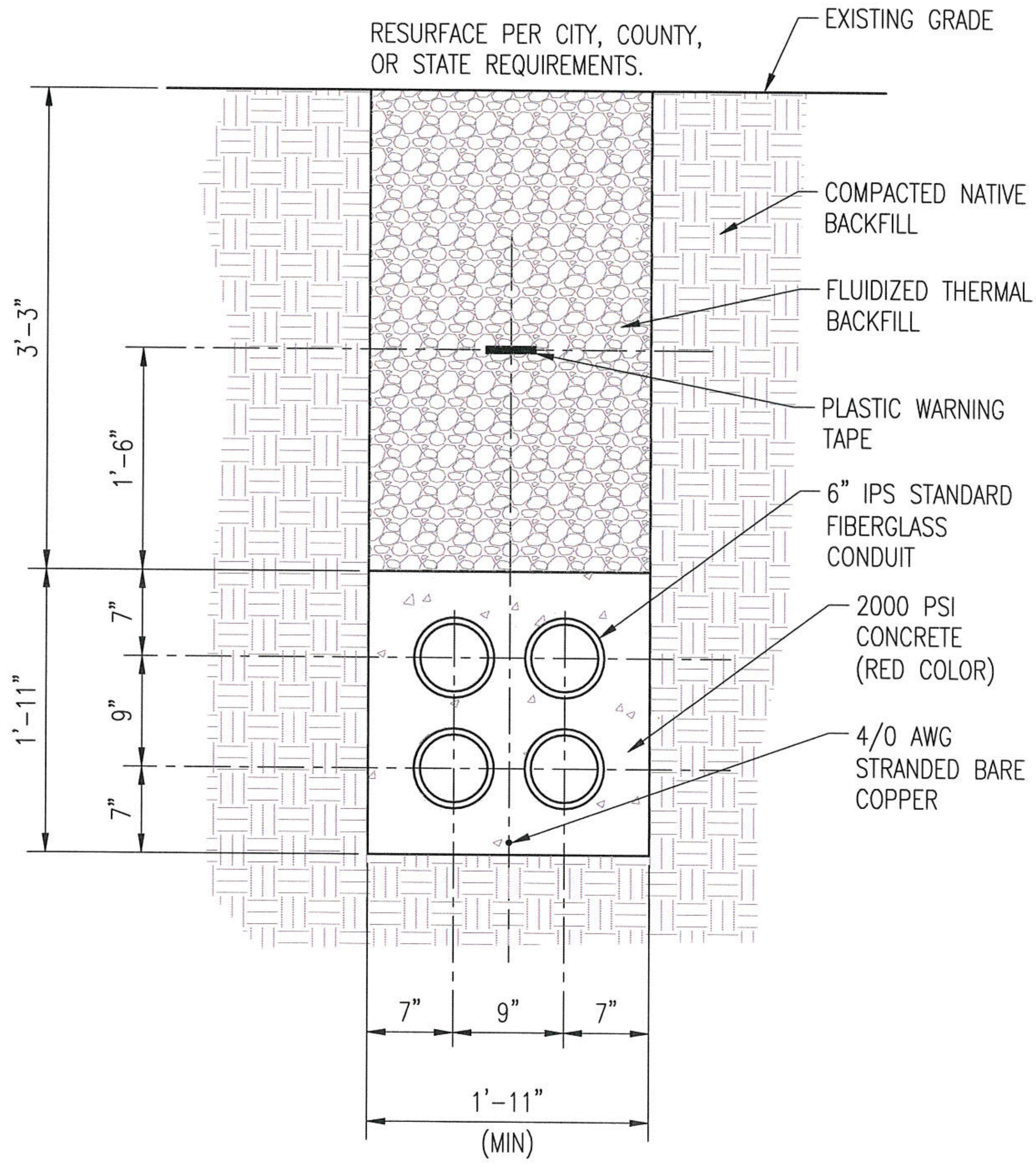
The overhead equivalent cost comparison with the underground segments has been made based on the cost data supplied by Heber Light & Power for two recent one-mile-long segments. This indicates an approximate cost of $1.1M per mile. For this study, a value of $1.1M per mile is used for the double circuit 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 547'.
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.
Segment 9 ~6,280ft ~1.19mi
College Substation
Segment 2 ~14,391ft ~2.73mi
Segment 1 ~9,603ft ~1.82mi
Heber Substation
Gas Plant Substation
Provo River Substation
Segment 3 ~7,367ft ~1.4mi
Segment 4 ~13,178ft ~2.5mi
Segment 7 ~4,594ft ~0.87mi
Segment 5 ~6,342ft ~1.24mi
Midway Substation
Segment 6 ~3,051ft ~0.58mi
Segment 8 ~6,696ft ~1.27mi
Cloyes Substation
Jailhouse Substation
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



Intermountain Consumer Professional Engineers, Inc.
CONSULTING ENGINEERS
1145 E. SOUTH UNION AVE.
MIDVALE, UTAH 84047
BUS. (801) 255-1111 FAX. 566-0086

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

REVISIONS

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		

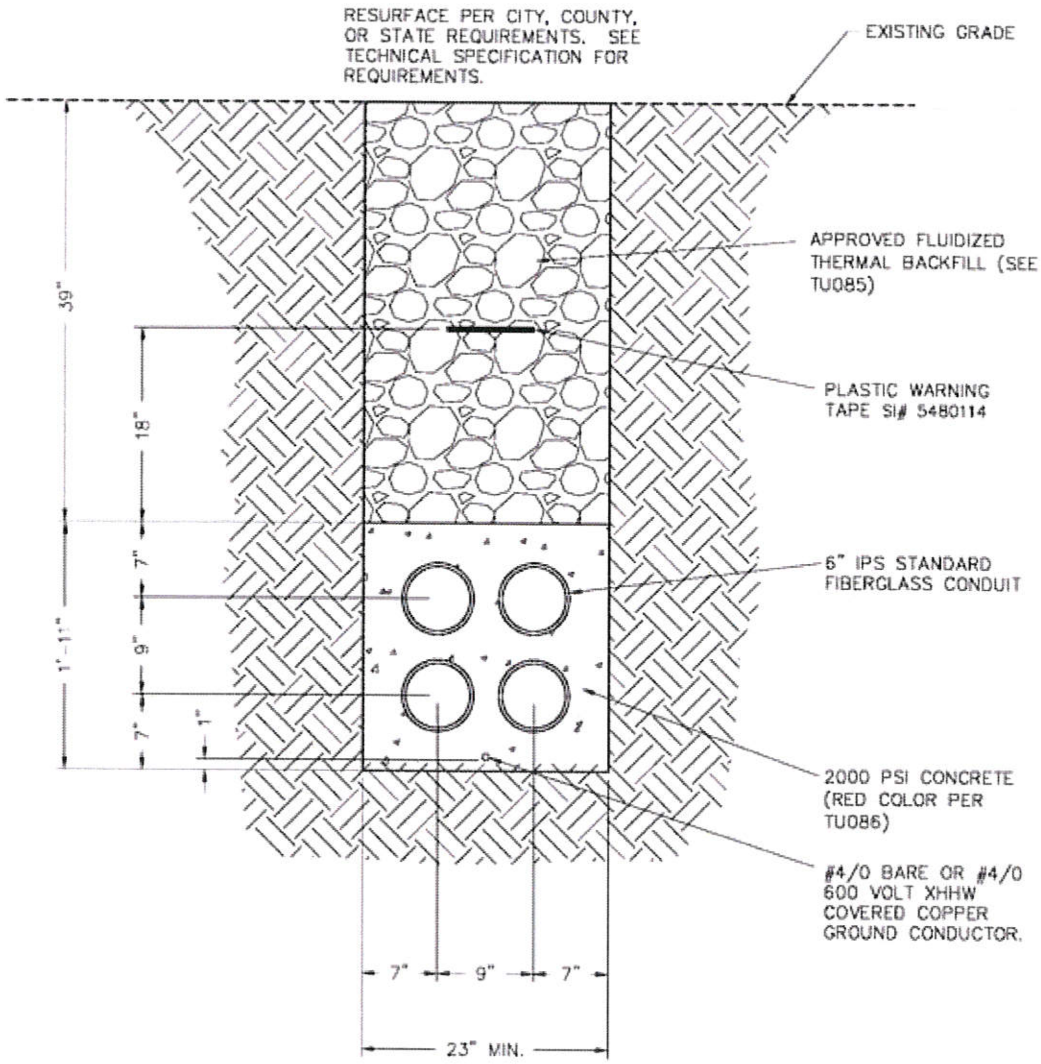


Figure 1—Typical Single-Circuit Conduit Layout

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.

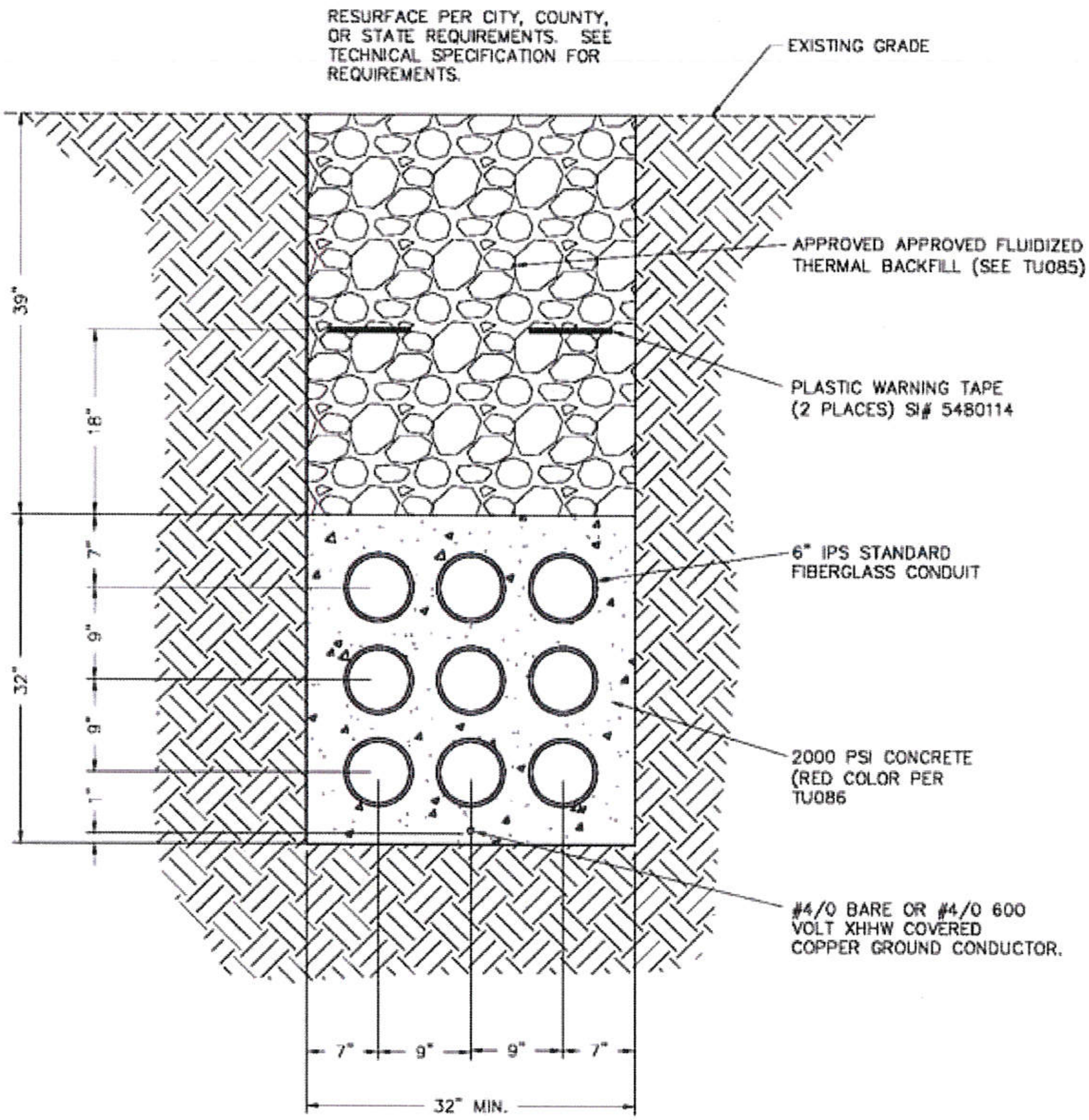
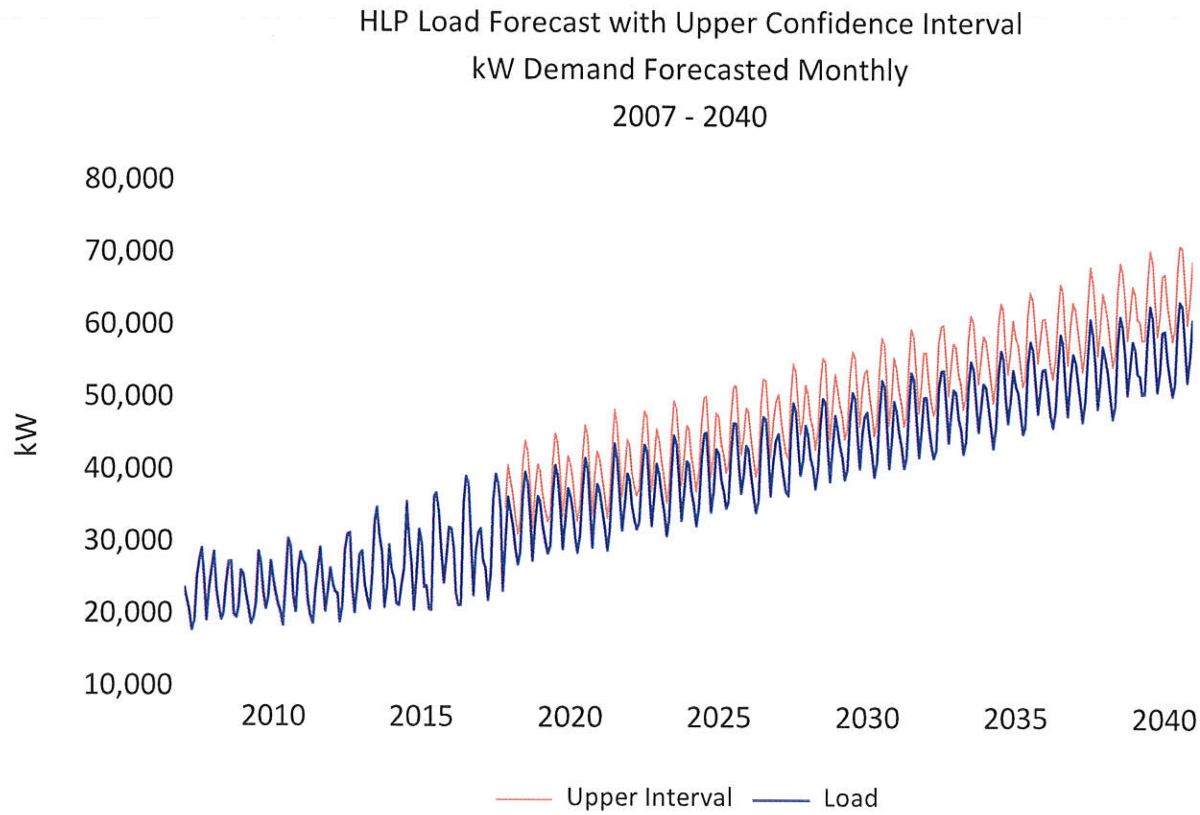


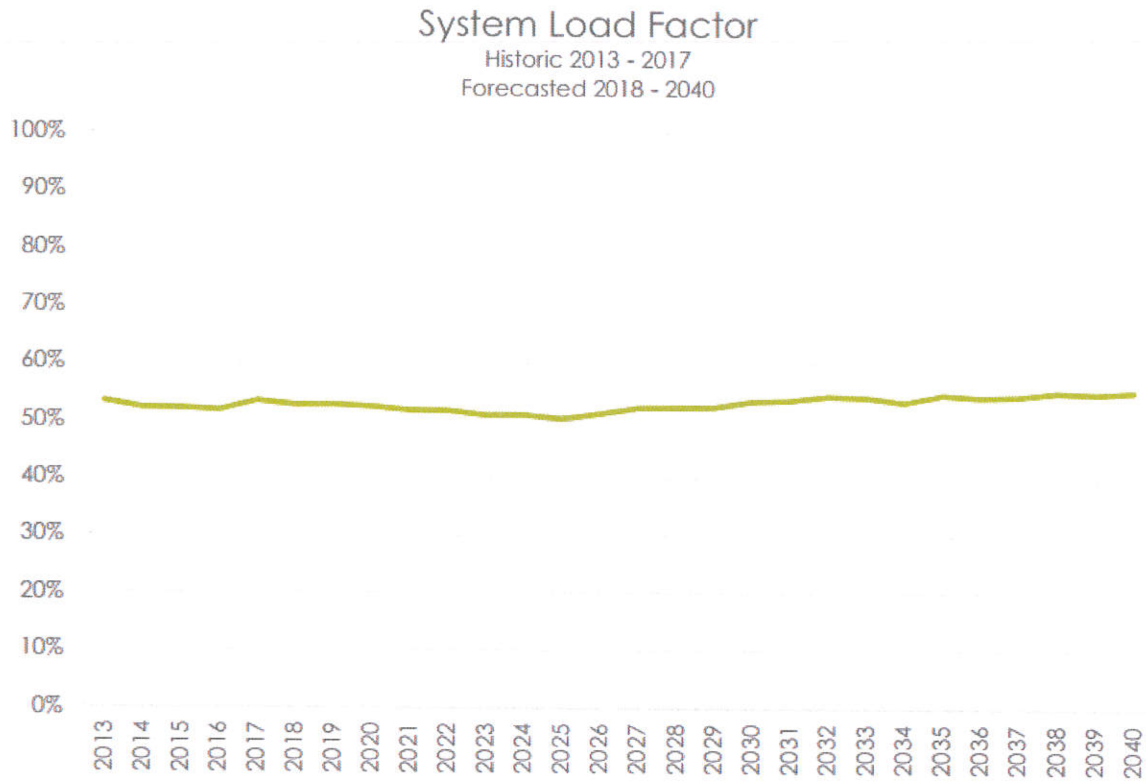
Figure 2—Typical Double-Circuit Conduit Layout

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

electric power engineering incorporated

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

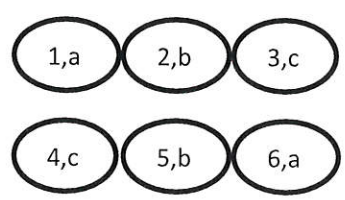
<u>From IEEE 575 D.2.3</u>

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

<u>Charging Current</u>

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



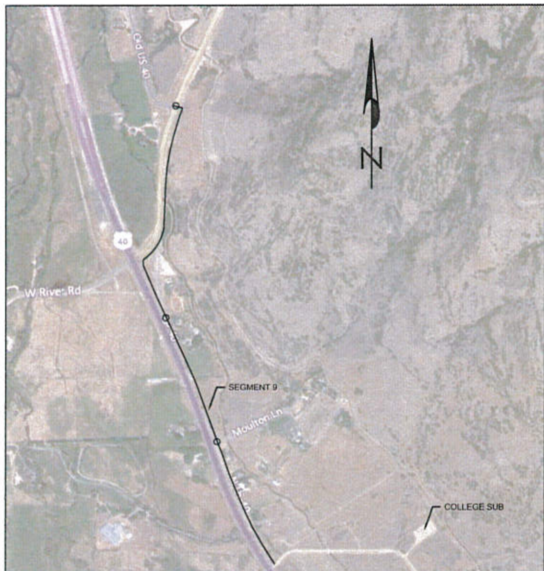
<u>Parallel Circuit</u>

	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	

<u>Transient Shield Voltage</u>

I fault - 3 Phase	4000	A	
Section Length	2100	ft	
Ia	-2000+3464.10		
Ib	4000		
Ic	-2000-3464.10		
Ea0	0.474691110	**0.677**	V/m
Eb0	0.548126080	**0.548**	V/m
Ec0	-0.474691110	**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	



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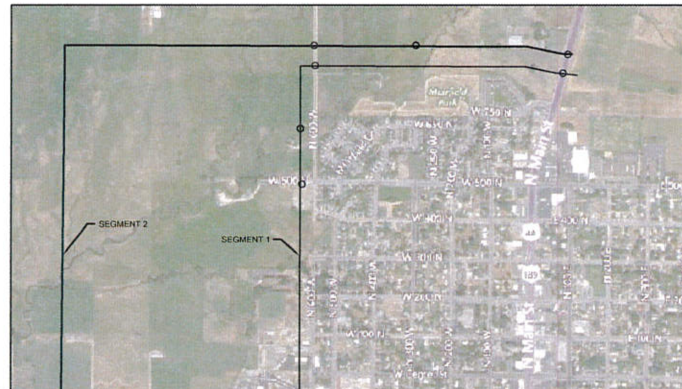
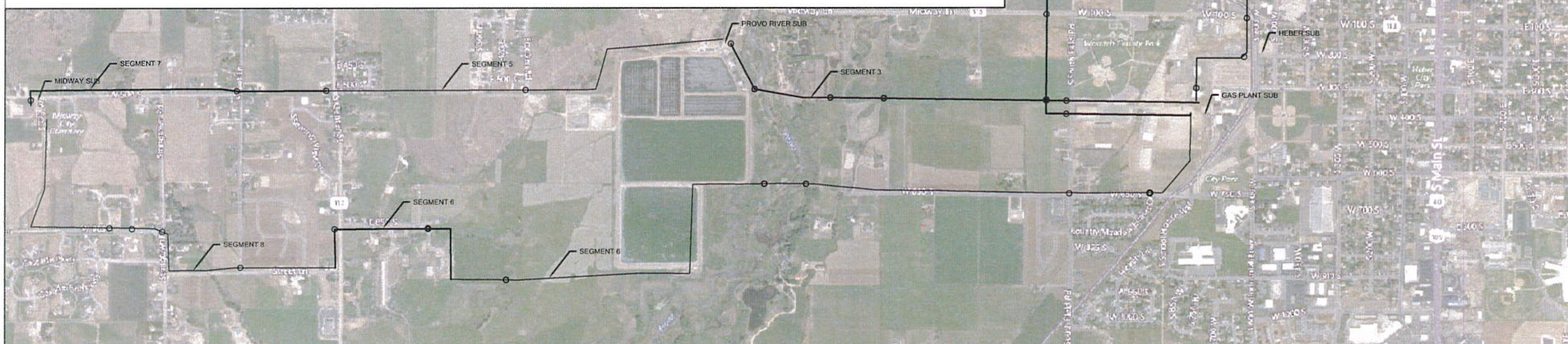
NOT FOR CONSTRUCTION
FOR REVIEW & APPROVAL ONLY

o = 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.neieng.com

DATE	SCALE
03/16/18	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 ar	$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

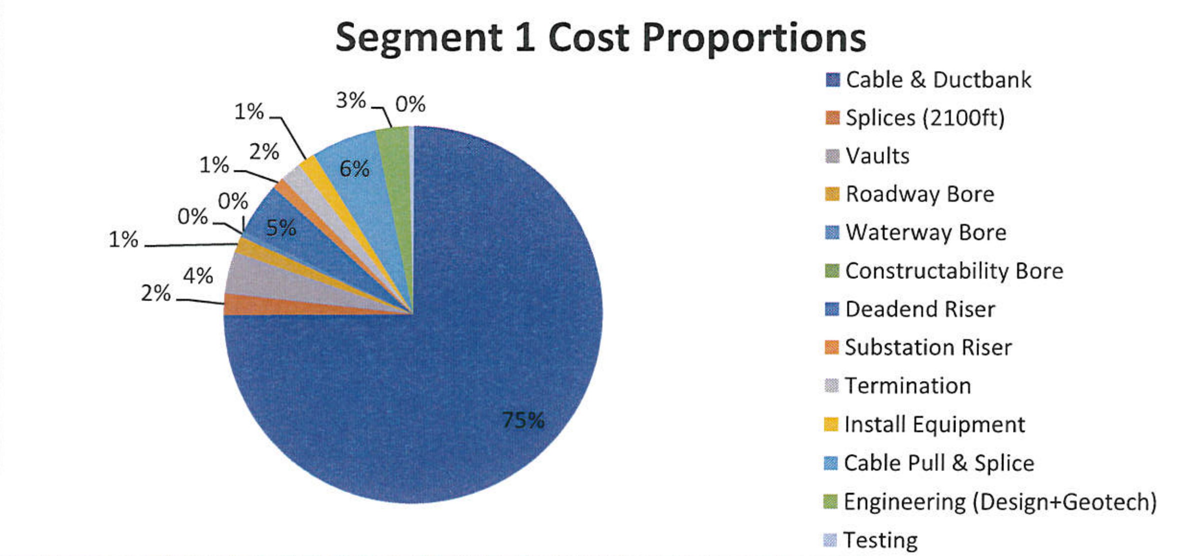
Total (+25% Contractor)	Engineering (Design+Geotech)	Testing	Total (+15% Contingency)	Spare (splice, SVL, term, 2100ft cable)
$3,891,141	$91,219	$15,000	$4,596,964	$96,200
$5,590,117	$136,715	$21,000	$6,610,006	$96,200
$2,947,117	$69,987	$12,000	$3,483,469	$96,200
$5,210,953	$125,191	$21,000	$6,160,716	$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

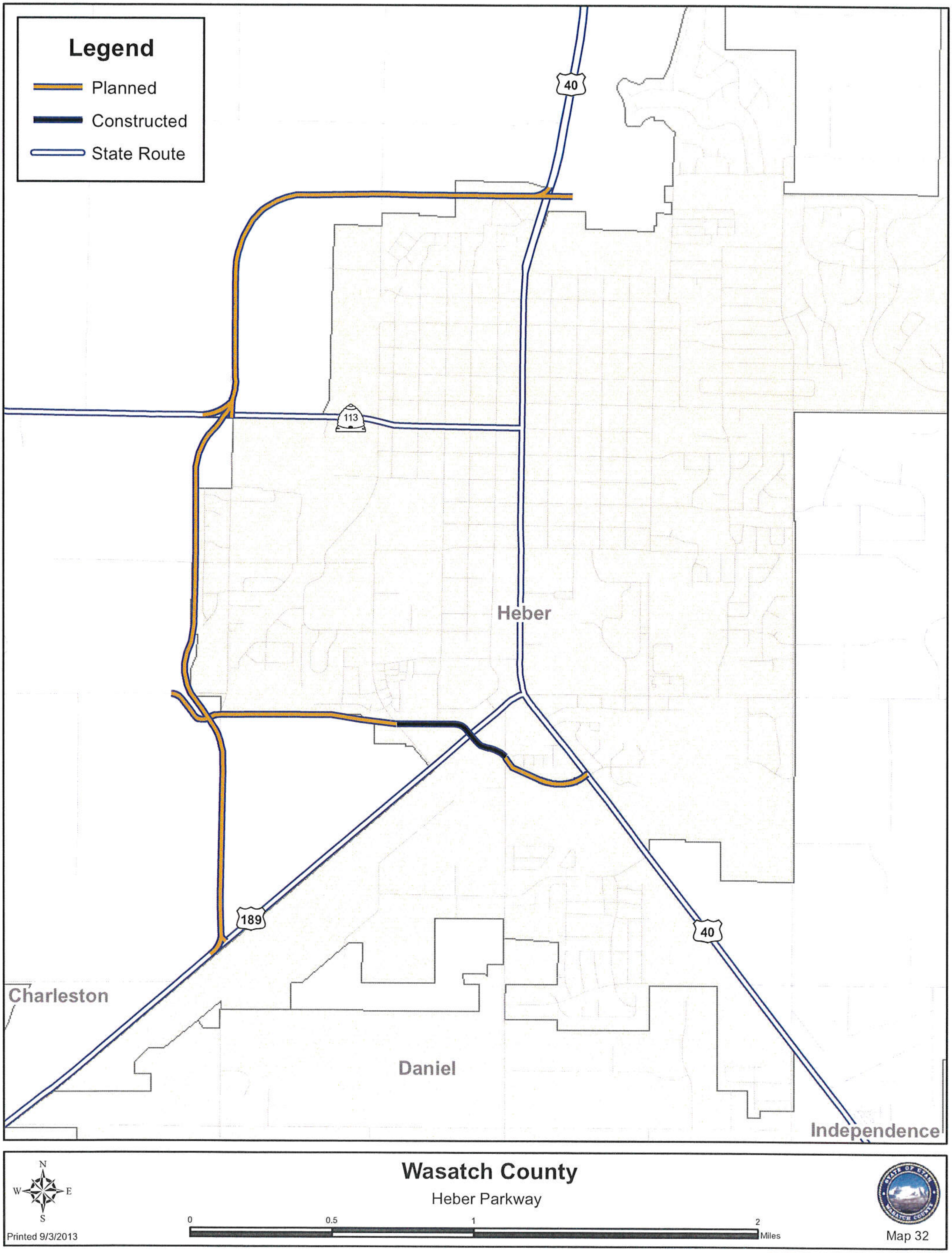
Total (+25% Contractor)	Engineering (Design+Geotech)	Testing	Total (+15% Contingency)	Spare (splice, SVL, term, 2100ft cable)
$3,552,872	$73,935	$15,000	$4,188,078	$92,090
$5,140,831	$110,811	$21,000	$6,063,538	$92,090
$2,721,822	$56,726	$12,000	$3,209,130	$92,090
$4,788,222	$101,471	$21,000	$5,647,296	$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


Legend
Planned
Constructed
State Route
40
113
Heber
189
40
Charleston
Daniel
Independence
N
W
E
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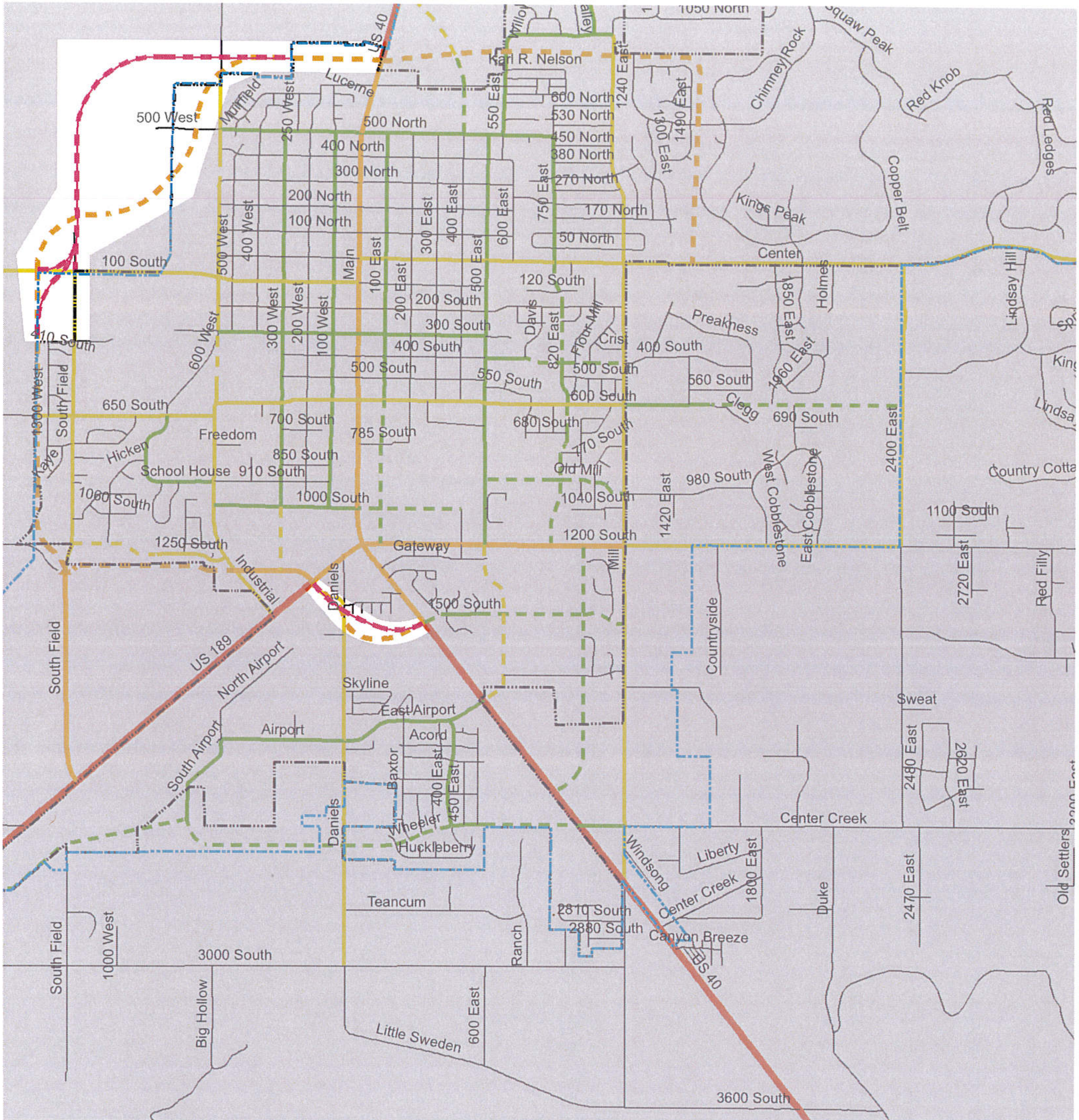
Wasatch County
Heber Parkway
0
0.5
1
2
Miles
Printed 9/3/2013
Map 32



er City Master Road Plan

Changes April 2010

hows the current and future roads planned

ity. Heber City's goals for transportation

Legend

Local

Minor Collector

Collector

Minor Arterial

Transmission Lines and Property Values: Review of the Research

Presentation to the Emerging Technology Issues Advisory Committee of the Virginia General Assembly Joint Commission on Technology and Science

July 18, 2005

Prepared by
Thomas Priestley, Ph.D.

CH2MHILL

There is a substantial body of systematic research on the relationship between transmission lines and property values.

The research provides empirically based data points against which claims based on anecdotes and speculation can be evaluated.

What the Research Findings Suggest:

- Proximity to transmission lines is not the major factor that determines property values.
- In some cases, there may not be any impacts.
- Any impacts on the value of single family homes tend to be small.
- In some cases, the impact can be positive.

What the Research Findings Suggest:
(Continued)

- In some specific cases – single family homes located immediately adjacent to towers, vacant rural land suitable for residential development – the degree of impact could be somewhat higher.

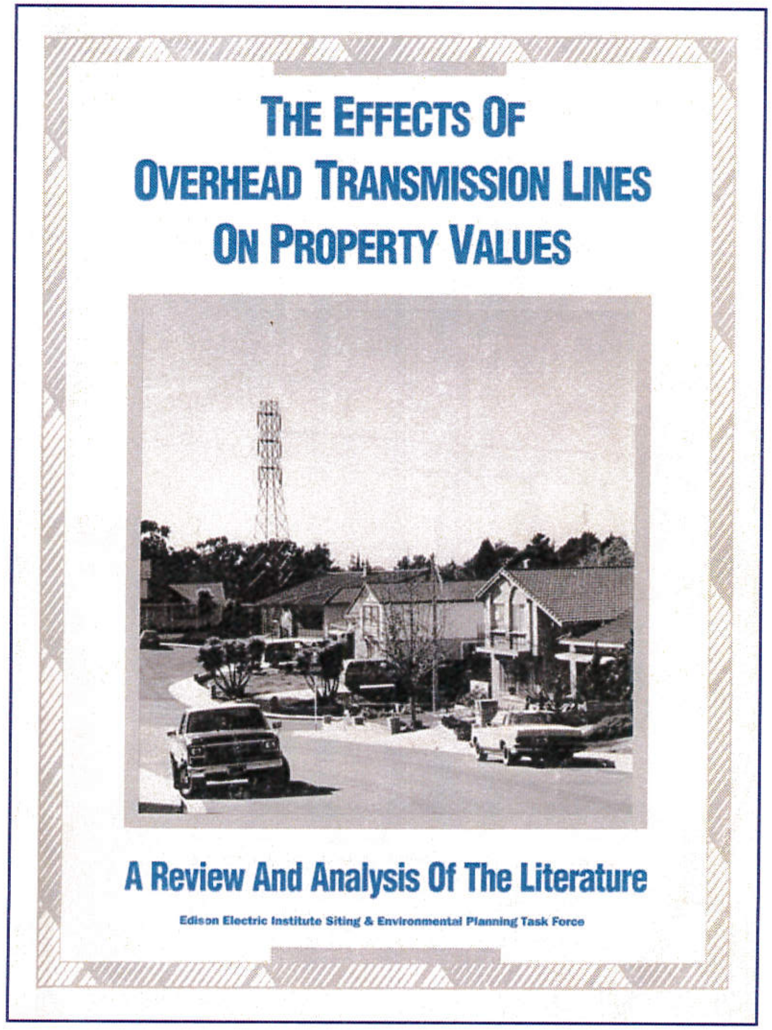
- When there are impacts, they tend to be highest right next to the line, and to taper off very quickly with distance, essentially disappearing at distances ranging from 200 to 650 feet.

What the Research Findings Suggest:
(Continued)

- Some studies indicate that property value impacts are greatest right after a transmission line is constructed or upgraded, and that the impacts decrease over time.

- Northern California study found effects of a transmission line project to be greatest in the first year, then fading out after 4 years.

Drew From 1992 Research Review



Supplemented the 1992 Review

Supplemented the 1992 EEI report with a search for and assessment of the North American research published since the 1992 review was completed.

The Research Landscape

- Appraiser Studies
- Attitudinal Surveys
- Statistical Analyses/Regression Modeling

Findings – Single Family Residences

- Most of the paired sales analyses and two of the multiple regression analyses have concluded that transmission lines do not have an effect on the value of nearby single family residences.

Findings – Single Family Residences

- Other paired sales analyses and multiple regression analyses have found some degree of impact (in the range of 2% to 10%) to single family properties located in close proximity to transmission lines.

Findings – Single Family Residences

- Positive impacts found in some cases.
- In a Montreal suburb, positive price impacts (from 7% to 22%) related to increased privacy and more open views.
- In a northern California suburb, positive price impacts of 10% for parcels located next to a transmission line that had been integrated in the subdivision's open space system.

Findings – Vacant Residential Land

- Mixed results

- Studies of properties with residential development potential in Maine and New York found power lines had no effects.

- Study in Maryland found no effect on lots in one subdivision and 4% to 5% effect on lots adjacent to the transmission line in another subdivision.

Findings – Distance Effects

- For studies that find impacts, the impacts are highest next to the right-of-way and/or close to the towers.
- Effects drop off sharply with distance.
- In studies that have found effects, these effects essentially disappear after 200, 500, and 650 feet.

Findings – Temporal Effects

- Illinois study found transmission line property value effects to decrease over time, possibly because of increased growth in screening vegetation.

- Northern California study found effects of a transmission line project to be greatest in the first year, and then to decrease quickly, fading out after 4 years.

Findings - Appreciation

- A topic that has not received much attention in the studies so far

- A study in the Pacific Northwest that looked at this issue with an analysis of a large number of sales concluded that properties next to the transmission right of way appreciated at the same rate as similar properties located away from the line.

Summary

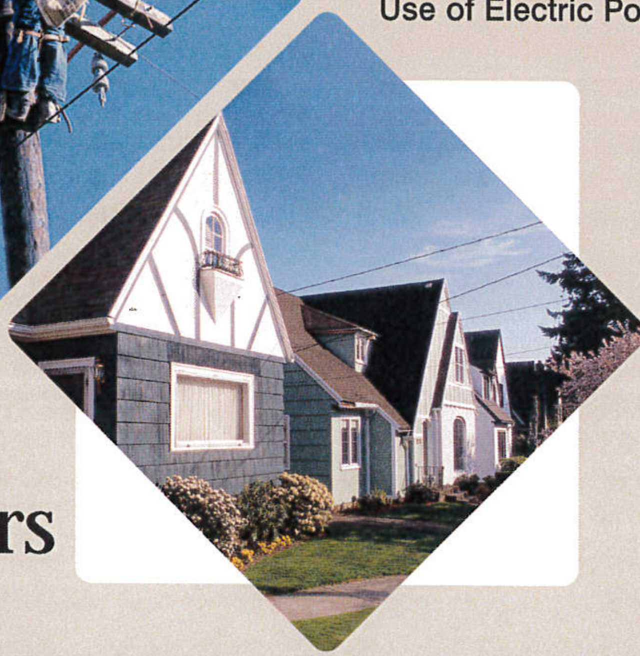
A valuable body of research on the relationships between transmission lines and property values.

This research provides data and insights that are of assistance in putting property value concerns into perspective. However, it is important to emphasize that each of the studies reflect site specific circumstances and caution is required in applying their findings to other situations.

June 2002

EMF

Electric and Magnetic Fields Associated with the Use of Electric Power



Questions & Answers

prepared by the
National Institute of Environmental Health Sciences
National Institutes of Health

EMF RAPID
Electric and Magnetic Fields Research and Public Information Dissemination Program

sponsored by the
NIEHS/DOE EMF RAPID Program

Contents

Introduction

Since the mid-twentieth century, electricity has been an essential part of our lives. Electricity powers our appliances, office equipment, and countless other devices that we use to make life safer, easier, and more interesting. Use of electric power is something we take for granted. However, some have wondered whether the electric and magnetic fields (EMF) produced through the generation, transmission, and use of electric power [power-frequency EMF, 50 or 60 hertz (Hz)] might adversely affect our health. Numerous research studies and scientific reviews have been conducted to address this question.

Unfortunately, initial studies of the health effects of EMF did not provide straightforward answers. The study of the possible health effects of EMF has been particularly complex and results have been reviewed by expert scientific panels in the United States and other countries. This booklet summarizes the results of these reviews. Although questions remain about the possibility of health effects related to EMF, recent reviews have substantially reduced the level of concern.

The largest evaluation to date was led by two U.S. government institutions, the National Institute of Environmental Health Sciences (NIEHS) of the National Institutes of Health and the Department of Energy (DOE), with input from a wide range of public and private agencies. This evaluation, known as the Electric and Magnetic Fields Research and Public Information Dissemination (EMF RAPID) Program, was a six-year project with the goal of providing scientific evidence to determine whether exposure to power-frequency EMF involves a potential risk to human health.

In 1999, at the conclusion of the EMF RAPID Program, the NIEHS reported to the U.S. Congress that the overall scientific evidence for human health risk from EMF exposure is weak. No consistent pattern of biological effects from exposure to EMF had emerged from laboratory studies with animals or with cells. However, epidemiological studies (studies of disease incidence in human populations) had shown a fairly consistent pattern that associated potential EMF exposure with a small increased risk for leukemia in children and chronic lymphocytic leukemia in adults. Since 1999, several other assessments have been completed that support an association between childhood leukemia and exposure to power-frequency EMF. These more recent reviews, however, do not support a link between EMF exposures and adult leukemias. For both childhood and adult leukemias, interpretation of the epidemiological findings has been difficult due to the absence of supporting laboratory evidence or a scientific explanation linking EMF exposures with leukemia.

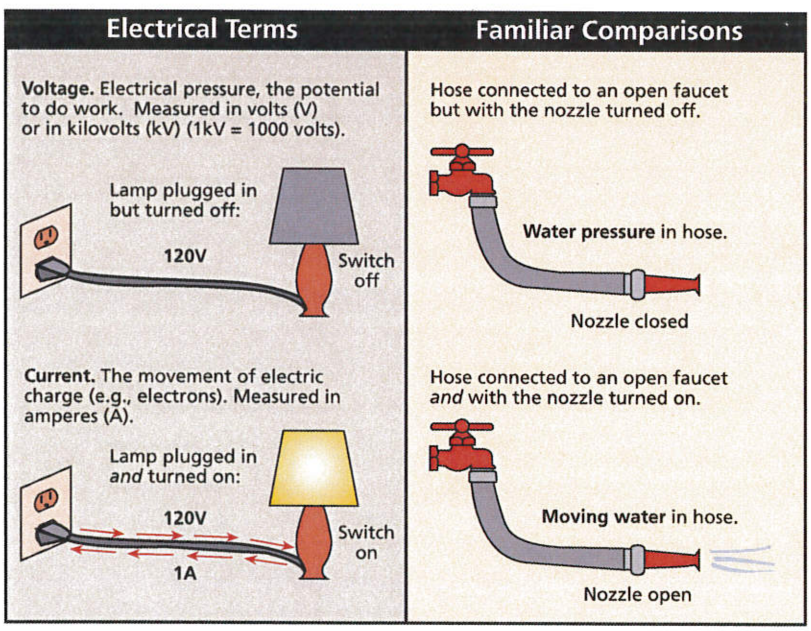
EMF exposures are complex and exist in the home and workplace as a result of all types of electrical equipment and building wiring as well as a result of nearby power lines. This booklet explains the basic principles of electric and magnetic fields, provides an overview of the results of major research studies, and summarizes conclusions of the expert review panels to help you reach your own conclusions about EMF-related health concerns.

1 EMF Basics

This chapter reviews terms you need to know to have a basic understanding of electric and magnetic fields (EMF), compares EMF with other forms of electromagnetic energy, and briefly discusses how such fields may affect us.

Q What are electric and magnetic fields?

A Electric and magnetic fields (EMF) are invisible lines of force that surround any electrical device. Power lines, electrical wiring, and electrical equipment all produce EMF. There are many other sources of EMF as well (see pages 33–35). The focus of this booklet is on power-frequency EMF—that is, EMF associated with the generation, transmission, and use of electric power.



Voltage produces an electric field and current produces a magnetic field.

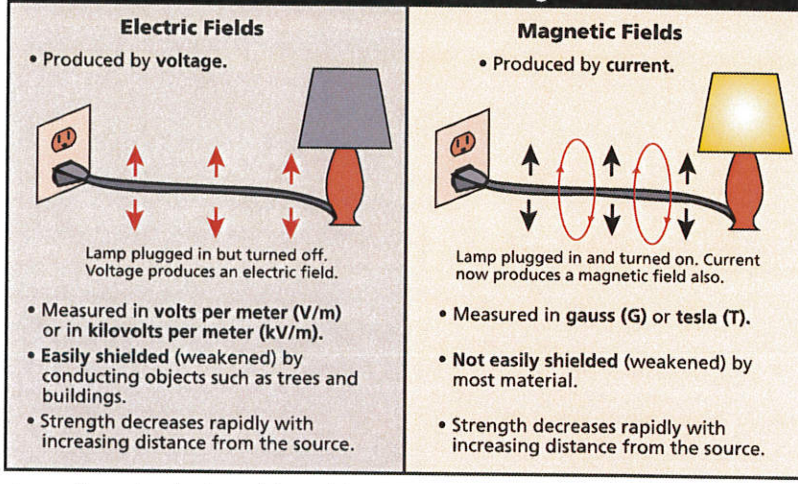
Electric fields are produced by voltage and increase in strength as the voltage increases. The electric field strength is measured in units of volts per meter (V/m). Magnetic fields result from the flow of current through wires or electrical devices and increase in strength as the current increases. Magnetic fields are measured in units of gauss (G) or tesla (T).

Most electrical equipment has to be turned on, i.e., current must be flowing, for a magnetic field to be produced. Electric fields are often present even when the equipment is switched off, as long as it remains connected to the source of electric power. Brief bursts of EMF (sometimes called "transients") can also occur when electrical devices are turned on or off.

Electric fields are shielded or weakened by materials that conduct electricity—even materials that conduct poorly, including trees, buildings, and human skin. Magnetic fields, however, pass through most materials and are therefore more difficult to shield. Both electric fields and magnetic fields decrease rapidly as the distance from the source increases.

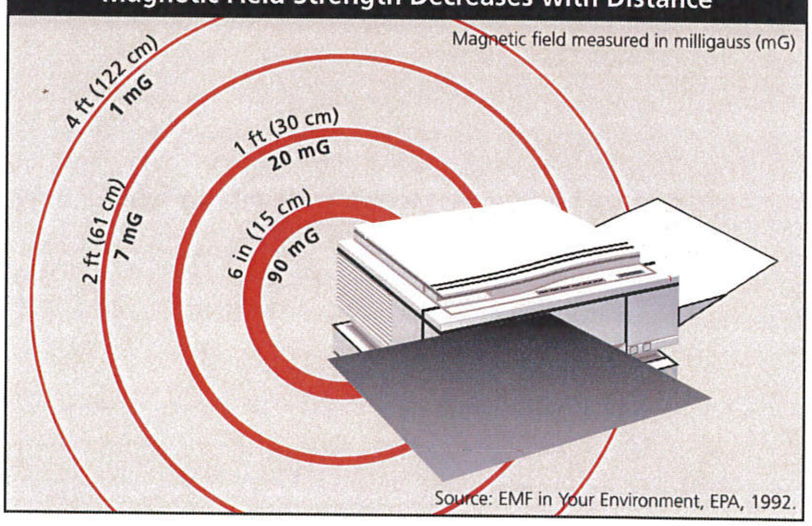
Even though electrical equipment, appliances, and power lines produce both electric and magnetic fields, most recent research has focused on potential health effects of magnetic field exposure. This is because some epidemiological studies have reported an increased cancer risk associated with estimates of magnetic field exposure (see pages 19 and 20 for a summary of these studies). No similar associations have been reported for electric fields; many of the studies examining biological effects of electric fields were essentially negative.

A Comparison of Electric and Magnetic Fields



An appliance that is plugged in and therefore connected to a source of electricity has an electric field even when the appliance is turned off. To produce a magnetic field, the appliance must be plugged in and turned on so that the current is flowing.

Magnetic Field Strength Decreases with Distance



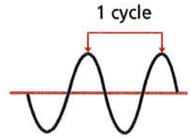
You cannot see a magnetic field, but this illustration represents how the strength of the magnetic field can diminish just 1–2 feet (30–61 centimeters) from the source. This magnetic field is a 60-Hz power-frequency field.

Characteristics of electric and magnetic fields

Electric fields and magnetic fields can be characterized by their wavelength, frequency, and amplitude (strength). The graphic below shows the waveform of an alternating electric or magnetic field. The direction of the field alternates from one polarity to the opposite and back to the first polarity in a period of time called one cycle. Wavelength describes the distance between a peak on the wave and the next peak of the same polarity. The frequency of the field, measured in hertz (Hz), describes the number of cycles that occur in one second. Electricity in North America alternates through 60 cycles per second, or 60 Hz. In many other parts of the world, the frequency of electric power is 50 Hz.

Frequency and Wavelength

Frequency is measured in hertz (Hz).
1 Hz = 1 cycle per second.



Examples:

Source	Frequency	Wavelength
Power line (North America)	60 Hz	3100 miles (5000 km)
Power line (Europe and most other locations)	50 Hz	3750 miles (6000 km)

Q How is the term EMF used in this booklet?

A The term "EMF" usually refers to electric and magnetic fields at extremely low frequencies such as those associated with the use of electric power. The term EMF can be used in a much broader sense as well, encompassing electromagnetic fields with low or high frequencies (see page 8).

Measuring EMF: Common Terms

Electric fields

Electric field strength is measured in volts per meter (V/m) or in kilovolts per meter (kV/m). 1 kV = 1000 V

Magnetic fields

Magnetic fields are measured in units of gauss (G) or tesla (T). Gauss is the unit most commonly used in the United States. Tesla is the internationally accepted scientific term. 1 T = 10,000 G

Since most environmental EMF exposures involve magnetic fields that are only a fraction of a tesla or a gauss, these are commonly measured in units of microtesla (μT) or milligauss (mG). A milligauss is 1/1,000 of a gauss. A microtesla is 1/1,000,000 of a tesla. 1 G = 1,000 mG; 1 T = 1,000,000 μT

To convert a measurement from microtesla (μT) to milligauss (mG), multiply by 10.
1 μT = 10 mG; 0.1 μT = 1 mG

When we use EMF in this booklet, we mean extremely low frequency (ELF) electric and magnetic fields, ranging from 3 to 3,000 Hz (see page 8). This range includes power-frequency (50 or 60 Hz) fields. In the ELF range, electric and magnetic fields are not coupled or interrelated in the same way that they are at higher frequencies. So, it is more useful to refer to them as "electric and magnetic fields" rather than "electromagnetic fields." In the popular press, however, you will see both terms used, abbreviated as EMF.

This booklet focuses on extremely low frequency EMF, primarily power-frequency fields of 50 or 60 Hz, produced by the generation, transmission, and use of electricity.

Q How are power-frequency EMF different from other types of electromagnetic energy?

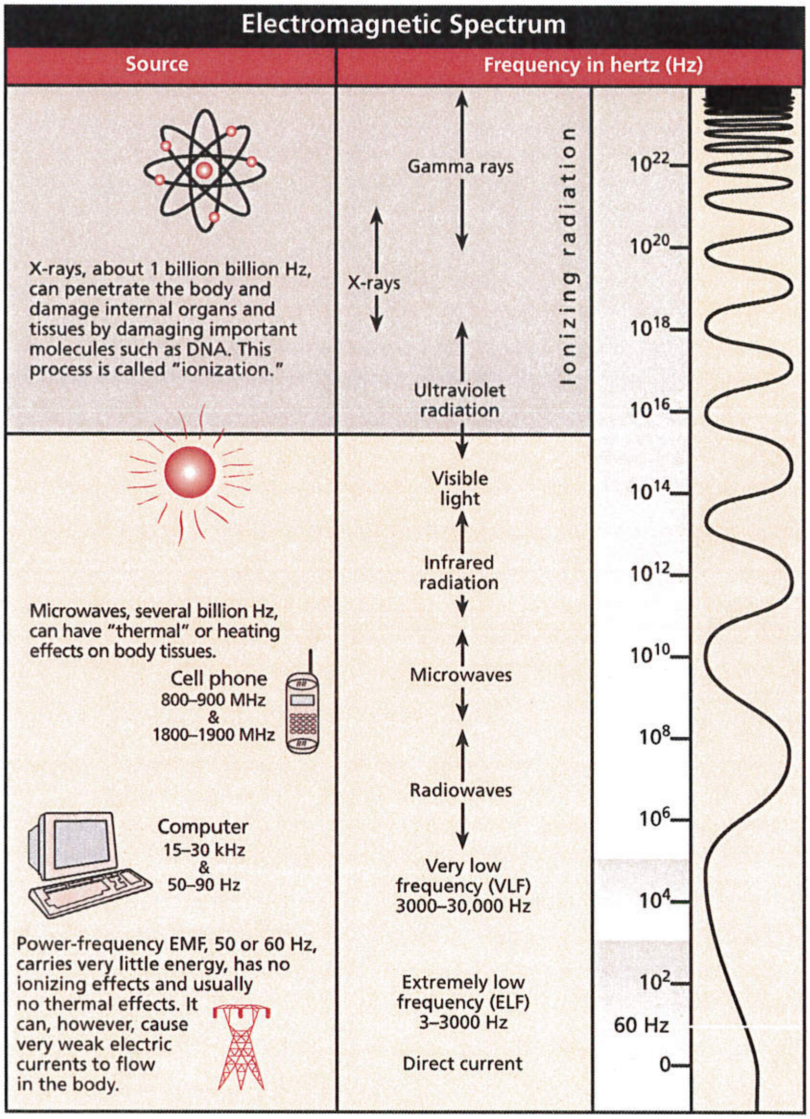
A X-rays, visible light, microwaves, radio waves, and EMF are all forms of electromagnetic energy. One property that distinguishes different forms of electromagnetic energy is the frequency, expressed in hertz (Hz). Power-frequency EMF, 50 or 60 Hz, carries very little energy, has no ionizing effects, and usually has no thermal effects (see page 8). Just as various chemicals affect our bodies in different ways, various forms of electromagnetic energy can have very different biological effects (see "Results of EMF Research" on page 16).

Some types of equipment or operations simultaneously produce electromagnetic energy of different frequencies. Welding operations, for example, can produce electromagnetic energy in the ultraviolet, visible, infrared, and radio-frequency ranges, in addition to power-frequency EMF. Microwave ovens produce 60-Hz fields of several hundred milligauss, but they also create microwave energy inside the oven that is at a much higher frequency (about 2.45 billion Hz). We are shielded from the higher frequency fields inside the oven by its casing, but we are not shielded from the 60-Hz fields.

Cellular telephones communicate by emitting high-frequency electric and magnetic fields similar to those used for radio and television broadcasts. These radio-frequency and microwave fields are quite different from the extremely low frequency EMF produced by power lines and most appliances.

Q How are alternating current sources of EMF different from direct current sources?

A Some equipment can run on either alternating current (AC) or direct current (DC). In most parts of the United States, if the equipment is plugged into a household wall socket, it is using AC electric current that reverses direction in the electrical wiring—or alternates—60 times per second, or at 60 hertz (Hz). If the equipment uses batteries, then electric current flows in one direction only. This



The wavy line at the right illustrates the concept that the higher the frequency, the more rapidly the field varies. The fields do not vary at 0 Hz (direct current) and vary trillions of times per second near the top of the spectrum. Note that 10^4 means 10 x 10 x 10 x 10 or 10,000 Hz. 1 kilohertz (kHz) = 1,000 Hz. 1 megahertz (MHz) = 1,000,000 Hz.

produces a "static" or stationary magnetic field, also called a direct current field. Some battery-operated equipment can produce time-varying magnetic fields as part of its normal operation.

Q What happens when I am exposed to EMF?

A In most practical situations, DC electric power does not induce electric currents in humans. Strong DC magnetic fields are present in some industrial environments, can induce significant currents when a person moves, and may be of concern for other reasons, such as potential effects on implanted medical devices (see page 47 for more information on pacemakers and other medical devices).

AC electric power produces electric and magnetic fields that create weak electric currents in humans. These are called "induced currents." Much of the research on how EMF may affect human health has focused on AC-induced currents.

Electric fields

A person standing directly under a high-voltage transmission line may feel a mild shock when touching something that conducts electricity. These sensations are caused by the strong electric fields from the high-voltage electricity in the lines. They occur only at close range because the electric fields rapidly become weaker as the distance from the line increases. Electric fields may be shielded and further weakened by buildings, trees, and other objects that conduct electricity.

Magnetic fields

Alternating magnetic fields produced by AC electricity can induce the flow of weak electric currents in the body. However, such currents are estimated to be smaller than the measured electric currents produced naturally by the brain, nerves, and heart.

Q Doesn't the earth produce EMF?

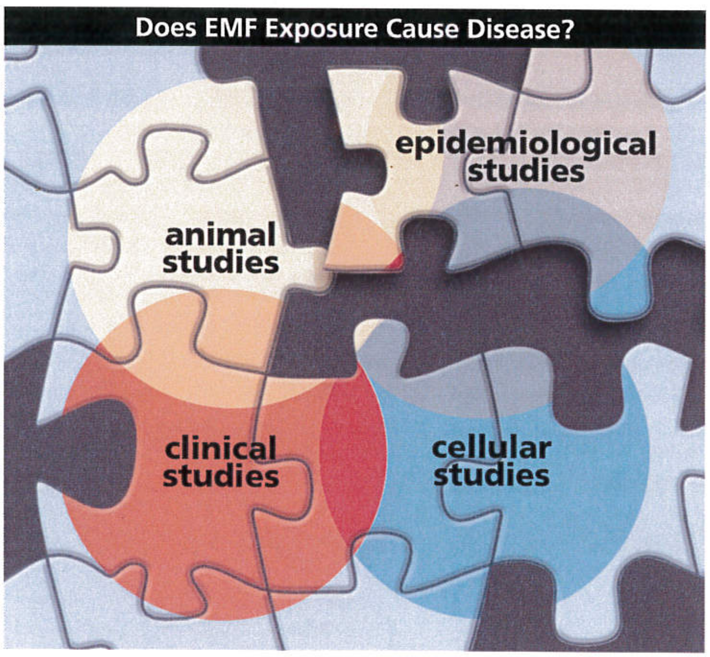
A Yes. The earth produces EMF, mainly in the form of static fields, similar to the fields generated by DC electricity. Electric fields are produced by air turbulence and other atmospheric activity. The earth's magnetic field of about 500 mG is thought to be produced by electric currents flowing deep within the earth's core. Because these fields are static rather than alternating, they do not induce currents in stationary objects as do fields associated with alternating current. Such static fields can induce currents in moving and rotating objects.

2 Evaluating Potential Health Effects

This chapter explains how scientific studies are conducted and evaluated to assess potential health effects.

Q How do we evaluate whether EMF exposures cause health effects?

A Animal experiments, laboratory studies of cells, clinical studies, computer simulations, and human population (epidemiological) studies all provide valuable information. When evaluating evidence that certain exposures cause disease, scientists consider results from studies in various disciplines. No single study or type of study is definitive.



Laboratory studies and human studies provide pieces of the puzzle, but no single study can give us the whole picture.

Laboratory studies

Laboratory studies with cells and animals can provide evidence to help determine if an agent such as EMF causes disease. Cellular studies can increase our understanding of the biological mechanisms by which disease occurs. Experiments with animals provide a means to observe effects of specific agents under carefully controlled conditions. Neither cellular nor animal studies, however, can recreate the complex nature of the whole human organism and its environment. Therefore, we must use caution in applying the results of cellular or animal studies directly to humans or concluding that a lack of an effect in laboratory studies proves that an agent is safe. Even with these limitations, cellular and animal studies have proven very useful over the years for identifying and understanding the toxicity of numerous chemicals and physical agents.

Very specific laboratory conditions are needed for researchers to be able to detect EMF effects, and experimental exposures are not easily comparable to human exposures. In most cases, it is not clear how EMF actually produces the effects observed in some experiments. Without understanding how the effects occur, it is difficult to evaluate how laboratory results relate to human health effects.

Some laboratory studies have reported that EMF exposure can produce biological effects, including changes in functions of cells and tissues and subtle changes in hormone levels in animals. It is important to distinguish between a biological effect and a health effect. Many biological effects are within the normal range of variation and are not necessarily harmful. For example, bright light has a biological effect on our eyes, causing the pupils to constrict, which is a normal response.

Clinical studies

In clinical studies, researchers use sensitive instruments to monitor human physiology during controlled exposure to environmental agents. In EMF studies, volunteers are exposed to electric or magnetic fields at higher levels than those commonly encountered in everyday life. Researchers measure heart rate, brain activity, hormonal levels, and other factors in exposed and unexposed groups to look for differences resulting from EMF exposure.

Epidemiology

A valuable tool to identify human health risks is to study a human population that has experienced the exposure. This type of research is called epidemiology.

The epidemiologist observes and compares groups of people who have had or have not had certain diseases and exposures to see if the risk of disease is different between the exposed and unexposed groups. The epidemiologist does not control the exposure and cannot experimentally control all the factors that might affect the risk of disease.

Most researchers agree that epidemiology—the study of patterns and possible causes of diseases—is one of the most valuable tools to identify human health risks.

Q How do we evaluate the results of epidemiological studies of EMF?

A Many factors need to be considered when determining whether an agent causes disease. An exposure that an epidemiological study associates with increased risk of a certain disease is not always the actual cause of the disease. To judge whether an agent actually causes a health effect, several issues are considered.

Strength of association

The stronger the association between an exposure and disease, the more confident we can be that the disease is due to the exposure being studied. With cigarette smoking and lung cancer, the association is very strong—20 times the normal risk. In the studies that suggest a relationship between EMF and certain rare cancers, the association is much weaker (see page 19).

Dose-response

Epidemiological data are more convincing if disease rates increase as exposure levels increase. Such dose-response relationships have appeared in only a few EMF studies.

Consistency

Consistency requires that an association found in one study appears in other studies involving different study populations and methods. Associations found consistently are more likely to be causal. With regard to EMF, results from different studies sometimes disagree in important ways, such as what type of cancer is associated with EMF exposure. Because of this inconsistency, scientists cannot be sure whether the increased risks are due to EMF or other factors.

Biological plausibility

When associations are weak in an epidemiological study, results of laboratory studies are even more important to support the association. Many scientists remain skeptical about an association between EMF exposure and cancer because laboratory studies thus far have not shown any consistent evidence of adverse health effects, nor have results of experimental studies revealed a plausible biological explanation for such an association.

Reliability of exposure information

Another important consideration with EMF epidemiological studies is how the exposure information was obtained. Did the researchers simply estimate people's EMF exposures based on their job titles or how their houses were wired, or did they actually conduct EMF measurements? What did they measure (electric fields, magnetic fields, or both)? How often were the EMF measurements made and at what time? In how many different places were the fields measured? More recent studies have included measurements of magnetic field exposure. Magnetic fields measured at the time a study is conducted can only estimate exposures that occurred in previous years (at the time a disease process may have begun). Lack of comprehensive exposure information makes it more difficult to interpret the results of a study, particularly considering that everyone in the industrialized world has been exposed to EMF.

Confounding

Epidemiological studies show relationships or correlations between disease and other factors such as diet, environmental conditions, and heredity. When a disease is correlated with some factor, it does not necessarily mean that the correlated factor causes the disease. It could mean that the factor occurs together with some other factor, not measured in the study, that actually causes the disease. This is called confounding.

For example, a study might show that alcohol consumption is correlated with lung cancer. This could occur if the study group consists of people who drink and also smoke tobacco, as often happens. In this example, alcohol use is correlated with lung cancer, but cigarette smoking is a confounding factor and the true cause of the disease.

Statistical significance

Researchers use statistical methods to determine the likelihood that the association between exposure and disease is due simply to chance. For a result to be considered "statistically significant," the association must be stronger than would be expected to occur by chance alone.

Meta-analysis

One way researchers try to get more information from epidemiological studies is to conduct a meta-analysis. A meta-analysis combines the summary statistics of many studies to explore their differences and, if appropriate, calculates an overall summary risk estimate. The main challenge faced by researchers performing meta-analyses is that populations, measurements, evaluation techniques, participation rates, and potential confounding factors vary in the original studies. These differences in the studies make it difficult to combine the results in a meaningful way.

Pooled analysis

Pooled analysis combines the original data from several studies and conducts a new analysis on the primary data. It requires access to the original data from individual studies and can only include diseases or factors included in all the studies, but it has the advantage that the same parameters can be applied to all studies. As with meta-analysis, pooled analysis is still subject to the limitations of the experimental design of the original studies (for example, evaluation techniques, participation rates, etc.). Pooled analysis differs from meta-analysis, which combines the summary statistics from different studies, not their original data.

Q How do we characterize EMF exposure?

A No one knows which aspect of EMF exposure, if any, affects human health. Because of this uncertainty, in addition to the field strength, we must ask how long an exposure lasts, how it varies, and at what time of day or night it occurs. House wiring, for example, is often a significant source of EMF exposure for an individual, but the magnetic fields produced by the wiring depend on the amount of current flowing. As heating, lighting, and appliance use varies during the day, magnetic field exposure will also vary.

For many studies, researchers describe EMF exposures by estimating the average field strength. Some scientists believe that average exposure may not be the best measurement of EMF exposure and that other parameters, such as peak exposure or time of exposure, may be important.

Q What is the average field strength?

A In EMF studies, the information reported most often has been a person's EMF exposure averaged over time (average field strength). With cancer-causing chemicals, a person's average exposure over many years can be a good way to predict his or her chances of getting the disease.

There are different ways to calculate average magnetic field exposures. One method involves having a person wear a small monitor that takes many measurements over a work shift, a day, or longer. Then the average of those measurements is calculated. Another method involves placing a monitor that takes many measurements in a residence over a 24-hour or 48-hour period. Sometimes averages are calculated for people with the same occupation, people working in similar environments, or people using several brands of the same type or similar types of equipment.

Q How is EMF exposure measured in epidemiological studies?

A Epidemiologists study patterns and possible causes of diseases in human populations. These studies are usually observational rather than experimental. This means that the researcher observes and compares groups of people who have had certain diseases and exposures and looks for possible "associations." The epidemiologist must find a way to estimate the exposure that people had at an earlier time.

Association

In epidemiology, a positive association between an exposure (such as EMF) and a disease is not necessarily proof that the exposure *caused* the disease. However, the more often the exposure and disease occur together, the stronger the association, and the stronger is the possibility that the exposure may increase the risk of the disease.

Some exposure estimates for residential studies have been based on designation of households in terms of "wire codes." In other studies, measurements have been made in homes, assuming that EMF levels at the time of the measurement are similar to levels at some time in the past. Some studies involved "spot measurements." Exposure levels change as a person moves around in his or her environment, so spot measurements taken at specific locations only approximate the complex variations in exposure a person experiences. Other studies measured magnetic fields over a 24-hour or 48-hour period. Exposure levels for some occupational studies are measured by having certain employees wear personal monitors. The data taken from these monitors are sometimes used to estimate typical exposure levels for employees with certain job titles. Researchers can then estimate exposures using only an employee's job title and avoid measuring exposures of all employees.

Methods to Estimate EMF Exposure

Wire Codes

A classification of homes based on characteristics of power lines outside the home (thickness of the wires, wire configuration, etc.) and their distance from the home. This information is used to code the homes into groups with higher and lower predicted magnetic field levels.

Spot Measurement

An instantaneous or very short-term (e.g., 30-second) measurement taken at a designated location.

Time-Weighted Average

A weighted average of exposure measurements taken over a period of time that takes into account the time interval between measurements. When the measurements are taken with a monitor at a fixed sampling rate, the time-weighted average equals the arithmetic mean of the measurements.

Personal Monitor

An instrument that can be worn on the body for measuring exposure over time.

Calculated Historical Fields

An estimate based on a theoretical calculation of the magnetic field emitted by power lines using historical electrical loads on those lines.

3 Results of EMF Research

This chapter summarizes the results of EMF research worldwide, including epidemiological studies of children and adults, clinical studies of how humans react to typical EMF exposures, and laboratory research with animals and cells.

Q Is there a link between EMF exposure and childhood leukemia?

A Despite more than two decades of research to determine whether elevated EMF exposure, principally to magnetic fields, is related to an increased risk of childhood leukemia, there is still no definitive answer. Much progress has been made, however, with some lines of research leading to reasonably clear answers and others remaining unresolved. The best available evidence at this time leads to the following answers to specific questions about the link between EMF exposure and childhood leukemia:

Is there an association between power line configurations (wire codes) and childhood leukemia? No.

Is there an association between measured fields and childhood leukemia? Yes, but the association is weak, and it is not clear whether it represents a cause-and-effect relationship.

Q What is the epidemiological evidence for evaluating a link between EMF exposure and childhood leukemia?

A The initial studies, starting with the pioneering research of Dr. Nancy Wertheimer and Ed Leeper in 1979 in Denver, Colorado, focused on power line configurations near homes. Power lines were systematically evaluated and coded for their presumed ability to produce elevated magnetic fields in homes and classified into groups with higher and lower predicted magnetic field levels (see discussion of wire codes on page 15). Although the first study and two that followed in Denver and Los Angeles showed an association between wire codes indicative of elevated magnetic fields and childhood leukemia, larger, more recent studies in the central part of the United States and in several provinces of Canada did not find such an association. In fact, combining the evidence from all the studies, we can conclude with some confidence that wire codes are not associated with a measurable increase in the risk of childhood leukemia.

The other approach to assessing EMF exposure in homes focused on the measurements of magnetic fields. Unlike wire codes, which are only applicable in North America due to the nature of the electric power distribution system, measured fields have been studied in relation to childhood leukemia in research conducted around the world, including Sweden, England, Germany, New Zealand, and Taiwan. Large, detailed studies have recently been completed in the United States, Canada, and the United Kingdom that provide the most evidence for making an evaluation. These studies have produced variable findings, some reporting small associations, others finding no associations.

National Cancer Institute Study

In 1997, after eight years of work, Dr. Martha Linet and colleagues at the National Cancer Institute (NCI) reported the results of their study of childhood acute lymphoblastic leukemia (ALL). The case-control study involved more than 1,000 children living in 9 eastern and midwestern U.S. states and is the largest epidemiological study of childhood leukemia to date in the United States. To help resolve the question of wire code versus measured magnetic fields, the NCI researchers carried out both types of exposure assessment. Overall, Linet reported little evidence that living in homes with higher measured magnetic-field levels was a disease risk and found no evidence that living in a home with a high wire code configuration increased the risk of ALL in children.

United Kingdom Childhood Cancer Study

In December 1999, Sir Richard Doll and colleagues in the United Kingdom announced that the largest study of childhood cancer ever undertaken—involving nearly 4,000 children with cancer in England, Wales, and Scotland—found no evidence of excess risk of childhood leukemia or other cancers from exposure to power-frequency magnetic fields. It should be noted, however, that because most power lines in the United Kingdom are underground, the EMF exposures of these children were mostly lower than 0.2 microtesla or 2 milligauss.

After reviewing all the data, the U.S. National Institute of Environmental Health Sciences (NIEHS) concluded in 1999 that the evidence was weak, but that it was still sufficient to warrant limited concern. The NIEHS rationale was that no individual epidemiological study provided convincing evidence linking magnetic field exposure with childhood leukemia, but the overall pattern of results for some methods of measuring exposure suggested a weak association between increasing exposure to EMF and increasing risk of childhood leukemia. The small number of cases in these studies made it impossible to firmly demonstrate this association. However, the fact that similar results had been observed in studies of different populations using a variety of study designs supported this observation.

A major challenge has been to determine whether the most highly elevated, but rarely encountered, levels of magnetic fields are associated with an increased risk of leukemia. Early reports focused on the risk associated with exposures above 2 or 3 milligauss, but the more recent studies have been large enough to also provide some information on levels above 3 or 4 milligauss. It is estimated that 4.5% of homes in the United States have magnetic fields above 3 milligauss, and 2.5% of homes have levels above 4 milligauss.

What is Cancer?

Cancer

"Cancer" is a term used to describe at least 200 different diseases, all involving uncontrolled cell growth. The frequency of cancer is measured by the incidence—the number of new cases diagnosed each year. Incidence is usually described as the number of new cases diagnosed per 100,000 people per year.

The incidence of cancer in adults in the United States is 382 per 100,000 per year, and childhood cancers account for about 1% of all cancers. The factors that influence risk differ among the forms of cancer. Known risk factors such as smoking, diet, and alcohol contribute to specific types of cancer. (For example, smoking is a known risk factor for lung cancer, bladder cancer, and oral cancer.) For many other cancers, the causes are unknown.

Leukemia

Leukemia describes a variety of cancers that arise in the bone marrow where blood cells are formed. The leukemias represent less than 4% of all cancer cases in adults but are the most common form of cancer in children. For children age 4 and under, the incidence of childhood leukemia is approximately 6 per 100,000 per year, and it decreases with age to about 2 per 100,000 per year for children 10 and older. In the United States, the incidence of adult leukemia is about 10 cases per 100,000 people per year. Little is known about what causes leukemia, although genetic factors play a role. The only known causes are ionizing radiation, benzene, and other chemicals and drugs that suppress bone marrow function, and a human T-cell leukemia virus.

Brain Cancer

Cancer of the central nervous system (the brain and spinal cord) is uncommon, with incidence in the United States now at about 6 cases in 100,000 people per year. The causes of the disease are largely unknown, although a number of studies have reported an association with certain occupational chemical exposures. Ionizing radiation to the scalp is a known risk factor for brain cancer. Factors associated with an increased risk for other types of cancer—such as smoking, diet, and excessive alcohol use—have not been found to be associated with brain cancer.

To determine what the integrated information from all the studies says about magnetic fields and childhood leukemia, two groups have conducted pooled analyses in which the original data from relevant studies were integrated and analyzed. One report (Greenland et al., 2000) combined 12 relevant studies with magnetic field measurements, and the other considered 9 such studies (Ahlbom et al., 2000). The details of the two pooled analyses are different, but their findings are similar. There is weak evidence for an association (relative risk of approximately 2) at exposures above 3 mG. However, few individuals had high exposures in these studies; therefore, even combining all studies, there is uncertainty about the strength of the association.

The following table summarizes the results for the epidemiological studies of EMF exposure and childhood leukemia analyzed in the pooled analysis by Greenland et al. (2000). The focus of the summary review was the magnetic fields that occurred three months prior to diagnosis. The results were derived from either calculated historical fields or multiple measurements of magnetic fields. The North American

Residential Exposure to Magnetic Fields and Childhood Leukemia

	Magnetic field category (mG)					
	>1 – ≤2 mG		>2 – ≤3 mG		>3 mG	
First author	Estimate	95% CL	Estimate	95% CL	Estimate	95% CL
Coghill	0.54	0.17, 1.74	No controls		No controls	
Dockerty	0.65	0.26, 1.63	2.83	0.29, 27.9	No controls	
Feychting	0.63	0.08, 4.77	0.90	0.12, 7.00	4.44	1.67, 11.7
Linet	1.07	0.82, 1.39	1.01	0.64, 1.59	1.51	0.92, 2.49
London	0.96	0.54, 1.73	0.75	0.22, 2.53	1.53	0.67, 3.50
McBride	0.89	0.62, 1.29	1.27	0.74, 2.20	1.42	0.63, 3.21
Michaelis	1.45	0.78, 2.72	1.06	0.27, 4.16	2.48	0.79, 7.81
Olsen	0.67	0.07, 6.42	No cases		2.00	0.40, 9.93
Savitz	1.61	0.64, 4.11	1.29	0.27, 6.26	3.87	0.87, 17.3
Tomenius	0.57	0.33, 0.99	0.88	0.33, 2.36	1.41	0.38, 5.29
Tynes	1.06	0.25, 4.53	No cases		No cases	
Verkasalo	1.11	0.14, 9.07	No cases		2.00	0.23, 17.7
Study summary	0.95	0.80, 1.12	1.06	0.79, 1.42	1.69*	1.25, 2.29
	1 – <2 mG		2 – <4 mG		≥4 mG	
**United Kingdom	0.84	0.57, 1.24	0.98	0.50, 1.93	1.00	0.30, 3.37

95% CL = 95% confidence limits.
Source: Greenland et al., 2000.

*Mantel-Haenszel analysis (p = 0.01). Maximum-likelihood summaries differed by less than 1% from these summaries; based on 2,656 cases and 7,084 controls. Adjusting for age, sex, and other variables had little effect on summary results.

**These data are from a recent United Kingdom study not included in the Greenland analysis but included in another pooled analysis (Ahlbom et al. 2000). The United Kingdom study included 1,073 cases and 2,224 controls.

For this table, the column headed "estimate" describes the relative risk. Relative risk is the ratio of the risk of childhood leukemia for those in a magnetic field exposure group compared to persons with exposure levels of 1.0 mG or less. For example, Coghill estimated that children with exposures between 1 and 2 mG have 0.54 times the risk of children whose exposures were less than 1 mG. London's study estimates that children whose exposures were greater than 3 mG have 1.53 times the risk of children whose exposures were less than 1 mG. The column headed "95% CL" (confidence limits) describes how much random variation is in the estimate of relative risk. The estimate may be off by some amount due to random variation, and the width of the confidence limits gives some notion of that variation. For example, in Coghill's estimate of 0.54 for the relative risk, values as low as 0.17 or as high as 1.74 would not be statistically significantly different from the value of 0.54. Note there is a wide range of estimates of relative risk across the studies and wide confidence limits for many studies. In light of these findings, the pooling of results can be extremely helpful to calculate an overall estimate, much better than can be obtained from any study taken alone.

studies (Linet, London, McBride, Savitz) were 60 Hz; all other studies were 50 Hz. Results from the recent study from the United Kingdom (see page 17) are also included in the table. This study was included in the analysis by Ahlbom et al. (2000). The relative risk estimates from the individual studies show little or no association of magnetic fields with childhood leukemia. The study summary for the pooled analysis by Greenland et al. (2000) shows a weak association between childhood leukemia and magnetic field exposures greater 3 mG.

Q Is there a link between EMF exposure and childhood brain cancer or other forms of cancer in children?

A Although the earliest studies suggested an association between EMF exposure and all forms of childhood cancer, those initial findings have not been confirmed by other studies. At present, the available series of studies indicates no association between EMF exposure and childhood cancers other than leukemia. Far fewer of these studies have been conducted than studies of childhood leukemia.

Q Is there a link between residential EMF exposure and cancer in adults?

A The few studies that have been conducted to address EMF and adult cancer do not provide strong evidence for an association. Thus, a link has not been established between residential EMF exposure and adult cancers, including leukemia, brain cancer, and breast cancer (see table below).

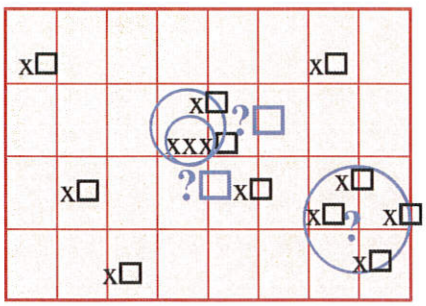
Residential Exposure to Magnetic Fields and Adult Cancer

First author	Location	Type of exposure data	Results (odds ratios)		
			Leukemia	CNS tumors	All cancers
Coleman	United Kingdom	Calculated historical fields	0.92	NA	NA
Feychting and Ahlbom	Sweden	Calculated & spot measurements	1.5*	0.7	NA
Li	Taiwan	Calculated historical fields	1.4*	1.1	NA
Li	Taiwan	Calculated historical fields		1.1 (breast cancer)	
McDowall	United Kingdom	Calculated historical fields	1.43	NA	1.03
Severson	Seattle	Wire codes & spot measurements	0.75	NA	NA
Wrensch	San Francisco	Wire codes & spot measurements	NA	0.9	NA
Youngson	United Kingdom	Calculated historical fields	1.88	NA	NA

CNS = central nervous system.
*The number is statistically significant (greater than expected by chance).
Study results are listed as "odds ratios" (OR). An odds ratio of 1.00 means there was no increase or decrease in risk. In other words, the odds that the people in the study who had the disease (in this case, cancer) and were exposed to a particular agent (in this case, EMF) are the same as for the people in the study who did not have the disease. An odds ratio greater than 1 may occur simply by chance, unless it is statistically significant.

Q Have clusters of cancer or other adverse health effects been linked to EMF exposure?

A An unusually large number of cancers, miscarriages, or other adverse health effects that occur in one area or over one period of time is called a "cluster." Sometimes clusters provide an early warning of a health hazard. But most of the time the reason for the cluster is not known. There have been no proven instances of cancer clusters linked with EMF exposure.



The definition of a "cluster" depends on how large an area is included. Cancer cases (x's in illustration) in a city, neighborhood, or workplace may occur in ways that suggest a cluster due to a common environmental cause. Often these patterns turn out to be due to chance. Delineation of a cluster is subjective—where do you draw the circles?

Q If EMF does cause or promote cancer, shouldn't cancer rates have increased along with the increased use of electricity?

A Not necessarily. Although the use of electricity has increased greatly over the years, EMF exposures may not have increased. Changes in building wiring codes and in the design of electrical appliances have in some cases resulted in lower magnetic field levels. Rates for various types of cancer have shown both increases and decreases through the years, due in part to improved prevention, diagnosis, reporting, and treatment.

Q Is there a link between EMF exposure in electrical occupations and cancer?

A For almost as long as we have been concerned with residential exposure to EMF and childhood cancers, researchers have been studying workplace exposure to EMF and adult cancers, focusing on leukemia and brain cancer. This research began with surveys of job titles and cancer risks, but has progressed to include very large, detailed studies of the health of workers, especially electric utility workers, in the United States, Canada, France, England, and several Northern European countries. Some studies have found evidence that suggests a link between EMF exposure and both leukemia and brain cancer, whereas other studies of similar size and quality have not found such associations.

California
A 1993 study of 36,000 California electric utility workers reported no strong, consistent evidence of an association between magnetic fields and any type of cancer.

Canada/France
A 1994 study of more than 200,000 utility workers in 3 utility companies in Canada and France reported no significant association between all leukemias combined and cumulative exposure to magnetic fields. There was a slight, but not statistically significant, increase in brain cancer. The researchers concluded that the study did not provide clear-cut evidence that magnetic field exposures caused leukemia or brain cancer.

North Carolina
Results of a 1995 study involving more than 138,000 utility workers at 5 electric utilities in the United States did not support an association between occupational magnetic field exposure and leukemia, but suggested a link to brain cancer.

Denmark
In 1997 a study of workers employed in all Danish utility companies reported a small, but statistically significant, excess risk for all cancers combined and for lung cancer. No excess risk was observed for leukemia, brain cancers, or breast cancer.

United Kingdom
A 1997 study among electrical workers in the United Kingdom did not find an excess risk for brain cancer. An extension of this work reported in 2001 also found no increased risk for brain cancer.

Efforts have also been made to pool the findings across several of the above studies to produce more accurate estimates of the association between EMF and cancer (Kheifets et al., 1999). The combined summary statistics across studies provide insufficient evidence for an association between EMF exposure in the workplace and either leukemia or brain cancer.

Q Have studies of workers in other industries suggested a link between EMF exposure and cancer?

A One of the largest studies to report an association between cancer and magnetic field exposure in a broad range of industries was conducted in Sweden (1993). The study included an assessment of EMF exposure in 1,015 different workplaces and involved more than 1,600 people in 169 different occupations. An association was reported between estimated EMF exposure and increased risk for chronic lymphocytic leukemia. An association was also reported between exposure to magnetic fields and brain cancer, but there was no dose-response relationship.

Another Swedish study (1994) found an excess risk of lymphocytic leukemia among railway engine drivers and conductors. However, the total cancer incidence (all tumors included) for this group of workers was lower than in the general Swedish population. A study of Norwegian railway workers found no evidence for an association between EMF exposure and leukemia or brain cancer. Although both positive and negative effects of EMF exposure have been reported, the majority of studies show no effects.

Q Is there a link between EMF exposure and breast cancer?

A Researchers have been interested in the possibility that EMF exposure might cause breast cancer, in part because breast cancer is such a common disease in adult women. Early studies identified a few electrical workers with male breast cancer, a very rare disease. A link between EMF exposure and alterations in the hormone melatonin was considered a possible hypothesis (see page 24). This idea provided motivation to conduct research addressing a possible link between EMF exposure and breast cancer. Overall, the published epidemiological studies have not shown such an association.

Q What have we learned from clinical studies?

A Laboratory studies with human volunteers have attempted to answer questions such as,

Does EMF exposure alter normal brain and heart function?
Does EMF exposure at night affect sleep patterns?
Does EMF exposure affect the immune system?
Does EMF exposure affect hormones?

The following kinds of biological effects have been reported. Keep in mind that a biological effect is simply a measurable change in some biological response. It may or may not have any bearing on health.

Heart rate

An inconsistent effect on heart rate by EMF exposure has been reported. When observed, the biological response is small (on average, a slowing of about three to five beats per minute), and the response does not persist once exposure has ended.

Two laboratories, one in the United States and one in Australia, have reported effects of EMF on heart rate variability. Exposures used in these experiments were relatively high (about 300 mG), and lower exposures failed to produce the effect. Effects have not been observed consistently in repeated experiments.

Sleep electrophysiology

A laboratory report suggested that overnight exposure to 60-Hz magnetic fields may disrupt brain electrical activity (EEG) during night sleep. In this study subjects were exposed to either continuous or intermittent magnetic fields of 283 mG. Individuals exposed to the intermittent magnetic fields showed alterations in traditional EEG sleep parameters indicative of a pattern of poor and disrupted sleep. Several studies have reported no effect with continuous exposure.

Hormones, immune system, and blood chemistry

Several clinical studies with human volunteers have evaluated the effects of power-frequency EMF exposure on hormones, the immune system, and blood chemistry. These studies provide little evidence for any consistent effect.

Melatonin

The hormone melatonin is secreted mainly at night and primarily by the pineal gland, a small gland attached to the brain. Some laboratory experiments with cells and animals have shown that melatonin can slow the growth of cancer cells, including breast cancer cells. Suppressed nocturnal melatonin levels have been observed in some studies of laboratory animals exposed to both electric and magnetic fields. These observations led to the hypothesis that EMF exposure might reduce melatonin and thereby weaken one of the body's defenses against cancer.

Many clinical studies with human volunteers have now examined whether various levels and types of magnetic field exposure affect blood levels of melatonin. Exposure of human volunteers at night to power-frequency EMF under controlled laboratory conditions has no apparent effect on melatonin. Some studies of people exposed to EMF at work or at home do report evidence for a small suppression of melatonin. It is not clear whether the decreases in melatonin reported under environmental conditions are related to the presence of EMF exposure or to other factors.

Q What effects of EMF have been reported in laboratory studies of cells?

A Over the years, scientists have conducted more than 1,000 laboratory studies to investigate potential biological effects of EMF exposure. Most have been ***in vitro*** studies; that is, studies carried out on cells isolated from animals and plants, or on cell components such as cell membranes. Other studies involved animals, mainly rats and mice. In general, these studies do not demonstrate a consistent effect of EMF exposure.

Most ***in vitro*** studies have used magnetic fields of 1,000 mG (100 μT) or higher, exposures that far exceed daily human exposures. In most incidences, when one laboratory has reported effects of EMF exposure on cells, other laboratories have not been able to reproduce the findings. For such research results to be widely accepted by scientists as valid, they must be replicated—that is, scientists in other laboratories should be able to repeat the experiment and get similar results. Cellular studies have investigated potential EMF effects on cell proliferation and differentiation, gene expression, enzyme activity, melatonin, and DNA. Scientists reviewing the EMF research literature find overall that the cellular studies provide little convincing evidence of EMF effects at environmental levels.

Q Have effects of EMF been reported in laboratory studies in animals?

A Researchers have published more than 30 detailed reports on both long-term and short-term studies of EMF exposures in laboratory animals (bioassays). Long-term animal bioassays constitute an important group of studies in EMF research. Such studies have a proven record for predicting the carcinogenicity of chemicals, physical agents, and other suspected cancer-causing agents. In the EMF studies, large groups of mice or rats were continuously exposed to EMF for two years or longer and were then evaluated for cancer. The U.S. National Toxicology Program (http://ntp-server.niehs.nih.gov/) has an extensive historical database for hundreds of different chemical and physical agents evaluated using this model. EMF long-term bioassays examined leukemia, brain cancer, and breast cancer—the diseases some epidemiological studies have associated with EMF exposure (see pages 16–23).

Several different approaches have been used to evaluate effects of EMF exposure in animal bioassays. To investigate whether EMF could promote cancer after genetic damage had occurred, some long-term studies used cancer initiators such as ultraviolet light, radiation, or certain chemicals that are known to cause genetic damage. Researchers compared groups of animals treated with cancer initiators to groups treated with cancer initiators and then exposed to EMF, to see if EMF exposure promoted the cancer growth (initiation-promotion model). Other studies tested the cancer promotion potential of EMF using mice that were predisposed to cancer because they had defects in the genes that control cancer.

Animal Leukemia Studies: Long-Term, Continuous Exposure Studies, Two or More Years in Length			
First author	**Sex/species**	**Exposure/animal numbers**	**Results**
Babbitt (U.S.)	Female mice	14,000 mG, 190 or 380 mice per group. Some groups treated with ionizing radiation.	No effect
Boorman (U.S.)	Male and female rats	20 to 10,000 mG, 100 per group	No effect
McCormick (U.S.)	Male and female mice	20 to 10,000 mG, 100 per group	No effect
Mandeville (Canada)	Female rats	20 to 20,000 mG, 50 per group *In utero* exposure	No effect
Yasui (Japan)	Male and female rats	5,000 to 50,000 mG, 50 per group	No effect

10 milligauss (mG) = 1 microtesla (μT) = 0.001 millitesla (mT)

Leukemia

Fifteen animal leukemia studies have been completed and reported. Most tested for effects of exposure to power-frequency (60-Hz) magnetic fields using rodents. Results of these studies were largely negative. The Babbitt study evaluated the subtypes of leukemia. The data provide no support for the reported epidemiology findings of leukemia from EMF exposure. Many scientists feel that the lack of effects seen in these laboratory leukemia studies significantly weakens the case for EMF as a cause of leukemia.

Breast cancer

Researchers in the Ukraine, Germany, Sweden, and the United States have used initiation-promotion models to investigate whether EMF exposure promotes breast cancer in rats.

The results of these studies are mixed; while the German studies showed some effects, the Swedish and U.S. studies showed none. Studies in Germany reported effects on the numbers of tumors and tumor volume. A National Toxicology Program long-term bioassay performed without the use of other cancer-initiating substances showed no effects of EMF exposure on the development of mammary tumors in rats and mice.

The explanation for the observed difference among these studies is not readily apparent. Within the limits of the experimental rodent model of mammary carcinogenesis, no conclusions are possible regarding a promoting effect of EMF on chemically induced mammary cancer.

Other cancers

Tests of EMF effects on skin cancer, liver cancer, and brain cancer have been conducted using both initiation-promotion models and non-initiated long-term bioassays. All are negative.

Three positive studies were reported for a co-promotion model of skin cancer in mice. The mice were exposed to EMF plus cancer-causing chemicals after cancers had already been initiated. The same research team as well as an independent laboratory were unable to reproduce these results in subsequent experiments.

Non-cancer effects

Many animal studies have investigated whether EMF can cause health problems other than cancer. Researchers have examined many endpoints, including birth defects, immune system function, reproduction, behavior, and learning. Overall, animal studies do not support EMF effects on non-cancer endpoints.

Q Can EMF exposure damage DNA?

A Studies have attempted to determine whether EMF has genotoxic potential; that is, whether EMF exposure can alter the genetic material of living organisms. This question is important because genotoxic agents often also cause cancer or birth defects. Studies of genotoxicity have included tests on bacteria, fruit flies, and some tests on rats and mice. Nearly 100 studies on EMF genotoxicity have been reported. Most evidence suggests that EMF exposure is not genotoxic. Based on experiments with cells, some researchers have suggested that EMF exposure may inhibit the cell's ability to repair normal DNA damage, but this idea remains speculative because of the lack of genotoxicity observed in EMF animal studies.

4 Your EMF Environment

This chapter discusses typical magnetic field exposures in home and work environments and identifies common EMF sources and field intensities associated with these sources.

Q How do we define EMF exposure?

A Scientists are still uncertain about the best way to define "exposure" because experiments have yet to show which aspect of the field, if any, may be relevant to reported biological effects. Important aspects of exposure could be the highest intensity, the average intensity, or the amount of time spent above a certain baseline level. The most widely used measure of EMF exposure has been the time-weighted average magnetic field level (see discussion on page 15).

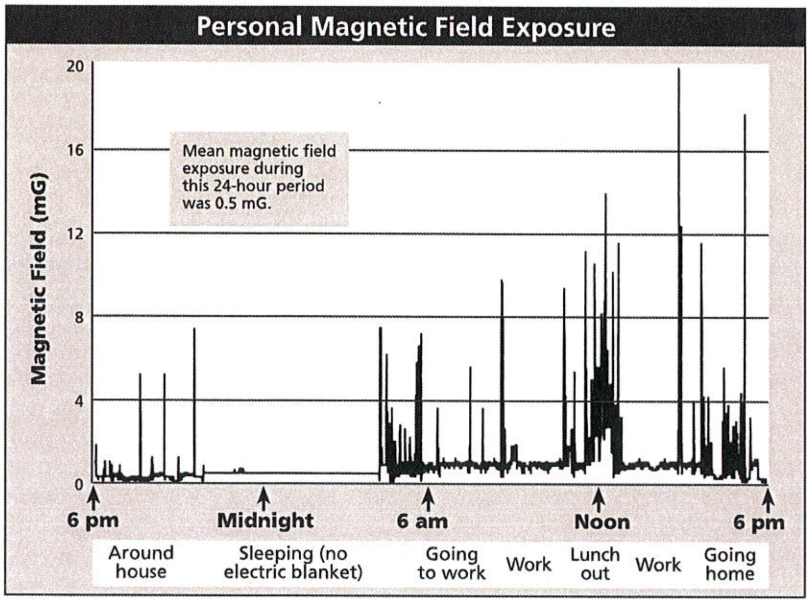
Q How is EMF exposure measured?

A Several kinds of personal exposure meters are now available. These automatically record the magnetic field as it varies over time. To determine a person's EMF exposure, the personal exposure meter is usually worn at the waist or is placed as close as possible to the person during the course of a work shift or day.

EMF can also be measured using survey meters, sometimes called "gaussmeters." These measure the EMF levels in a given location at a given time. Such measurements do not necessarily reflect personal EMF exposure because they are not always taken at the distance from the EMF source that the person would typically be from the source. Measurements are not always made in a location for the same amount of time that a person spends there. Such "spot measurements" also fail to capture variations of the field over time, which can be significant.

Q What are some typical EMF exposures?

A The figure below is an example of data collected with a personal exposure meter.



In the above example, the magnetic field was measured every 1.5 seconds over a period of 24 hours. For this person, exposure at home was very low. The occasional spikes (short exposure to high fields) occurred when the person drove or walked under power lines or over underground power lines or was close to appliances in the home or office.

Several studies have used personal exposure meters to measure field exposure in different environments. These studies tend to show that appliances and building wiring contribute to the magnetic field exposure that most people receive while at home. People living close to high voltage power lines that carry a lot of current tend to have higher overall field exposures. As shown on page 32, there is considerable variation among houses.

Q What are typical EMF exposures for people living in the United States?

A Most people in the United States are exposed to magnetic fields that average less than 2 milligauss (mG), although individual exposures vary.

The following table shows the estimated average magnetic field exposure of the U.S. population, according to a study commissioned by the U.S. government as part of the EMF Research and Public Information Dissemination (EMF RAPID) Program (see page 50). This study measured magnetic field exposure of about 1,000 people of all ages randomly selected among the U.S. population. Participants wore or carried with them a small personal exposure meter and kept a diary of their activities both at home and away from home. Magnetic field values were automatically recorded twice a second for 24 hours. The study reported that exposure to magnetic fields is similar in different regions of the country and similar for both men and women.

Estimated Average Magnetic Field Exposure of the U.S. Population

Average 24-hour field (mG)	Population exposed (%)	95% confidence interval (%)	People exposed* (millions)
> 0.5	76.3	73.8–78.9	197–211
> 1	43.6	40.9–46.5	109–124
> 2	14.3	11.8–17.3	31.5–46.2
> 3	6.3	4.7–8.5	12.5–22.7
> 4	3.6	2.5–5.2	6.7–13.9
> 5	2.42	1.65–3.55	4.4–9.5
> 7.5	0.58	0.29–1.16	0.77–3.1
> 10	0.46	0.20–1.05	0.53–2.8
> 15	0.17	0.035–0.83	0.09–2.2

*Based on a population of 267 million. This table summarizes some of the results of a study that sampled about 1,000 people in the United States. In the first row, for example, we find that 76.3% of the sample population had a 24-hour average exposure of greater than 0.5 mG. Assuming that the sample was random, we can use statistics to say that we are 95% confident that the percentage of the overall U.S. population exposed to greater than 0.5 mG is between 73.8% and 78.9%. Source: Zaffanella, 1993.

The following table shows average magnetic fields experienced during different types of activities. In general, magnetic fields are greater at work than at home.

Estimated Average Magnetic Field Exposure of the U.S. Population for Various Activities

Average field (mG)	Population exposed (%)				
	Home	Bed	Work	School	Travel
> 0.5	69	48	81	63	87
> 1	38	30	49	25	48
> 2	14	14	20	3.5	13
> 3	7.8	7.2	13	1.6	4.1
> 4	4.7	4.7	8.0	< 1	1.5
> 5	3.5	3.7	4.6		1.0
> 7.5	1.2	1.6	2.5		0.5
> 10	0.9	0.8	1.3		< 0.2
> 15	0.1	0.1	0.9		

Source: Zaffanella, 1993.

Q What levels of EMF are found in common environments?

A Magnetic field exposures can vary greatly from site to site for any type of environment. The data shown in the following table are median measurements taken at four different sites for each environment category.

EMF Exposures in Common Environments
Magnetic fields measured in milligauss (mG)

Environment	Median* exposure	Top 5th percentile
OFFICE BUILDING		
Support staff	0.6	3.7
Professional	0.5	2.6
Maintenance	0.6	3.8
Visitor	0.6	2.1
SCHOOL		
Teacher	0.6	3.3
Student	0.5	2.9
Custodian	1.0	4.9
Administrative staff	1.3	6.9
HOSPITAL		
Patient	0.6	3.6
Medical staff	0.8	5.6
Visitor	0.6	2.4
Maintenance	0.6	5.9
MACHINE SHOP		
Machinist	0.4	6.0
Welder	1.1	24.6
Engineer	1.0	5.1
Assembler	0.5	6.4
Office staff	0.7	4.7
GROCERY STORE		
Cashier	2.7	11.9
Butcher	2.4	12.8
Office staff	2.1	7.1
Customer	1.1	7.7

*The median of four measurements. For this table, the median is the average of the two middle measurements. Source: National Institute for Occupational Safety and Health.

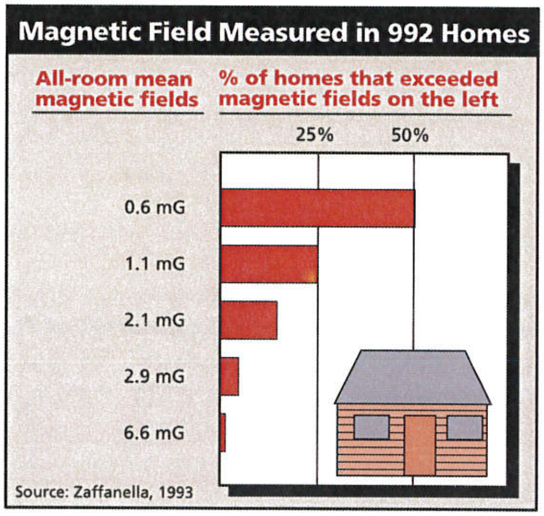
Q What EMF field levels are encountered in the home?

A Electric fields

Electric fields in the home, on average, range from 0 to 10 volts per meter. They can be hundreds, thousands, or even millions of times weaker than those encountered outdoors near power lines. Electric fields directly beneath power lines may vary from a few volts per meter for some overhead distribution lines to several thousands of volts per meter for extra high voltage power lines. Electric fields from power lines rapidly become weaker with distance and can be greatly reduced by walls and roofs of buildings.

Magnetic fields

Magnetic fields are not blocked by most materials. Magnetic fields encountered in homes vary greatly. Magnetic fields rapidly become weaker with distance from the source.



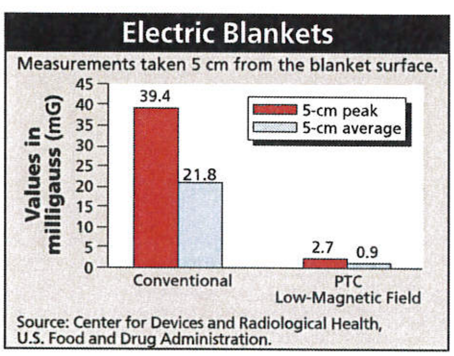
The chart on the left summarizes data from a study by the Electric Power Research Institute (EPRI) in which spot measurements of magnetic fields were made in the center of rooms in 992 homes throughout the United States. Half of the houses studied had magnetic field measurements of 0.6 mG or less, when the average of measurements from all the rooms in the house was calculated (the all-room mean magnetic field). The all-room mean magnetic field for all houses studied was 0.9 mG. The measurements were made away from electrical appliances and reflect primarily the fields from household wiring and outside power lines.

If you are comparing the information in this chart with measurements in your own home, keep in mind that this chart shows averages of measurements taken throughout the homes, not the single highest measurement found in the home.

Q What are EMF levels close to electrical appliances?

A Magnetic fields close to electrical appliances are often much stronger than those from other sources, including magnetic fields directly under power lines. Appliance fields decrease in strength with distance more quickly than do power line fields.

The following table, based on data gathered in 1992, lists the EMF levels generated by common electrical appliances. Magnetic field strength (magnitude) does not depend on how large, complex, powerful, or noisy the appliance is. Magnetic fields near large appliances are often weaker than those near small devices. Appliances in your home may have been redesigned since the data in the table were collected, and the EMF they produce may differ considerably from the levels shown here.



The graph shows magnetic fields produced by electric blankets, including conventional 110-V electric blankets as well as the PTC (positive temperature coefficient) low-magnetic-field blankets. The fields were measured at a distance of about 2 inches from the blanket's surface, roughly the distance from the blanket to the user's internal organs. Because of the wiring, magnetic field strengths vary from point to point on the blanket. The graph reflects this and gives both the peak and the average measurement.

Sources of Magnetic Fields (mG)*

Office Sources

	Distance from source 6″	1′	2′	4′
AIR CLEANERS				
Lowest	110	20	3	–
Median	180	35	5	1
Highest	250	50	8	2
COPY MACHINES				
Lowest	4	2	1	–
Median	90	20	7	1
Highest	200	40	13	4
FAX MACHINES				
Lowest	4	–	–	–
Median	6	–	–	–
Highest	9	2	–	–
FLUORESCENT LIGHTS				
Lowest	20	–	–	–
Median	40	6	2	–
Highest	100	30	8	4
ELECTRIC PENCIL SHARPENERS				
Lowest	20	8	5	–
Median	200	70	20	2
Highest	300	90	30	30
VIDEO DISPLAY TERMINALS (see page 48) (PCs with color monitors)**				
Lowest	7	2	1	–
Median	14	5	2	–
Highest	20	6	3	–

Bathroom Sources

	6″	1′	2′	4′
HAIR DRYERS				
Lowest	1	–	–	–
Median	300	1	–	–
Highest	700	70	10	1
ELECTRIC SHAVERS				
Lowest	4	–	–	–
Median	100	20	–	–
Highest	600	100	10	1

Workshop Sources

	Distance from source 6″	1′	2′	4′
BATTERY CHARGERS				
Lowest	3	2	–	–
Median	30	3	–	–
Highest	50	4	–	–
DRILLS				
Lowest	100	20	3	–
Median	150	30	4	–
Highest	200	40	6	–
POWER SAWS				
Lowest	50	9	1	–
Median	200	40	5	–
Highest	1000	300	40	4
ELECTRIC SCREWDRIVERS (while charging)				
Lowest	–	–	–	–
Median	–	–	–	–
Highest	–	–	–	–

Living/Family Room Sources

	Distance from source 1′	2′	4′
CEILING FANS			
Lowest	–	–	–
Median	3	–	–
Highest	50	6	1
WINDOW AIR CONDITIONERS			
Lowest	–	–	–
Median	3	1	–
Highest	20	6	4
COLOR TELEVISIONS**			
Lowest	–	–	–
Median	7	2	–
Highest	20	8	4

Continued

Sources of Magnetic Fields (mG)*

	Distance from source 6″	1′	2′	4′
Kitchen Sources				
BLENDERS				
Lowest	30	5	–	–
Median	70	10	2	–
Highest	100	20	3	–
CAN OPENERS				
Lowest	500	40	3	–
Median	600	150	20	2
Highest	1500	300	30	4
COFFEE MAKERS				
Lowest	4	–	–	–
Median	7	–	–	–
Highest	10	1	–	–
DISHWASHERS				
Lowest	10	6	2	–
Median	20	10	4	–
Highest	100	30	7	1
FOOD PROCESSORS				
Lowest	20	5	–	–
Median	30	6	2	–
Highest	130	20	3	–
GARBAGE DISPOSALS				
Lowest	60	8	1	–
Median	80	10	2	–
Highest	100	20	3	–
MICROWAVE OVENS* **				
Lowest	100	1	1	–
Median	200	4	10	2
Highest	300	200	30	20
MIXERS				
Lowest	30	5	–	–
Median	100	10	1	–
Highest	600	100	10	–
Kitchen Sources				
ELECTRIC OVENS				
Lowest	4	1	–	–
Median	9	4	–	–
Highest	20	5	1	–
ELECTRIC RANGES				
Lowest	20	–	–	–
Median	30	8	2	–
Highest	200	30	9	6
REFRIGERATORS				
Lowest	–	–	–	–
Median	2	2	1	–
Highest	40	20	10	10
TOASTERS				
Lowest	5	–	–	–
Median	10	3	–	–
Highest	20	7	–	–
Bedroom Sources				
DIGITAL CLOCK******				
Lowest		–	–	–
Median		1	–	–
High		8	2	1
ANALOG CLOCKS (conventional clockface)******				
Lowest		1	–	–
Median		15	2	–
Highest		30	5	3
BABY MONITOR (unit nearest child)				
Lowest	4	–	–	–
Median	6	1	–	–
Highest	15	2	–	–

Continued

Sources of Magnetic Fields (mG)*

	Distance from source					Distance from source			
	6"	1'	2'	4'		6"	1'	2'	4'
Laundry/Utility Sources					**Laundry/Utility Sources**				
ELECTRIC CLOTHES DRYERS					PORTABLE HEATERS				
Lowest	2	–	–	–	Lowest	5	1	–	–
Median	3	2	–	–	Median	100	20	4	–
Highest	10	3	–	–	Highest	150	40	8	1
WASHING MACHINES					VACUUM CLEANERS				
Lowest	4	1	–	–	Lowest	100	20	4	–
Median	20	7	1	–	Median	300	60	10	1
Highest	100	30	6	–	Highest	700	200	50	10
IRONS					SEWING MACHINES				
Lowest	6	1	–	–	Home sewing machines can produce magnetic fields of 12 mG at chest level and 5 mG at head level. Magnetic fields as high as 35 mG at chest level and 215 mG at knee level have been measured from industrial sewing machine models (Sobel, 1994).				
Median	8	1	–	–					
Highest	20	3	–	–					

Source: EMF In Your Environment, U.S. Environmental Protection Agency, 1992.

* Dash (–) means that the magnetic field at this distance from the operating appliance could not be distinguished from background measurements taken before the appliance had been turned on.

** Some appliances produce both 60-Hz and higher frequency fields. For example, televisions and computer screens produce fields at 10,000-30,000 Hz (10-30 kHz) as well as 60-Hz fields.

*** Microwave ovens produce 60-Hz fields of several hundred milligauss, but they also create microwave energy inside the appliance that is at a much higher frequency (about 2.45 billion hertz). We are shielded from the higher frequency fields but not from the 60-Hz fields.

**** Most digital clocks have low magnetic fields. In some analog clocks, however, higher magnetic fields are produced by the motor that drives the hands. In the above table, the clocks are electrically powered using alternating current, as are all the appliances described in these tables.

Q What EMF levels are found near power lines?

A Power transmission lines bring power from a generating station to an electrical substation. Power distribution lines bring power from the substation to your home. Transmission and distribution lines can be either overhead or underground. Overhead lines produce both electric fields and magnetic fields. Underground lines do not produce electric fields above ground but may produce magnetic fields above ground.

Power transmission lines

Typical EMF levels for transmission lines are shown in the chart on page 37. At a distance of 300 feet and at times of average electricity demand, the magnetic fields from many lines can be similar to typical background levels found in most homes. The distance at which the magnetic field from the line becomes indistinguishable from typical background levels differs for different types of lines.

Power distribution lines

Typical voltage for power distribution lines in North America ranges from 4 to 24 kilovolts (kV). Electric field levels directly beneath overhead distribution lines may vary from a few volts per meter to 100 or 200 volts per meter. Magnetic fields directly beneath overhead distribution lines typically range from 10 to 20 mG for main feeders and less than 10 mG for laterals. Such levels are also typical directly above underground lines. Peak EMF levels, however, can vary considerably depending on the amount of current carried by the line. Peak magnetic field levels as high as 70 mG have been measured directly below overhead distribution lines and as high as 40 mG above underground lines.

Q How strong is the EMF from electric power substations?

A In general, the strongest EMF around the outside of a substation comes from the power lines entering and leaving the substation. The strength of the EMF from equipment within the substations, such as transformers, reactors, and capacitor banks, decreases rapidly with increasing distance. Beyond the substation fence or wall, the EMF produced by the substation equipment is typically indistinguishable from background levels.

Q Do electrical workers have higher EMF exposure than other workers?

A Most of the information we have about occupational EMF exposure comes from studies of electric utility workers. It is therefore difficult to compare electrical workers' EMF exposures with those of other workers because there is less information about EMF exposures in work environments other than electric utilities. Early studies did not include actual measurements of EMF exposure on the job but used job titles as an estimate of EMF exposure among electrical workers. Recent studies, however, have included extensive EMF exposure assessments.

A report published in 1994 provides some information about estimated EMF exposures of workers in Los Angeles in a number of electrical jobs in electric utilities and other industries. Electrical workers had higher average EMF exposures (9.6 mG) than did workers in other jobs (1.7 mG). For this study, the category "electrical workers" included electrical engineering technicians, electrical engineers, electricians, power line workers, power station operators, telephone line workers, TV repairers, and welders.

Typical EMF Levels for Power Transmission Lines*

115 kV

	At line	Approx. Edge of Right-of-Way 15 m (50 ft)	30 m (100 ft)	61 m (200 ft)	91 m (300 ft)
Electric Field (kV/m)	1.0	0.5	0.07	0.01	0.003
Mean Magnetic Field (mG)	29.7	6.5	1.7	0.4	0.2

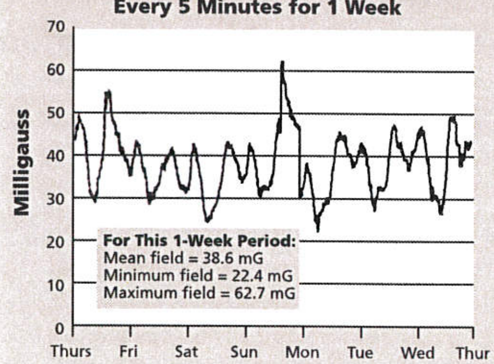
230 kV

	At line	Approx. Edge of Right-of-Way 15 m (50 ft)	30 m (100 ft)	61 m (200 ft)	91 m (300 ft)
Electric Field (kV/m)	2.0	1.5	0.3	0.05	0.01
Mean Magnetic Field (mG)	57.5	19.5	7.1	1.8	0.8

500 kV

	At line	Approx. Edge of Right-of-Way 20 m (65 ft)	30 m (100 ft)	61 m (200 ft)	91 m (300 ft)
Electric Field (kV/m)	7.0	3.0	1.0	0.3	0.1
Mean Magnetic Field (mG)	86.7	29.4	12.6	3.2	1.4

Magnetic Field from a 500-kV Transmission Line Measured on the Right-of-Way Every 5 Minutes for 1 Week



Electric fields from power lines are relatively stable because line voltage doesn't change very much. Magnetic fields on most lines fluctuate greatly as current changes in response to changing loads. Magnetic fields must be described statistically in terms of averages, maximums, etc. The magnetic fields above are means calculated for 321 power lines for 1990 annual mean loads. During peak loads (about 1% of the time), magnetic fields are about twice as strong as the mean levels above. The graph on the left is an example of how the magnetic field varied during one week for one 500-kV transmission line.

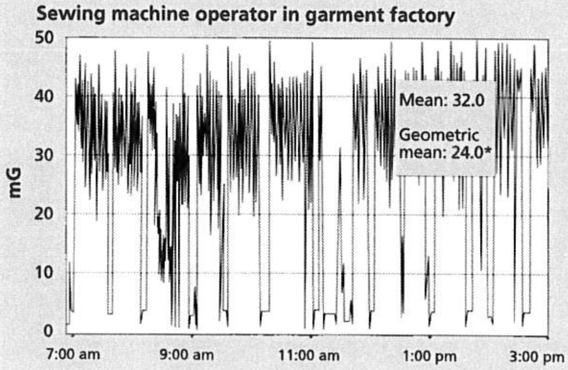
*These are typical EMFs at 1 m (3.3 ft) above ground for various distances from power lines in the Pacific Northwest. They are for general information. For information about a specific line, contact the utility that operates the line.
Source: Bonneville Power Administration, 1994.

Q What are possible EMF exposures in the workplace?

A The figures below are examples of magnetic field exposures determined with exposure meters worn by four workers in different occupations. These measurements demonstrate how EMF exposures vary among individual workers. They do not necessarily represent typical EMF exposures for workers in these occupations.

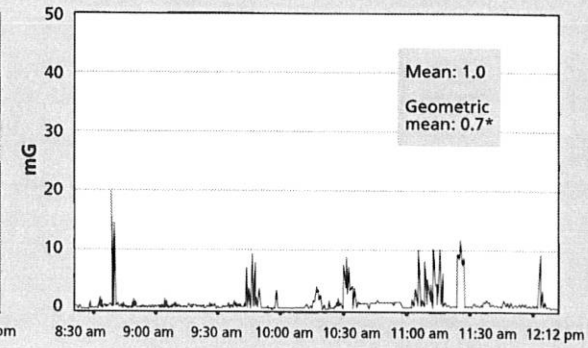
Magnetic Field Exposures of Workers (mG)

Sewing machine operator in garment factory



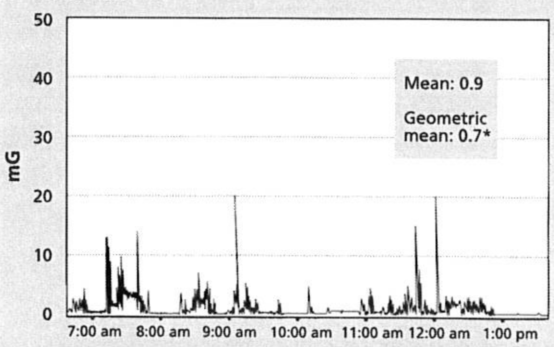
The sewing machine operator worked all day, took a 1-hour lunch break at 11:15 am, and took 10-minute breaks at 8:55 am and 2:55 pm.

Maintenance mechanic



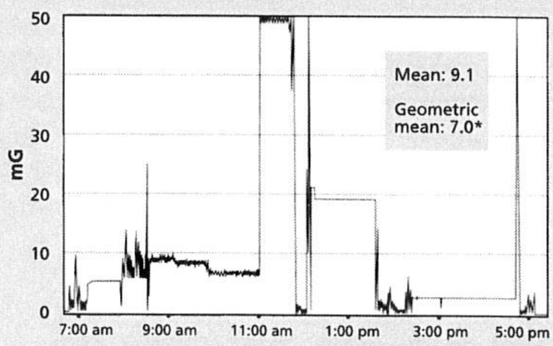
The mechanic repaired a compressor at 9:45 am and 11:10 am.

Electrician



The electrician repaired a large air-conditioning motor at 9:10 am and at 11:45 am.

Government office worker



The government worker was at the copy machine at 8:00 am, at the computer from 11:00 am to 1:00 pm and also from 2:30 pm to 4:30 pm.

*The geometric mean is calculated by squaring the values, adding the squares, and then taking the square root of the sum.
Source: National Institute for Occupational Safety and Health and U.S. Department of Energy.

The tables below and on page 41 can give you a general idea about magnetic field levels for different jobs and around various kinds of electrical equipment. It is important to remember that EMF levels depend on the actual equipment used in

EMF Measurements During a Workday

Industry and occupation	ELF magnetic fields measured in mG: Median for occupation*	ELF magnetic fields measured in mG: Range for 90% of workers**
ELECTRICAL WORKERS IN VARIOUS INDUSTRIES		
Electrical engineers	1.7	0.5–12.0
Construction electricians	3.1	1.6–12.1
TV repairers	4.3	0.6–8.6
Welders	9.5	1.4–66.1
ELECTRIC UTILITIES		
Clerical workers without computers	0.5	0.2–2.0
Clerical workers with computers	1.2	0.5–4.5
Line workers	2.5	0.5–34.8
Electricians	5.4	0.8–34.0
Distribution substation operators	7.2	1.1–36.2
Workers off the job (home, travel, etc.)	0.9	0.3–3.7
TELECOMMUNICATIONS		
Install, maintenance, & repair technicians	1.5	0.7–3.2
Central office technicians	2.1	0.5–8.2
Cable splicers	3.2	0.7–15.0
AUTO TRANSMISSION MANUFACTURE		
Assemblers	0.7	0.2–4.9
Machinists	1.9	0.6–27.6
HOSPITALS		
Nurses	1.1	0.5–2.1
X-ray technicians	1.5	1.0–2.2
SELECTED OCCUPATIONS FROM ALL ECONOMIC SECTORS		
Construction machine operators	0.5	0.1–1.2
Motor vehicle drivers	1.1	0.4–2.7
School teachers	1.3	0.6–3.2
Auto mechanics	2.3	0.6–8.7
Retail sales	2.3	1.0–5.5
Sheet metal workers	3.9	0.3–48.4
Sewing machine operators	6.8	0.9–32.0
Forestry and logging jobs	7.6	0.6–95.5***

Source: National Institute for Occupational Safety and Health.
ELF (extremely low frequency)—frequencies 3–3,000 Hz.

* The median is the middle measurement in a sample arranged by size. These personal exposure measurements reflect the median magnitude of the magnetic field produced by the various EMF sources and the amount of time the worker spent in the fields.

** This range is between the 5th and 95th percentiles of the workday averages for an occupation.

*** Chain saw engines produce strong magnetic fields that are not pure 60-Hz fields.

the workplace. Different brands or models of the same type of equipment can have different magnetic field strengths. It is also important to keep in mind that the strength of a magnetic field decreases quickly with distance.

If you have questions or want more information about your EMF exposure at work, your plant safety officer, industrial hygienist, or other local safety official can be a good source of information. The National Institute for Occupational Safety and Health (NIOSH) is asked occasionally to conduct health hazard evaluations in workplaces where EMF is a suspected cause for concern. For further technical assistance contact NIOSH at 800-356-4674.

Q What are some typical sources of EMF in the workplace?

A Exposure assessment studies so far have shown that most people's EMF exposure at work comes from electrical appliances and tools and from the building's power supply. People who work near transformers, electrical closets, circuit boxes, or other high-current electrical equipment may have 60-Hz magnetic field exposures of hundreds of milligauss or more. In offices, magnetic field levels are often similar to those found at home, typically 0.5 to 4.0 mG. However, these levels can increase dramatically near certain types of equipment.

EMF Spot Measurements

Industry and sources	ELF magnetic fields (mG)	Other frequencies	Comments
ELECTRICAL EQUIPMENT USED IN MACHINE MANUFACTURING			
Electric resistance heater	6,000–14,000	VLF	
Induction heater	10–460	High VLF	
Hand-held grinder	3,000	–	Tool exposures measured at operator's chest.
Grinder	110	–	Tool exposures measured at operator's chest.
Lathe, drill press, etc.	1–4	–	Tool exposures measured at operator's chest.
ALUMINUM REFINING			
Aluminum pot rooms	3.4–30	Very high static field	Highly-rectified DC current (with an ELF ripple) refines aluminum.
Rectification room	300–3,300	High static field	
STEEL FOUNDRY			
Ladle refinery			
Furnace active	170–1,300	High ULF from the ladle's big magnetic stirrer	Highest ELF field was at the chair of control room operator.
Furnace inactive	0.6–3.7	High ULF from the ladle's big magnetic stirrer	Highest ELF field was at the chair of control room operator.
Electrogalvanizing unit	2–1,100	High VLF	
TELEVISION BROADCASTING			
Video cameras (studio and minicams)	7.2–24.0	VLF	
Video tape degaussers	160–3,300	–	Measured 1 ft away.
Light control centers	10–300	–	Walk-through survey.
Studio and newsrooms	2–5	–	Walk-through survey.
HOSPITALS			
Intensive care unit	0.1–220	VLF	Measured at nurse's chest.
Post-anesthesia care unit	0.1–24	VLF	
Magnetic resonance imaging (MRI)	0.5–280	Very high static field, VLF and RF	Measured at technician's work locations.
TRANSPORTATION			
Cars, minivans, and trucks	0.1–125	Most frequencies less than 60 Hz	Steel-belted tires are the principal ELF source for gas/diesel vehicles.
Bus (diesel powered)	0.5–146	Most frequencies less than 60 Hz	
Electric cars	0.1–81	Some elevated static fields	
Chargers for electric cars	4–63	–	Measured 2 ft from charger.
Electric buses	0.1–88	–	Measured at waist. Fields at ankles 2-5 times higher.
Electric train passenger cars	0.1–330	25 & 60 Hz power on U.S. trains	Measured at waist. Fields at ankles 2-5 times higher.
Airliner	0.8–24.2	400 Hz power on airliners	Measured at waist.
GOVERNMENT OFFICES			
Desk work locations	0.1–7	–	Peaks due to laser printers.
Desks near power center	18–50	–	
Power cables in floor	15–170	–	
Building power supplies	25–1,800	–	
Can opener	3,000	–	Appliance fields measured 6 in. away.
Desktop cooling fan	1,000	–	Appliance fields measured 6 in. away.
Other office appliances	10–200	–	

Source: National Institute for Occupational Safety and Health, 2001.
ULF (ultra low frequency)—frequencies above 0, below 3 Hz.
ELF (extremely low frequency)—frequencies 3–3,000 Hz.
VLF (very low frequency)—frequencies 3,000–30,000 Hz (3–30 kilohertz).

Q What EMF exposure occurs during travel?

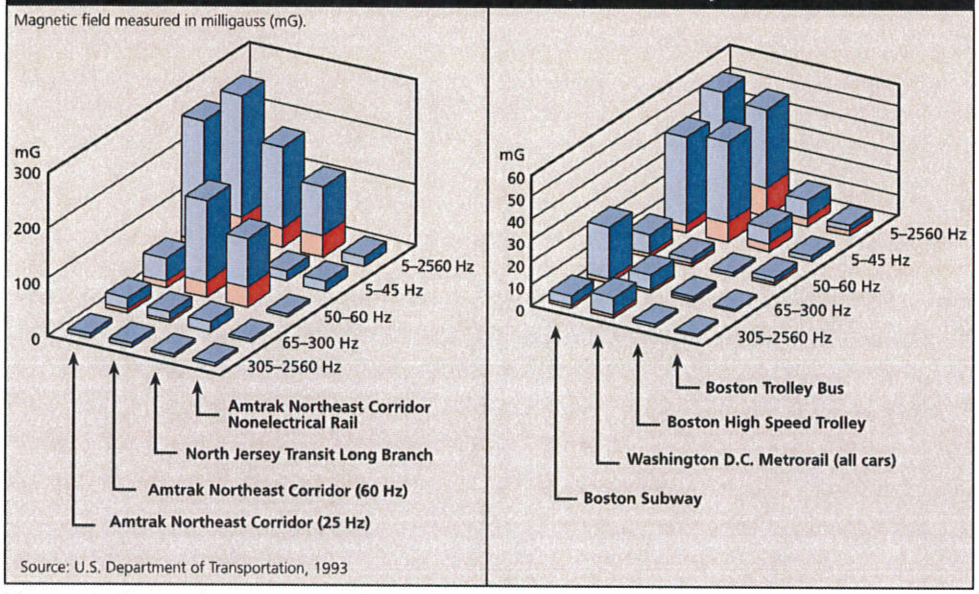
A Inside a car or bus, the main sources of magnetic field exposure are those you pass by (or under) as you drive, such as power lines. Car batteries involve direct current (DC) rather than alternating current (AC). Alternators can create EMF, but at frequencies other than 60 Hz. The rotation of steel-belted tires is also a source of EMF.

Most trains in the United States are diesel powered. Some electrically powered trains operate on AC, such as the passenger trains between Washington, D.C. and New Haven, Connecticut. Measurements taken on these trains using personal exposure monitors have suggested that average 60-Hz magnetic field exposures for passengers and conductors may exceed 50 mG. A U.S. government-sponsored exposure assessment study of electric rail systems found average 60-Hz magnetic field levels in train operator compartments that ranged from 0.4 mG (Boston high speed trolley) to 31.1 mG (North Jersey transit). The graph on the next page shows average and maximum magnetic field measurements in operator compartments of several electric rail systems. It illustrates that 60 Hz is one of several electromagnetic frequencies to which train operators are exposed.

Workers who maintain the tracks on electric rail lines, primarily in the northeastern United States, also have elevated magnetic field exposures at both 25 Hz and 60 Hz. Measurements taken by the National Institute for Occupational Safety and Health show that typical average daily exposures range from 3 to 18 mG, depending on how often trains pass the work site.

Rapid transit and light rail systems in the United States, such as the Washington D.C. Metro and the San Francisco Bay Area Rapid Transit, run on DC electricity. These DC-powered trains contain equipment that produces AC fields. For example, areas of strong AC magnetic fields have been measured on the Washington Metro close to the floor, during braking and acceleration, presumably near equipment located underneath the subway cars.

Magnetic Field Measurements in Train Operators' Compartments



These graphs illustrate that 60 Hz is one of several electromagnetic frequencies to which train operators are exposed. The maximum exposure is the top of the blue (upper) portion of the bar; the average exposure is the top of the red (lower) portion.

Q How can I find out how strong the EMF is where I live and work?

A The tables throughout this chapter can give you a general idea about magnetic field levels at home, for different jobs, and around various kinds of electrical equipment. For specific information about EMF from a particular power line, contact the utility that operates the line. Some will perform home EMF measurements.

You can take your own EMF measurements with a magnetic field meter. For a spot measurement to provide a useful estimate of your EMF exposure, it should be taken at a time of day and location when and where you are typically near the equipment. Keep in mind that the strength of a magnetic field drops off quickly with distance.

Independent technicians will conduct EMF measurements for a fee. Search the Internet under "EMF meters" or "EMF measurement." You should investigate the experience and qualifications of commercial firms, since governments do not standardize EMF measurements or certify measurement contractors.

At work, your plant safety officer, industrial hygienist, or other local safety official can be a good source of information. The National Institute for Occupational Safety and Health (NIOSH) sometimes conducts health hazard evaluations in workplaces where EMF is a suspected cause for concern. For further technical assistance, contact NIOSH at 800-356-4674.

Q How much do computers contribute to my EMF exposure?

A Personal computers themselves produce very little EMF. However, the video display terminal (VDT) or monitor provides some magnetic field exposure unless it is of the new flat-panel design. Conventional VDTs containing cathode ray tubes use magnetic fields to produce the image on the screen, and some emission of those magnetic fields is unavoidable. Unlike most other appliances which produce predominantly 60-Hz magnetic fields, VDTs emit magnetic fields in both the extremely low frequency (ELF) and very low frequency (VLF) frequency ranges (see page 8). Many newer VDTs have been designed to minimize magnetic field emissions, and those identified as "TCO'99 compliant" meet a standard for low emissions (see page 48).

Q What can be done to limit EMF exposure?

A Personal exposure to EMF depends on three things: the strength of the magnetic field sources in your environment, your distance from those sources, and the time you spend in the field.

If you are concerned about EMF exposure, your first step should be to find out where the major EMF sources are and move away from them or limit the time you spend near them. Magnetic fields from appliances decrease dramatically about an arm's length away from the source. In many cases, rearranging a bed, a chair, or a work area to increase your distance from an electrical panel or some other EMF source can reduce your EMF exposure.

Another way to reduce EMF exposure is to use equipment designed to have relatively low EMF emissions. Sometimes electrical wiring in a house or a building can be the source of strong magnetic field exposure. Incorrect wiring is a common source of higher-than-usual magnetic fields. Wiring problems are also worth correcting for safety reasons.

In its 1999 report to Congress, the National Institute of Environmental Health Sciences suggested that the power industry continue its current practice of siting power lines to reduce EMF exposures.

There are more costly actions, such as burying power lines, moving out of a home, or restricting the use of office space that may reduce exposures. Because scientists are still debating whether EMF is a hazard to health, it is not clear that the costs of such measures are warranted. Some EMF reduction measures may create other problems. For instance, compacting power lines reduces EMF but increases the danger of accidental electrocution for line workers.

We are not sure which aspects of the magnetic field exposure, if any, to reduce. Future research may reveal that EMF reduction measures based on today's limited understanding are inadequate or irrelevant. No action should be taken to reduce EMF exposure if it increases the risk of a known safety hazard.

5 EMF Exposure Standards

This chapter describes standards and guidelines established by state, national, and international safety organizations for some EMF sources and exposures.

Q Are there exposure standards for 60-Hz EMF?

A In the United States, there are no federal standards limiting occupational or residential exposure to 60-Hz EMF.

At least six states have set standards for transmission line electric fields; two of these also have standards for magnetic fields (see table below). In most cases, the maximum fields permitted by each state are the maximum fields that existing lines produce at maximum load-carrying conditions. Some states further limit electric field strength at road crossings to ensure that electric current induced into large metal objects such as trucks and buses does not represent an electric shock hazard.

State Transmission Line Standards and Guidelines

	Electric Field		Magnetic Field	
State	On R.O.W.*	Edge R.O.W.	On R.O.W.	Edge R.O.W.
Florida	8 kV/m[a] 10 kV/m[b]	2 kV/m	—	150 mG[a] (max. load) 200 mG[b] (max. load) 250 mG[c] (max. load)
Minnesota	8 kV/m	—	—	—
Montana	7 kV/m[d]	1 kV/m[e]		
New Jersey	—	3 kV/m		
New York	11.8 kV/m 11.0 kV/m[f] 7.0 kV/m[d]	1.6 kV/m	—	200 mG (max. load)
Oregon	9 kV/m	—	—	—

*R.O.W. = right-of-way (or in the Florida standard, certain additional areas adjoining the right-of-way). kV/m = kilovolt per meter. One kilovolt = 1,000 volts. [a]For lines of 69-230 kV. [b]For 500 kV lines. [c]For 500 kV lines on certain existing R.O.W. [d]Maximum for highway crossings. [e]May be waived by the landowner. [f]Maximum for private road crossings.

Two organizations have developed voluntary occupational exposure guidelines for EMF exposure. These guidelines are intended to prevent effects, such as induced currents in cells or nerve stimulation, which are known to occur at high magnitudes, much higher (more than 1,000 times higher) than EMF levels found typically in occupational and residential environments. These guidelines are summarized in the tables on the right.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) concluded that available data regarding potential long-term effects, such as increased risk of cancer, are insufficient to provide a basis for setting exposure restrictions.

The American Conference of Governmental Industrial Hygienists (ACGIH) publishes "Threshold Limit Values" (TLVs) for various physical agents. The TLVs for 60-Hz EMF shown in the table are identified as guides to control exposure; they are not intended to demarcate safe and dangerous levels.

ICNIRP Guidelines for EMF Exposure

Exposure (60 Hz)	Electric field	Magnetic field
Occupational	8.3 kV/m	4.2 G (4,200 mG)
General Public	4.2 kV/m	0.833 G (833 mG)

International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an organization of 15,000 scientists from 40 nations who specialize in radiation protection.
Source: ICNIRP, 1998.

ACGIH Occupational Threshold Limit Values for 60-Hz EMF

	Electric field	Magnetic field
Occupational exposure should not exceed	25 kV/m	10 G (10,000 mG)
Prudence dictates the use of protective clothing above	15 kV/m	–
Exposure of workers with cardiac pacemakers should not exceed	1 kV/m	1 G (1,000 mG)

American Conference of Governmental Industrial Hygienists (ACGIH) is a professional organization that facilitates the exchange of technical information about worker health protection. It is not a government regulatory agency.
Source: ACGIH, 2001.

Q Does EMF affect people with pacemakers or other medical devices?

A According to the U.S. Food and Drug Administration (FDA), interference from EMF can affect various medical devices including cardiac pacemakers and implantable defibrillators. Most current research in this area focuses on higher frequency sources such as cellular phones, citizens band radios, wireless computer links, microwave signals, radio and television transmitters, and paging transmitters.

Sources such as welding equipment, power lines at electric generating plants, and rail transportation equipment can produce lower frequency EMF strong enough to interfere with some models of pacemakers and defibrillators. The occupational exposure guidelines developed by ACGIH state that workers with cardiac pacemakers should not be exposed to a 60-Hz magnetic field greater than 1 gauss (1,000 mG) or a 60-Hz electric field greater than 1 kilovolt per meter (1,000 V/m) (see ACGIH guidelines above). Workers who are concerned about EMF exposure effects on pacemakers, implantable defibrillators, or other implanted electronic medical devices should consult their doctors or industrial hygienists.

Nonelectronic metallic medical implants (such as artificial joints, pins, nails, screws, and plates) can be affected by high magnetic fields such as those from magnetic resonance imaging (MRI) devices and aluminum refining equipment, but are generally unaffected by the lower fields from most other sources.

The FDA MedWatch program is collecting information about medical device problems thought to be associated with exposure to or interference from EMF. Anyone experiencing a problem that might be due to such interference is encouraged to call and report it (800-332-1088).

Q What about products advertised as producing low or reduced magnetic fields?

A Virtually all electrical appliances and devices emit electric and magnetic fields. The strengths of the fields vary appreciably both between types of devices and among manufacturers and models of the same type of device. Some appliance manufacturers are designing new models that, in general, have lower EMF than older models. As a result, the words "low field" or "reduced field" may be relative to older models and not necessarily relative to other manufacturers or devices. At this time, there are no domestic or international standards or guidelines limiting the EMF emissions of appliances.

The U.S. government has set no standards for magnetic fields from computer monitors or video display terminals (VDTs). The Swedish Confederation of Professional Employees (TCO) established in 1992 a standard recommending strict limits on the EMF emissions of computer monitors. The VDTs should produce magnetic fields of no more than 2 mG at a distance of 30 cm (about 1 ft) from the front surface of the monitor and 50 cm (about 1 ft 8 in) from the sides and back of the monitor. The TCO'92 standard has become a *de facto* standard in the VDT industry worldwide. A 1999 standard, promulgated by the Swedish TCO (known as the TCO'99 standard), provides for international and environmental labeling of personal computers. Many computer monitors marketed in the U.S. are certified as compliant with TCO'99 and are thereby assured to produce low magnetic fields.

Beware of advertisements claiming that the federal government has certified that the advertised equipment produces little or no EMF. The federal government has no such general certification program for the emissions of low-frequency EMF. The U.S. Food and Drug Administration's Center for Devices and Radiological Health (CDRH) does certify medical equipment and equipment producing high levels of ionizing radiation or microwave radiation. Information about certain devices as well as general information about EMF is available from the CDRH at 888-463-6332.

Q Are cellular telephones and towers sources of EMF exposure?

A Cellular telephones and towers involve radio-frequency and microwave-frequency electromagnetic fields (see page 8). These are in a much higher frequency range than are the power-frequency electric and magnetic fields associated with the transmission and use of electricity.

The U.S. Federal Communications Commission (FCC) licenses communications systems that use radio-frequency and microwave electromagnetic fields and ensures that licensed facilities comply with exposure standards. Public information on this topic is published on two FCC Internet sites: http://www.fcc.gov/oet/info/documents/bulletins/#56 and http://www.fcc.gov/oet/rfsafety/

The U.S. Food and Drug Administration also provides information about cellular telephones on its web site (http://www.fda.gov/cdrh/ocd/mobilphone.html).

6 National and International EMF Reviews

This chapter presents the findings and recommendations of major EMF research reviews, including the U.S. government's EMF RAPID Program.

Q What have national and international agencies concluded about the impact of EMF exposure on human health?

A Since 1995, two major U.S. reports have concluded that limited evidence exists for an association between EMF exposure and increased leukemia risk, but that when all the scientific evidence is considered, the link between EMF exposure and cancer is weak. The World Health Organization in 1997 reached a similar conclusion.

The two reports were the U.S. National Academy of Sciences report in 1996 and, in 1999, the National Institute of Environmental Health Sciences report to the U.S. Congress at the end of the U.S. EMF Research and Public Information Dissemination (RAPID) Program.

The U.S. EMF RAPID Program

EMF RAPID
Electric and Magnetic Fields Research and Public Information Dissemination Program

Initiated by the U.S. Congress and established by law in 1992, the U.S. EMF Research and Public Information Dissemination (EMF RAPID) Program set out to study whether exposure to electric and magnetic fields produced by the generation, transmission, or use of electric power posed a risk to human health. For more information about the EMF RAPID Program, visit the web site (http://www.niehs.nih.gov/emfrapid).

The U.S. Department of Energy (DOE) administered the overall EMF RAPID Program, but health effects research and risk assessment were supervised by the National Institute of Environmental Health Sciences (NIEHS), a branch of the U.S. National Institutes of Health (NIH). Together, DOE and NIEHS oversaw more than 100 cellular and animal studies, as well as engineering and exposure assessment studies. Although the EMF RAPID Program did not fund any additional epidemiological studies, an analysis of the many studies already conducted was an important part of its final report.

The electric power industry contributed about half, or $22.5 million, of the $45 million eventually spent on EMF research over the course of the EMF RAPID Program. The NIEHS received $30.1 million from this program for research, public outreach, administration, and the health assessment evaluation of extremely low frequency (ELF) EMF. The DOE received approximately $15 million from this program for engineering and EMF mitigation research. The NIEHS contributed an additional $14.5 million for support of extramural and intramural research including long-term toxicity and carcinogenicity studies conducted by the National Toxicology Program.

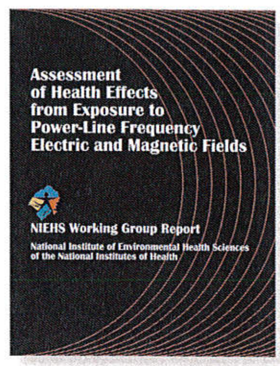
EMF RAPID Program Interagency Committee

- National Institute of Environmental Health Sciences
- Department of Energy
- Department of Defense
- Department of Transportation
- Environmental Protection Agency
- Federal Energy Regulatory Commission
- National Institute of Standards and Technology
- Occupational Safety and Health Administration
- Rural Electrification Administration

An interagency committee was established by the President of the United States to provide oversight and program management support for the EMF RAPID Program. The interagency committee included representatives from NIEHS, DOE, and seven other federal agencies with EMF-related responsibilities.

The EMF RAPID Program also received advice from a National EMF Advisory Committee (NEMFAC), which included representatives from citizen groups, labor, utilities, the National Academy of Sciences, and other groups. They met regularly with DOE and NIEHS staff to express their views. NEMFAC meetings were open to the public. The EMF RAPID Program sponsored citizen participation in some scientific meetings as well. A broad group of citizens reviewed all major public information materials produced for the program.

NIEHS Working Group Report 1998

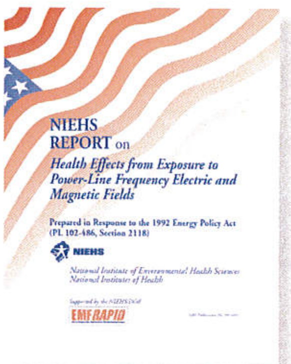


In preparation for the EMF RAPID Program's goal of reporting to the U.S. Congress on possible health effects from exposure to EMF from power lines, the NIEHS convened an expert working group in June 1998. Over 9 days, about 30 scientists conducted a complete review of EMF studies, including those sponsored by the EMF RAPID Program and others. Their conclusions offered guidance to the NIEHS as it prepared its report to Congress.

Using criteria developed by the International Agency for Research on Cancer, a majority of the members of the working group concluded that exposure to power-frequency EMF is a possible human carcinogen.

The majority called their opinion "a conservative public health decision based on limited evidence for an increased occurrence of childhood leukemias and an increased occurrence of chronic lymphocytic leukemia (CLL) in occupational settings." For these diseases, the working group reported that animal and cellular studies neither confirm nor deny the epidemiological studies' suggestion of a disease risk. This report is available on the NIEHS EMF RAPID web site (http://www.niehs.nih.gov/emfrapid).

NIEHS Report to Congress at Conclusion of EMF RAPID Program



In June 1999, the NIEHS reported to the U.S. Congress that scientific evidence for an EMF-cancer link is weak.

The following are excerpts from the 1999 NIEHS report:

> The NIEHS believes that the probability that ELF-EMF exposure is truly a health hazard is currently small. The weak epidemiological associations and lack of any laboratory support for these associations provide only marginal, scientific support that exposure to this agent is causing any degree of harm.
>
> The scientific evidence suggesting that extremely low frequency EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies, although sporadic findings of biological effects (including increased cancers in animals) have been reported. No indication of increased leukemias in experimental animals has been observed.

The full report is available on the NIEHS EMF RAPID web site (http://www.niehs.nih.gov/emfrapid).

No regulatory action was recommended or taken based on the NIEHS report. The NIEHS director, Dr. Kenneth Olden, told the Congress that, in his opinion, the conclusion of the NIEHS report was not sufficient to warrant aggressive regulatory action.

The NIEHS did not recommend adopting EMF standards for electric appliances or burying electric power lines. Instead, it recommended providing public information about practical ways to reduce EMF exposure. The NIEHS also suggested that power companies and utilities "continue siting power lines to reduce exposures and . . . explore ways to reduce the creation of magnetic fields around transmission and distribution lines without creating new hazards." The NIEHS encouraged manufacturers to reduce magnetic fields at a minimal cost, but noted that the risks do not warrant expensive redesign of electrical appliances.

The NIEHS also encouraged individuals who are concerned about EMF in their homes to check to see if their homes are properly wired and grounded, since incorrect wiring or other code violations are a common source of higher-than-usual magnetic fields.

National Academy of Sciences Report

In October 1996, a National Research Council committee of the National Academy of Sciences (NAS) released its evaluation of research on potential associations between EMF exposure and cancer, reproduction, development, learning, and behavior. The report concluded:

> Based on a comprehensive evaluation of published studies relating to the effects of power-frequency electric and magnetic fields on cells, tissues, and organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard. Specifically, no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer, adverse neurobehavioral effects, or reproductive and developmental effects.

The NAS report focused primarily on the association of childhood leukemia with the proximity of the child's home to power lines. The NAS panel found that although a link between EMF exposure and increased risk for childhood leukemia was observed in studies that had estimated EMF exposure using the wire code method (distance of home from power line), such a link was not found in studies that had included actual measurements of magnetic fields at the time of the study. The panel called for more research to pinpoint the unexplained factors causing small increases in childhood leukemia in houses close to power lines.

World Health Organization International EMF Project

The World Health Organization (WHO) International EMF Project, with headquarters in Geneva, Switzerland, was launched at a 1996 meeting with representatives of 23 countries attending. It was intended to respond to growing concerns in many member states over possible EMF health effects and to address the conflict between such concerns and technological and economic progress. In its advisory role, the WHO International EMF Project is now reviewing laboratory and epidemiological evidence, identifying gaps in scientific knowledge, developing an agenda for future research, and developing risk communication booklets and other public information. The WHO International EMF Project is funded with contributions from governments and institutions and is expected to provide an overall EMF health risk assessment. Additional information about this program can be found on the WHO EMF web site (http://www.who.int/peh-emf).

As part of this project, in 1997 a working group of 45 scientists from around the world surveyed the evidence for adverse

EMF health effects. They reported that, "taken together, the findings of all published studies are suggestive of an association between childhood leukemia and estimates of ELF (extremely low frequency or power-frequency) magnetic fields."

Much like the 1996 U.S. NAS report, the WHO report noted that living in homes near power lines was associated with an approximate 1.5-fold excess risk of childhood leukemia. But unlike the NAS panel, WHO scientists had seen the results of the 1997 U.S. National Cancer Institute study of EMF and childhood leukemia (see page 17). This work showed even more strongly the inconsistency between results of studies that used a wire code to estimate EMF exposure and studies that actually measured magnetic fields.

Regarding health effects other than cancer, the WHO scientists reported that the epidemiological studies "do not provide sufficient evidence to support an association between extremely-low-frequency magnetic-field exposure and adult cancers, pregnancy outcome, or neurobehavioural disorders."

World Health Organization International Agency for Research on Cancer

The WHO International Agency for Research on Cancer (IARC) produces a monograph series that reviews the scientific evidence regarding potential carcinogenicity associated with exposure to environmental agents. An international scientific panel of 21 experts from 10 countries met in June 2001 to review the scientific evidence regarding the potential carcinogenicity of static and ELF (extremely low frequency or power-frequency) EMF. The panel categorized its conclusions for carcinogenicity based on the IARC classification system—a system that evaluates the strength of evidence from epidemiological, laboratory (human and cellular), and mechanistic studies. The panel classified power-frequency EMF as "possibly carcinogenic to humans" based on a fairly consistent statistical association between a doubling of risk of childhood leukemia and magnetic field exposure above 0.4 microtesla (0.4 μT, 4 milligauss or 4 mG).

In contrast, they found no consistent evidence that childhood EMF exposures are associated with other types of cancer or that adult EMF exposures are associated with increased risk for any kind of cancer. The IARC panel reported that no consistent carcinogenic effects of EMF exposure have been observed in experimental animals and that there is currently no scientific explanation for the observed association between childhood leukemia and EMF exposure. Further information can be obtained at the IARC web sites (http://www.iarc.fr and http://monographs.iarc.fr).

International Commission on Non-Ionizing Radiation Protection

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) issued exposure guidelines to guard against known adverse effects such as stimulation of nerves and muscles at very high EMF levels, as well as shocks and burns caused by touching objects that conduct electricity (see page 47). In April 1998, ICNIRP revised its exposure guidelines and characterized as "unconvincing" the evidence for an association between everyday power-frequency EMF and cancer.

European Union

In 1996, a European Union (EU) advisory panel provided an overview of the state of science and standards among EU countries. With respect to power-frequency EMF, the panel members said that there is no clear evidence that exposure to EMF results in an increased risk of cancer.

Australia—Radiation Advisory Committee Report to Parliament

In 1997, Australia's Radiation Advisory Committee briefly reviewed the EMF scientific literature and advised the Australian Parliament that, overall, there is insufficient evidence to come to a firm conclusion regarding possible health effects from exposure to power-frequency magnetic fields.

The committee also reported that "the weight of opinion as expressed in the U.S. National Academy of Sciences report, and the negative results from the National Cancer Institute study (Linet et al., 1997) would seem to shift the balance of probability more towards there being no identifiable health effects" (see pages 17 and 53).

Canada—Health Canada Report

In December 1998, a working group of public health officers at Health Canada, the federal agency that manages Canada's health care system, issued a review of the scientific literature regarding power-frequency EMF health effects. They found the evidence to be insufficient to conclude that EMF causes a risk of cancer.

The report concluded that while EMF effects may be observed in biological systems in a laboratory, no adverse health effects have been demonstrated at the levels to which humans and animals are typically exposed.

As for epidemiology, 25 years of study results are inconsistent and inconclusive, the panel said, and a plausible EMF-cancer mechanism is missing. Health Canada pledged to continue monitoring EMF research and to reassess this position as new information becomes available.

Germany—Ordinance 26

On January 1, 1997, Germany became the first nation to adopt a national rule on EMF exposure for the general public. Ordinance 26 applies only to facilities such as overhead and underground transmission and distribution lines, transformers, switchgear and overhead lines for electric-powered trains. Both electric (5 kV/m) and magnetic field exposure limits (1 Gauss) are high enough that they are unlikely to be encountered in ordinary daily life. The ordinance also requires that precautionary measures be taken on a case-by-case basis when electric facilities are sited or upgraded near homes, hospital, schools, day care centers, and playgrounds.

Great Britain—National Radiological Protection Board Report

The National Radiological Protection Board (NRPB) in Great Britain advises the government of the United Kingdom regarding standards of protection for exposure to non-ionizing radiation. The NRPB's advisory group on non-ionizing radiation periodically reviews new developments in EMF research and reports its findings. Results of the advisory group's latest review were published in 2001. The report reviewed residential and occupational epidemiological studies, as well as cellular, animal, and human volunteer studies that had been published.

The advisory group noted that there is "some epidemiological evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukaemia in children." Specifically, the NRPB advisory group's analysis suggests "that relatively heavy average exposures of 0.4 μT [4 mG] or more are associated with a doubling of the risk of leukaemia in children under 15 years of age." The group pointed out, however, that laboratory experiments have provided "no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer."

Scandinavia—EMF Developments

In October 1995, a group of Swedish researchers and government officials published a report about EMF exposure in the workplace. This "Criteria Group" reviewed EMF scientific literature and, using the IARC classification system, ranked occupational EMF exposure as "possibly carcinogenic to humans." They also endorsed the Swedish government's 1994 policy statement that public exposure limits to EMFs were not needed, but that people might simply want to use caution with EMFs.

In 1996, five Swedish government agencies further explained their precautionary advice about EMF. EMF exposure should be reduced, they said, but only when practical, without great inconvenience or cost.

Health experts in Norway, Denmark, and Finland generally agreed in reviews published in the 1990s that if an EMF health risk exists, it is small. They acknowledged that a link between residential magnetic fields and childhood leukemia cannot be confirmed or denied. In 1994, several Norwegian government ministries also recommended increasing the distance between residences and electrical facilities, if it could be done at low cost and with little inconvenience.

Q What other U.S. organizations have reported on EMF?

A

American Medical Association

In 1995, the American Medical Association advised physicians that no scientifically documented health risk had been associated with "usually occurring" EMF, based on a review of EMF epidemiological, laboratory studies, and major literature reviews.

American Cancer Society

In 1996, the American Cancer Society released a review of 20 years of EMF epidemiological research including occupational studies and residential studies of adult and childhood cancer. The society noted that some data support a possible relationship of magnetic field exposure with leukemia and brain cancer, but further research may not be justified if studies continue to find uncertain results. Of particular interest is the summary of results from eight studies of risk from use of household appliances with relatively high magnetic fields, such as electric blankets and electric razors. The summary suggested that there is no persuasive evidence for increased risk with more frequent or longer use of these appliances.

American Physical Society

The American Physical Society (APS) represents thousands of U.S. physicists. Responding to the NIEHS Working Group's conclusion that EMF is a possible human carcinogen, the APS executive board voted in 1998 to reaffirm its 1995 opinion that there is "no consistent, significant link between cancer and power line fields."

California's Department of Health Services

In 1996, California's Department of Health Services (DHS) began an ambitious five-year effort to assess possible EMF public health risk and offer guidance to school administrators and other decision-makers. The California Electric and Magnetic Fields (EMF) Program is a research, education, and technical assistance program concerned with the possible health effects of EMF from power lines, appliances, and other uses of electricity. The program's goal is to find a rational and fair approach to dealing with the potential risks, if any, of exposure to EMF. This is done through research, policy analysis, and education. The web site has educational materials on EMF and related health issues for individuals, schools, government agencies, and professional organizations (http://www.dhs.ca.gov/ps/deodc/ehib/emf).

Q What can we conclude about EMF at this time?

A Electricity is a beneficial part of our daily lives, but whenever electricity is generated, transmitted, or used, electric and magnetic fields are created. Over the past 25 years, research has addressed the question of whether exposure to power-frequency EMF might adversely affect human health. For most health outcomes, there is no evidence that EMF exposures have adverse effects. There is some evidence from epidemiology studies that exposure to power-frequency EMF is associated with an increased risk for childhood leukemia. This association is difficult to interpret in the absence of reproducible laboratory evidence or a scientific explanation that links magnetic fields with childhood leukemia.

EMF exposures are complex and come from multiple sources in the home and workplace in addition to power lines. Although scientists are still debating whether EMF is a hazard to health, the NIEHS recommends continued education on ways of reducing exposures. This booklet has identified some EMF sources and some simple steps you can take to limit your exposure. For your own safety, it is important that any steps you take to reduce your exposures do not increase other obvious hazards such as those from electrocution or fire. At the current time in the United States, there are no federal standards for occupational or residential exposure to 60-Hz EMF.

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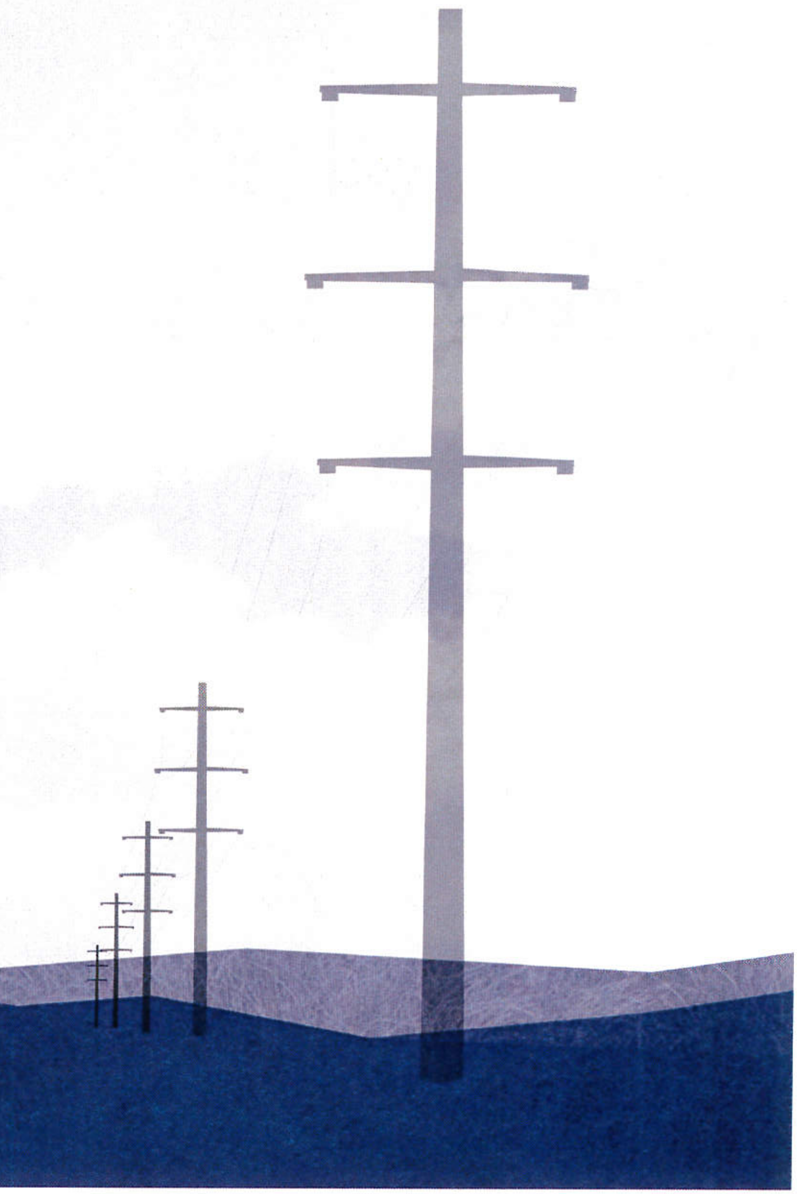
Powering Our FUTURE

Summit Wasatch Electrical Plan
Local Planning Handbook

September 2010



Acknowledgements

Summit Wasatch Electrical Plan Task Force

- Allison Weyher – Francis Planning
- Bob Richins -- Henefer Planning
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- Bob Martino – Hideout Mayor
- Bob Wells -- Deer Valley
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This document and the accompanying map can be found at:

www.rockymountainpower.net/planning

Table of Contents

Executive summary

Planning, financing and building infrastructure to meet future growth in Summit and Wasatch Counties poses major challenges. Essential facilities like water, sewer, schools, roads and highways are routinely considered by government and community leaders in planning for the future. Equally critical but typically given less forethought by local planners, however, is electrical infrastructure.

Various projections put Summit and Wasatch Counties' population at approximately 132,000 by 2030, an increase of about 100 percent over 2010. How much electrical capacity will these counties need and where will they need it are questions rarely considered in traditional growth scenarios and planning decisions--until now.

The Summit Wasatch Electrical Plan is an unprecedented collaborative effort to keep pace with these counties' growth through 2030 by integrating local governments' long-term land-use development plans with future electrical network requirements. The effort recognizes that planning decisions made by local government are a major impetus of energy intensity requirements. The primary goal of this process is to develop a clear and documented plan to guide future infrastructure siting decisions to ensure adequate electrical capacity for local communities to achieve their goals.

The task force leading this effort includes a broad range of stakeholders including planning representatives from Summit and Wasatch Counties, municipalities in the counties served by Rocky Mountain Power, regional transportation and growth planners and other key stakeholders. An independent facilitator guided their deliberations while Rocky Mountain Power served as a technical adviser. As a group they share the goal of encouraging mutual understanding and cooperation with a county-wide perspective.

The product of the task force's year-long effort includes three elements:

- A list of criteria for evaluating future substation and transmission sites
- A map of approximate preferred locations of future substations and transmission lines and
- A tool kit, including general plan language for use by local governments to implement the facility siting plan in their respective jurisdictions

The plan does not address "main grid" high-voltage facilities used for bulk power. It is limited to substations and transmission lines of 138,000 volts or less.

Members of the Summit Wasatch Electrical Plan Task Force recognize that principles contained within the plan do not necessarily reflect the position of the particular jurisdictions or organizations they represent. As individuals, however, they support the Summit Wasatch Electrical Plan as a good-faith representation of the task force's input and ideas. They also support the Summit Wasatch Electrical Plan as a good-faith effort to balance community and regional quality of life and economic development considerations with the need to ensure that all jurisdictions in Summit and Wasatch Counties have a safe, adequate and reliable supply of electricity.

The task force members and Rocky Mountain Power support using the plan to guide future infrastructure planning efforts within their respective organizations. They jointly commit to share the plan and its underlying process with decision-makers and to introduce options to integrate electrical infrastructure considerations, including the Summit Wasatch Electrical Plan, into their formal planning processes. Identifying where electrical facilities are needed to support future growth will benefit local governments, transportation planners, developers, residents, businesses and Rocky Mountain Power. This type of clarity and predictability will not only help assure electrical capacity is available to meet communities' development needs, but also make more efficient use of limited financial resources and minimize potential conflict in the future.

Jacquelyn Mauer, Park City Planning; Diane Foster, Summit County; Allison Weyher, Francis Planning; Bob Richins, Henefer Planning; Sean Lewis, Summit County Planning; Liza Simpson, Park City Council; Tami Stevenson, Oakley Planning; Robert Whiteley, Coalville Engineer; Ted Knowlton, The Planning Center; Bob Martino, Hideout Mayor; Jani Gamble, Rocky Mountain Power; Demi Corbett, The Planning Center; Mike Sweeney, Town Lift Plaza; Chad Ambrose, Rocky Mountain Power; Mike Coopman, Promontory; Mickey Beaver, Rocky Mountain Power; Brent Giles, Park City Mountain Resort; Cliff Blonquist, Summit County; John Thomas, Utah Department of Transportation; Scott Kettle, Kamas & Francis Planning; Matt Cassel, Park City Engineer; Ken Shortt, Rocky Mountain Power

Task force members brainstormed potential infrastructure locations

1. Developing the Plan

"We can't solve today's problems by using the same kind of thinking we used when we created them."

\- Albert Einstein

Background

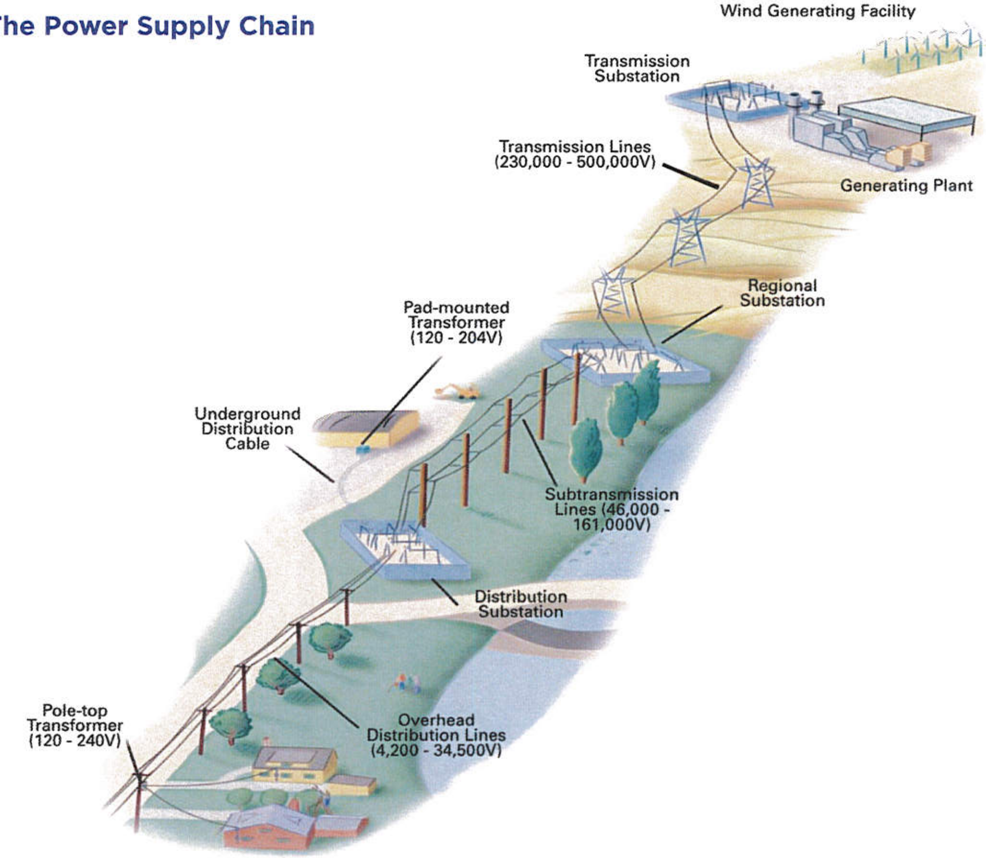
Like most utilities in the United States, Rocky Mountain Power operates as a regulated utility within a framework of regulatory, legal and financial requirements. The utility's prices and policies are regulated by the Utah Public Service Commission, which closely scrutinizes Rocky Mountain Power's resource portfolio, energy efficiency and peak-reduction programs, customer services, capital expenses, and operations and administrative costs. The utility is also subject to rules and regulations of various federal agencies and national reliability standards and electrical safety codes.

A legal obligation to deliver a safe, adequate and reliable supply of electricity at the lowest reasonable cost guides utility decisions about timing and location of new substation and transmission capacity. Historically, system requirements were the primary driver of the utility infrastructure planning process with secondary consideration given to local government land-use plans. When customers' needs approached the capacity limits of existing substations and power lines, Rocky Mountain Power made plans to bring new projects on line to meet growing customer demand.

Rocky Mountain Power's Utah residential customers use about 26 percent more electricity today than they did 20 years ago (see graph on page 5). In fact, usage among Utah households has grown at a higher rate since 1990 than the national average. Paradoxically, customers don't readily connect their dependence on electricity with the infrastructure needed to power their homes and businesses. At times, intense opposition to construction of new facilities or expansion of existing infrastructure to meet growing needs has resulted in project delays, reduced system reliability, costly mitigation measures, project cost overruns—and customers dissatisfied with their electric service.

As Rocky Mountain Power contemplated a two-fold increase in Summit and Wasatch Counties' population by 2030, it determined the time was right for a new approach to infrastructure planning. Working together with local government and key stakeholders gives communities and the utility an opportunity to jointly develop a mutually acceptable plan to meet customers' future electric energy needs.

The Power Supply Chain



MAGNITUDE OF THE CHALLENGE

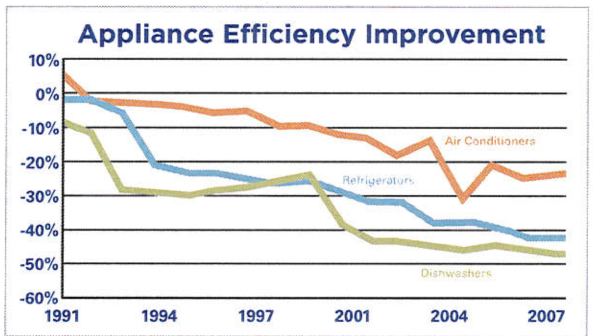
Electrical infrastructure systems are designed to meet customers' needs when usage is at its greatest point during the year. Utilities call this "peak demand." Peak demand on Rocky Mountain Power's system in Summit and Wasatch Counties occurs in winter during the ski season. The 2009-2010 winter "peak" registered 182,500 kilowatts (kW) on December 31, 2009.

A network of 14 substations and over 1,538 miles of high-voltage transmission lines and local distribution lines delivers electricity to approximately 67,300 people in Summit and Wasatch Counties. At present, the average per capita "demand" on the electric system in the two counties is 2.7 kilowatts per person. Although it is difficult to predict future per-capita electrical demand, the task force agreed to apply this factor to a projected population of 132,000 by 2030, bringing future customer requirements to approximately 358,000 kilowatts. Approximately four new substations will be required during the next 20 years to satisfy growing communities' electricity needs, while up to six will either be upgraded or re-located.

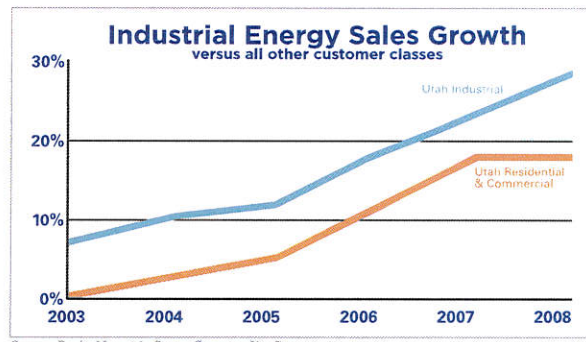
A significant challenge facing task force members and Rocky Mountain Power is, quite simply, the unknowable future. It is prudent to plan for tomorrow based on what we know today—realizing that a host of uncertainties will change many of the assumptions. For that reason, task force members and Rocky Mountain Power agree it is essential to update the plan periodically to account for changing circumstances. Some of the uncertainties include:

- Population projections, employment projections and development patterns are subject to economic, demographic and market conditions.
- The current economy is the most fragile it has been since the Great Depression. The speed and scope of economic recovery may alter customer demand projections.
- Climate change and carbon-reduction strategies could impose higher energy costs on consumers. Utah is among the states where prices are expected to increase significantly due to gradual replacement of inexpensive coal-based generation by more costly alternatives.
- Residential usage continues to climb despite improved appliance efficiency. According to the International Energy Agency, the average household today owns 25 electronic consumer devices compared with three in 1980. Central air conditioning is also more prevalent today.
- Electric rates are projected to escalate. Price elasticity could reduce the growth rate of future customer demand.
- Technology advancements in "smart" homes and buildings could allow customers to view real-time usage and prices and change their usage habits. The technology could also allow utilities to control certain appliances to manage peak demand. Emerging technologies popularly known as "smart grid," which call for bi-directional meters, are not currently economically viable in many utility regulatory environments. However, existing technologies like Rocky Mountain Power's industrial and agricultural load-control programs are currently cost effective in managing peak system use.
- Customer-owned wind and solar generation enjoys public support but it is not expected to appreciably reduce the need for future utility infrastructure. Peak generating periods of wind and solar seldom correlate with peak periods of customer usage. Battery storage is still an expensive option.
- Electric vehicles may gain broader penetration with technology advancements and higher oil prices. How might widespread use affect peak demand? Utilities will offer off-peak charging incentives, but will consumers respond to price signals or re-charge at their own convenience? A handful of communities nationwide have already installed charging receptacles in public places.

Task force members recognize that barring any new technology developments that eliminate the need for substations and transmission lines, these facilities will continue to be necessary to supply future growth of Summit and Wasatch Counties. The foregoing uncertainties, and perhaps others that are unfathomable today, will alter the timing of new facilities. This plan represents the best efforts of local government, important stakeholders and Rocky Mountain Power to identify preferred locations for electrical infrastructure based on today's knowledge about Summit and Wasatch Counties' future growth. It offers a starting point where local government, stakeholders and the utility can begin the conversation when increased customer use calls for new facilities.



Source: Trends in Energy Efficiency 2008, Association of Home Appliance Manufacturers



Source: Rocky Mountain Power Customer Use Data

The task force process

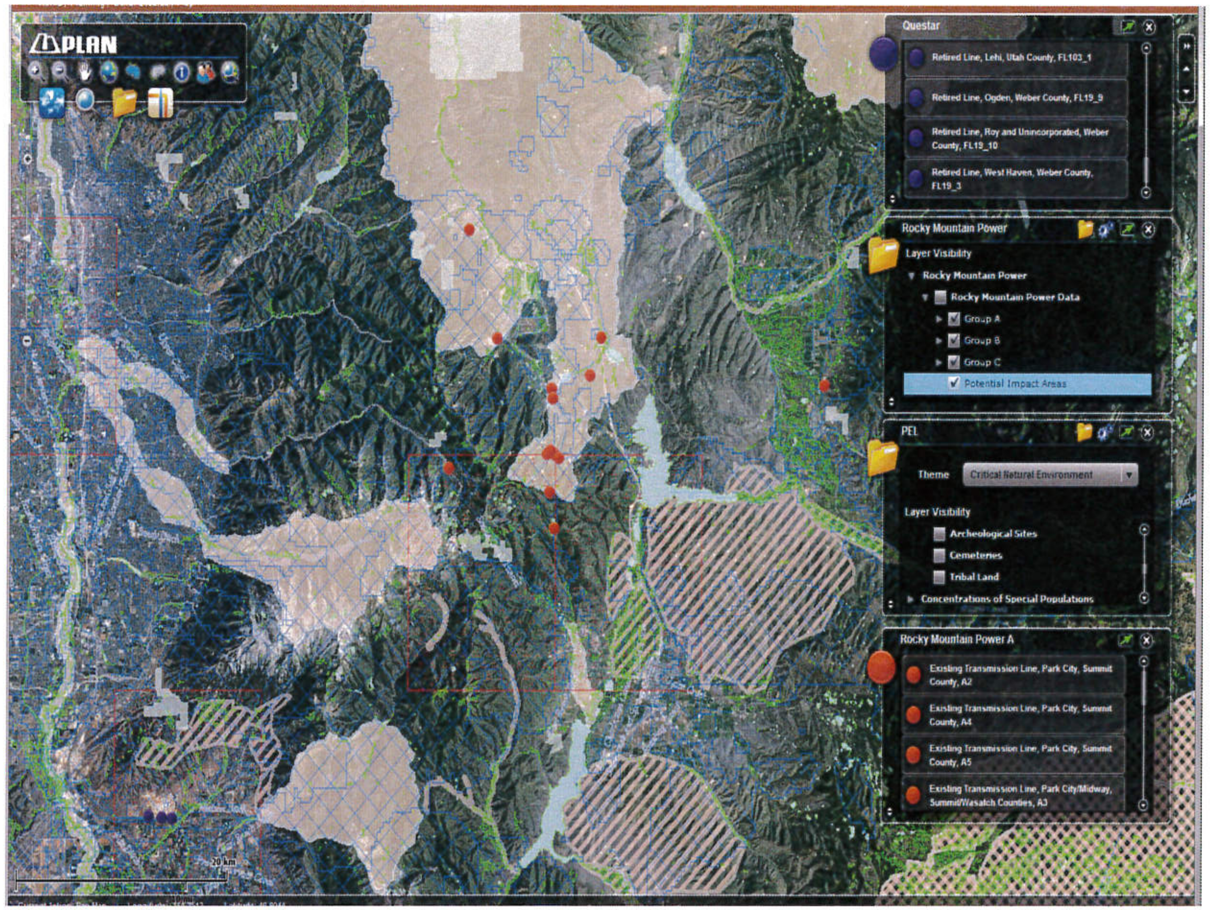
The Summit Wasatch Electrical Plan Task Force met monthly from October 2009 through May 2010. An independent facilitator guided their discussions, emphasizing from the outset that the task force would control the process within the overall scope of the effort and work towards consensus. Rocky Mountain Power participated with technical assistance and offered perspective on legal and regulatory requirements.

Throughout several months of meetings, members became more knowledgeable about the generation, transmission and distribution aspects of the electric utility industry as well as its legal and regulatory requirements. They discussed alternative energy resources, energy efficiency and peak-reduction measures as potential means to offset future infrastructure needs. They also learned about utility operating requirements such as reliability standards required by the National Electric Regulatory Commission and Western Electricity Coordinating Council. They became familiar with transmission structure design and clearance requirements prescribed by the National Electric Safety Code.

The task force set 2030 as the planning horizon for the Summit Wasatch Electrical Plan. Members reviewed population growth assumptions from the Governor's Office of Planning and Budget as well as Mountainland Association of Governments, which reflect future development potential according to each jurisdiction's general land-use plans. They also brought personal knowledge to the discussion about planned developments under consideration and insights about communities' future plans.

Task force members discussed and prioritized community issues and concerns during the course of several meetings. These discussions, which ultimately developed into a set of siting criteria, guided several mapping sessions to identify preferred locations for new substations in areas where future growth and development potential are expected to exceed existing electrical capacity. The plan does not address "main grid" high-voltage facilities used for bulk power. It is limited to substations and transmission lines of 138,000 volts or less.

The Summit Wasatch Electrical Plan map evolved over several months. Task force members worked in small groups using maps that showed existing electrical infrastructure and general plans. They discussed local impacts

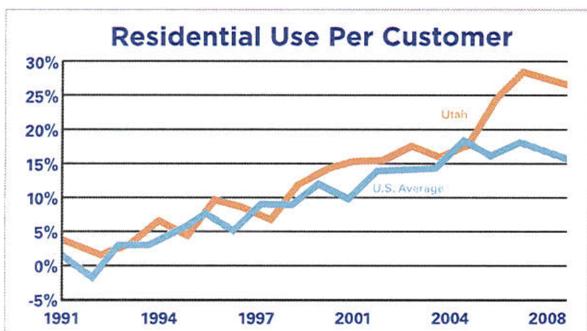


and issues relevant to their own communities while designating suitable locations for new infrastructure with small place-markers (substations) and tape (transmission lines) on the map. Initially they divided the study area into two sections, which were later combined into a single map of both counties. Between mapping sessions they critiqued and refined their choices. The task force utilized UDOT's interactive Internet-based mapping software to understand the impacts of various locations on land features such as floodplains or fault lines, habitat and other infrastructure plans. Finally, Rocky Mountain Power reviewed the facility locations for engineering and operations feasibility and recommended minor changes.

DEVELOPMENT OF COMMUNITY SITING PRIORITIES

Community issues and concerns were at the center of the task force's discussions about facility siting. Members devoted several meetings to identifying and ranking factors that are important to the siting process from a community perspective. They ultimately created a set of "siting criteria" to guide future infrastructure planning decisions.

The siting criteria are an essential element of the plan. They are less likely than specific map locations to become outdated over time and can serve a broader application. The siting criteria represent the considerations that the task force believes should be taken into account when evaluating sites for new infrastructure.



Source: U.S. Energy Information Administration

The siting criteria capture the intent and goals of the task force in terms of important considerations and also their relative importance to site selection. Members refined and prioritized the criteria through online surveys and voting sessions during task force meetings. They discussed and refined many of the more difficult criteria until the group could reach agreement. Finally, members ranked the criteria in order of importance. Thus, higher ranked criteria take precedence over lower ranked ones. Inherent conflicts may exist in some cases.

EVALUATION AND REFINEMENT OF PREFERRED LOCATIONS

During refinement of the map, task force members evaluated future infrastructure locations for potential environmental impacts and constraints. They took advantage of a tool developed by the Utah Department of Transportation, called UPlan, to view transmission line and substation locations in relation to natural conditions such as hillside slope, natural drainage and flood plains, earthquake potential, natural habitat, etc. The tool allowed task force members to magnify aerial imagery to a street-level view to see potential infrastructure sites at a more realistic scale than two-dimensional maps. Accordingly, they made some adjustments after seeing precise locations.

The siting criteria were essential to refining facility locations on the map. However the map does not identify precise locations. At this point, new substation "markers" indicate approximate locations. When customer demand increases to the point that new infrastructure is required in an area, the community and Rocky Mountain Power can use the siting criteria as a tool to evaluate alternate site options and select a specific location.

The task force refined the map in May 2010 using the siting criteria as well as feedback from Rocky Mountain Power following its technical review of facility locations for engineering and operations feasibility. The map represents the consensus of members' location choices for new substations and transmission lines to meet projected growth by 2030. Rather than pinpointing precise locations, the map identifies the general vicinity where future infrastructure will be needed. It is intended to facilitate discussion about final site selection among local jurisdictions, the community and Rocky Mountain Power when it comes time to build additional electrical infrastructure to meet customers' needs.

To provide additional capacity in the future, the plan calls for four new substations located throughout Summit and Wasatch Counties, while up to six will either be upgraded or relocated. Potential expansion of several existing substations reduced the number that was initially projected. The majority of new transmission capacity can be supplied by upgrading voltage of existing lines or adding second circuits where possible. Both courses of action will reduce community impacts by minimizing the total number of new facilities required to meet customer demand.

The final product gives both local government and Rocky Mountain Power a degree of predictability that neither has previously enjoyed. New facilities will be built over a 20-year period as Summit and Wasatch Counties' electrical needs grow. As a regulated utility, Rocky Mountain Power must provide capacity to meet customers' needs but it cannot build facilities until they are necessary. As that point approaches, the Summit Wasatch Electrical Plan, including both the map and siting criteria, will serve as a blueprint for facility siting decisions.

2. The Plan

A. Principles of the Summit Wasatch Electrical Plan

The Summit Wasatch Electrical Plan Task Force defined key considerations that shaped the plan over the course of the nine-month dialogue. The key principles are listed here.

1. Bring together a broad range of stakeholders with varied perspectives to jointly develop a long-range regional electrical plan.
2. Foster communication and broader understanding of all stakeholders' needs and concerns.
3. Improve predictability of electrical infrastructure improvements for communities, residents, property owners and Rocky Mountain Power.
4. Integrate community considerations into electrical infrastructure planning.
5. Develop and maintain a plan that works among jurisdictions and across Rocky Mountain Power's service territory in Summit and Wasatch Counties.
6. Establish and maintain a long-term basis for continuing collaboration.
7. Establish a logical relationship between electrical infrastructure and land use, both existing and future.
8. Integrate planning efforts for electrical infrastructure, transportation, and local and regional land use. In short, engage in cooperative planning.
9. Maintain communication among stakeholders and update the plan's elements over time.

The plan's final products and suggested 'next steps' are consistent with these principles. Future plan updates should address the final products and 'next steps' in a manner to advance the overarching principles.

B. Siting criteria

Siting criteria were developed to guide the future facility siting process. The criteria represent the priorities established by the task force to optimize benefits and mitigate drawbacks to both the community and Rocky Mountain Power. They will be particularly useful in comparative evaluation of alternative sites.

Criteria are divided into three categories and listed in an order based on priorities established by the Summit Wasatch Electrical Plan Task Force. The categories are as follows:

- General considerations
- Criteria for substations
- Criteria for transmission lines

Criteria include the following:

- Priority: An indication of the priority level or relative importance on a scale of 1 to 3, shown with compact fluorescent lamp icons
- Why: A statement of rationale and underlying logic
- Example Application: In some instances, an example explaining how the criterion should be applied in siting electrical infrastructure

There may be conflicts among the criteria at any given site. For example, one site may be in a residential area (a negative consideration), yet have few impacts on prominent views. The siting criteria must be considered as relative priorities among several others and adapted to community circumstances.

Berms and slopes are used to integrate a substation into the surrounding neighborhood

The area under a transmission line is used to create a path and greenway providing a needed amenity for the community

1. GENERAL CONSIDERATIONS

System capacity, reliability and cost considerations are inherent in utility system planning. Other important considerations also have broad application to facility siting decisions. The following criteria are included as general factors that should be considered in future facility siting decisions. Given their general nature, they are not ranked and example applications are not provided.

- 1A System reliability
- 1B Utilize city and county land-use general plans
- 1C Future generation options
- 1D Follow soil ordinances
- 1E Balance reliability, design and cost
- 1F Minimize transmission line-miles

1A System reliability

Rocky Mountain Power is required to provide adequate electrical capacity to meet customers' needs during peak use times and emergencies, i.e., loss of generation resource, main grid transmission line or substation transformer. Rocky Mountain Power facilities are usually designed with alternate service capability, or redundancy, so service can be maintained from an alternate source if the main source is interrupted.

Rocky Mountain Power is the second largest utility-owner of wind generation in the United States

1B Utilize city and county land-use general plans

Rocky Mountain Power, municipalities and Summit and Wasatch Counties should combine planning efforts of the utility, local government and other planning organizations, such as transportation and regional land use, to include electrical infrastructure in their general plans. Coordinated planning could address siting issues in advance of development and potentially avoid future conflicts with existing uses, such as agriculture. The Summit Wasatch Electrical Plan Task Force should provide the plan as a guide for adoption by local planning commissions through their respective public processes.

1C Future generation options

The scope of the Summit Wasatch Electrical Plan does not encompass future generation sites. When large generation facilities become necessary to meet customers' needs, Rocky Mountain Power will work with local authorities to select the best locations. In addition, technology advancements may create new generation options. Local authorities and Rocky Mountain Power should work together to facilitate capacity contributions from diverse generation resources, including wind, solar, bio-mass, etc.

1D Follow soil ordinances

Rocky Mountain Power should follow ordinances relating to soil structure, composition, etc., and conduct geotechnical studies before building new infrastructure. Substation design should include spill prevention and retention mechanisms.

1E Balance reliability, design and cost

While aesthetics is important to communities, it must be balanced with cost, electric service reliability and operational requirements. Careful consideration should be given to sites or design elements that create operational issues and are not economically justifiable.

Communities may prefer siting infrastructure on public land rather than private property. In some instances, in fact, it is necessary. However, the increased cost and lead time required to comply with the National Environmental Policy Act should also be considered.

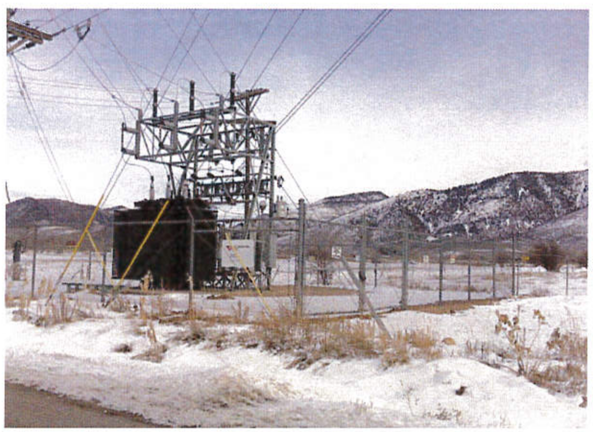
1F Minimize transmission line-miles

Consistent with other siting criteria, the electrical infrastructure plan should utilize a greater number of smaller regional substations, rather than fewer but larger regional substations, to minimize transmission line-miles and to also provide better reliability. Regional substations typically have three or more supply sources and convert voltage from 138,000 volts to 46,000 volts or to 12,500 volts.

2. CRITERIA FOR SUBSTATIONS

The following criteria pertain to important land characteristics or related considerations in relation to siting NEW substations.

- 2A Maximize use of existing facilities and adjacent properties before building new facilities
- 2B Use topography to reduce visual impacts
- 2C Protect significant viewsheds
- 2D Build aesthetically pleasing facilities
- 2E Avoid dedicated open space and parks
- 2F Site in areas with high development potential
- 2G Avoid residential neighborhoods
- 2H Avoid adverse aesthetic impacts on development
- 2I Avoid discrimination based on income or ethnicity
- 2J Utilize land adjacent to other infrastructure
- 2K Protect critical habitat, wetlands, rivers and stream corridors



Oakley substation

2A Maximize use of existing facilities and adjacent properties before building new facilities

Priority – Tier 1

It is preferable to expand existing facilities rather than build new facilities whenever feasible. Voltage upgrades and/or expansion of existing facilities will minimize land disturbance by reducing the total number of new sites needed for new substations and also potentially reduce land acquisition costs. Maximizing use of existing facilities may also produce fewer conflicts with nearby buildings, land uses and environmental issues. A community already accustomed to existing facilities may prefer an upgrade or expansion over building a new facility at another location.

New substations should be designed to allow for future expansion. Sufficient property should be acquired at the time of initial purchase to accommodate such expansion. This way, there will be minimal impacts to the area when new capacity is added.

Resolving conflicting criteria may require tradeoffs with other considerations. For instance, upgrading an existing substation may be considered visually inappropriate (see Criterion #2D) or incompatible with existing land uses (see Criterion #2G). But it may be preferable to other alternatives.

Example Application

In order to serve the growing needs of industrial customers, an existing substation is expanded, requiring the purchase of additional adjacent land. Although the expanded substation occupies a larger footprint, the overall impact is less than building a new facility in a different location. It is compatible with existing uses and customers are accustomed to the facility in the area. Making aesthetic improvements during expansion may better integrate it into the neighborhood.

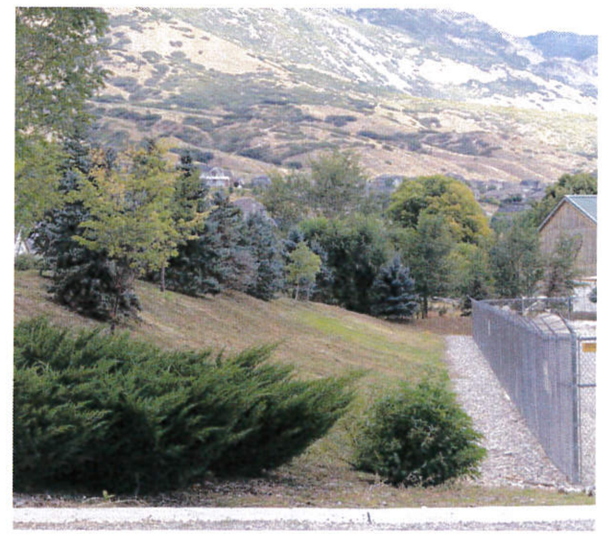
2B Use topography to reduce visual impacts

Priority – Tier 1

Topography, such as coves or raised berms, can be used to obscure a substation. This technique can lead to greater neighborhood integration, reduce adverse visual impacts and create greater cohesion.

Example Application

A new substation is sited in a cove. Drainage is not an issue. The site naturally reduces the visual impact of substation structures and incorporates the natural topography to screen the substation from view.



A natural slope obscures the view of a substation to the surrounding neighborhood

2C Protect significant viewsheds

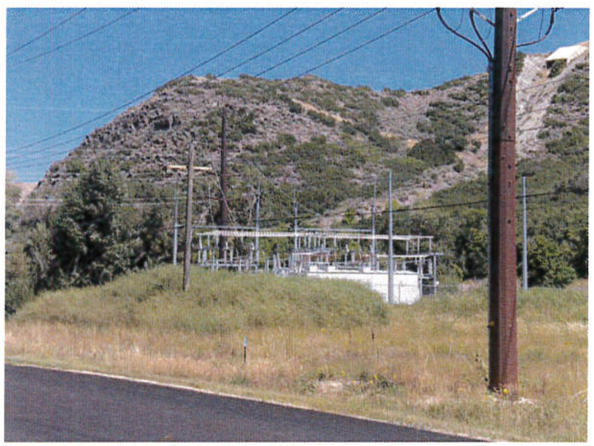
Priority – Tier 1

Viewsheds are an essential element of community character and scenery. It is important to consider impacts to the neighborhood landscape as well as the view from surrounding areas. For example, ridge lines and undeveloped benches throughout Summit and Wasatch Counties should be avoided.

Where possible, avoid siting a substation on top of a ridge or high point where it would disrupt residents' view of the mountains.

Example Application

A new substation is needed to serve customers who built homes up the slope of a prominent hillside and over the top to the other side. A site for the new substation is found at the base of the hillside.



Jordanelle Substation, with a simple fence and landscaping ties into surrounding area

2D Build aesthetically pleasing facilities

Priority – Tier 1

Infrastructure will be better integrated into the area and find greater acceptance if it is built to be aesthetically pleasing. Landscaping and concrete walls can be used to improve aesthetics. The use of high quality materials will ensure facilities withstand years of operation without deterioration and costly maintenance. Wall/fence design should be complementary to the area. For instance, a simple fence may draw less attention than a solid concrete wall.

Example Application

A substation is designed to integrate into the surrounding neighborhood by using high quality concrete walls. Little maintenance is required over time. Additionally, landscaping is designed to require little water and low maintenance. The concrete walls and landscaping are designed to match those within the neighborhood.

2E Avoid dedicated open space and parks

Priority – Tier 2

Dedicated open space and parks are an essential element of the community and may not be appropriate for construction of new electrical facilities. Care should be taken to avoid using open space for new electrical infrastructure.

Communities are encouraged, however, to utilize green space surrounding substations for pocket parks or other active uses. It is important to evaluate the uses in green space to ensure compatibility.

2F Site in areas with high development potential

Priority – Tier 2

Optimize use of land in projected growth areas, thus ensuring adequate electrical capacity is available to meet communities' growing needs. Where possible, it is valuable to plan infrastructure locations in advance of development to minimize conflicts with expanding uses. However, care should be taken to preserve prime real-estate parcels needed for economic development.

2G Avoid residential neighborhoods

Priority – Tier 2

Residential areas are the least desirable locations for new substations due to impacts to the character of the neighborhood and important community viewsheds. Avoiding these areas will reduce community concern about perceived reduction of property values and health effects.

Example Application

While customer demand in a residential area may be driving the need for additional electrical capacity, an alternative substation site in an adjacent commercial area is preferable.

2H Avoid adverse aesthetic impacts on development

Priority – Tier 2

Electrical facilities are essential to meet communities' plans for growth and development. However, their location and design can influence how well they are integrated into the community. Task force members emphasized that the aesthetics of new facilities should not have a significant adverse effect on new development. Avoid areas where the facility would harm development potential.

2I Avoid discrimination based on income or ethnicity

Priority – Tier 3

Whenever possible, work to ensure that demographic or ethnic groups are not impacted unfairly. New substations should be sited according to electrical supply needs and not within areas that may offer less public resistance. Be sensitive to low-income demographics in areas where property is cheaper and permitting requirements may be less restrictive.

Example Application

A low-income residential neighborhood in an industrialized area appears to be an ideal substation location. In order to protect the neighborhood, however, the substation is built in the industrial park.

2J Utilize land adjacent to other infrastructure

Priority – Tier 3

Where possible, substations should be sited adjacent to existing infrastructure and other complementary uses such as transportation corridors and other utilities. However, issues can arise from locating in or near freeway rights-of-way, including salt spray from snow plows, lack of access and insufficient clearance for in-coming transmission lines.

Silver Creek Substation, adjacent to other infrastructure

2K Protect critical habitat, wetlands, rivers and stream corridors

Priority – Tier 3

It is Rocky Mountain Power's policy to treat critical habitat, wetlands, rivers and stream corridors with extreme care and to avoid them where possible. Sites with potential for environmental issues should be evaluated for impacts and possible mitigation measures. Discussions with concerned parties should be made to identify locations with fewer adverse impacts.

Wetlands near Swaner Eco Center

3. CRITERIA FOR TRANSMISSION LINES

Criteria in this section pertain to important land characteristics or related considerations in relation to siting NEW transmission lines.

- 3A Protect significant viewsheds
- 3B Upgrade existing facilities before building new facilities
- 3C Avoid dedicated open space and parks
- 3D Build aesthetically pleasing facilities
- 3E Share rights-of-way with utilities, trails, railroads, canals, roads, etc.
- 3F Avoid residential neighborhoods
- 3G Utilize areas with development potential
- 3H Avoid discrimination based on income or ethnicity
- 3I Avoid adverse aesthetic impacts on development
- 3J Protect critical habitat, river and stream corridors
- 3K Avoid existing trails
- 3L Select sites that allow operations and maintenance access
- 3M Utilize large-format (big-box) retail

3A Protect significant viewsheds

Priority – Tier 1

Viewsheds are an essential element of community character and scenery. It is important to consider impacts to the neighborhood as well as the view from surrounding areas. For example, ridge lines and undeveloped benches throughout Summit and Wasatch Counties should be avoided. It is also preferable to use topography to make transmission lines less visible and blend in with the surroundings.

3B Upgrade existing facilities before building new facilities

Priority – Tier 1

Whenever possible, it is preferable to upgrade existing facilities rather than build new facilities. Voltage upgrades and/or addition of a second circuit will minimize land disturbance by reducing the total number of new corridors and also potentially reduce land acquisition and rights-of-way costs. Maximizing use of existing facilities may also produce fewer conflicts with nearby buildings, land uses and environmental issues. A community already accustomed to existing facilities may prefer an upgrade over building a new transmission line in another corridor.

Upgrading an existing transmission line may be considered visually inappropriate (see Criterion #3A) or incompatible with existing land uses (see Criterion #3F). Resolving conflicting criteria may require tradeoffs with other considerations.

Example Application

A transmission line adjacent to commercial development is upgraded to a higher voltage to provide new capacity for a growing community. The taller structures required for the upgrade are preferable to building a new transmission line.

Linemen work to replace an existing transmission line

3C Avoid dedicated open space and parks

Priority – Tier 1

Dedicated open space and parks are essential to the community and should be left undisturbed by electrical infrastructure. Care should be taken to avoid using open space for new electrical infrastructure. It is preferable to build transmission lines in industrial or commercial areas.

Example Application

The utility acquires right-of-way for a new transmission corridor through an industrial zone rather than using vacant land that is dedicated to open space on the periphery.

3D Build aesthetically pleasing facilities

Priority – Tier 1

Infrastructure will be better integrated into the area and find greater acceptance if it is built to be aesthetically pleasing. In siting new facilities, seek locations with minimal adverse aesthetic impact, such as utility corridors, industrial areas and highway rights-of-way. This may reduce impacts on surrounding areas such as residential viewsheds.

Communities may choose to create greenways, trails and pocket parks under transmission lines to beautify the corridor and enhance community amenities.

Within accepted industry standards, communities may also work with Rocky Mountain Power to make poles more aesthetically pleasing. For example, community art could be placed near a pole base as long as it doesn't interfere with utility operations or create maintenance problems.

Communities increasingly prefer underground transmission lines. State law provides that Rocky Mountain Power will build underground transmission lines if the community pays the cost difference with overhead construction and reliability is not jeopardized. Cost is currently about 6-15 times greater than overhead construction due to additional civil engineering, excavation,

A greenway and trail enhance the area under a transmission corridor

restoration, conduit, underground cable and potential congestion with other underground utilities. Outage times and expense are also significantly longer for underground transmission because it takes significantly longer to locate and repair the problem. Communities may decide, despite these issues, to pay the additional cost for underground transmission lines in high-density locations or other areas where new transmission lines will generate significant resistance. Nevertheless, the task force would like to see underground transmission utilized when feasible.

3E Share rights-of-way with utilities, trails, railroads, canals, roads, etc.

Priority – Tier 2

Where possible, co-locate transmission lines in existing major corridors and identified rights-of-way. Utilizing existing utility corridors and rights-of-way will minimize the cost of purchasing additional rights-of-way and mitigating potential impacts. Sharing corridors with complementary uses creates fewer disturbances to the aesthetic character of the area.

Transmission lines in a greenway serve as a buffer between major transportation corridors and other uses. Where transmission lines can be co-located with trails, railroads, and canals, they are more easily integrated into the neighborhood landscape. Communities may choose to convert areas under transmission lines into trails or greenways to utilize and beautify the existing right-of-way. This can benefit the community by adding green space and recreation.

Transmission line co-located with a trail near HWY 224 in Snyderville Basin

Example Application

A new transmission corridor is co-located with a new highway during the planning phase to combine similar uses. It results in reduced siting difficulty and provides a buffer between the roadway and the neighboring uses.

3F Avoid residential neighborhoods

Priority – Tier 2

Residential areas are the least desirable locations for new transmission lines due to impacts to the character of the neighborhood and important community viewsheds. Avoiding these areas will reduce community concern about perceived reduction of property values and health effects.

Example Application

To avoid a growing residential development, a transmission line is sited to circumvent the area by crossing a nearby commercial district.

Transmission lines placed outside a residential area buffered by a golf course

3G Utilize areas with development potential

Priority – Tier 2

Optimize use of land in projected growth areas, thus ensuring adequate electrical capacity is available to meet communities' growing needs. It is valuable to plan electrical infrastructure in advance of development to minimize conflicts with developing uses. However, care should be taken to preserve prime real-estate parcels needed for economic development.

Example Application

A new transmission corridor is master-planned near an area with high development potential to provide for future electrical requirements.

3H Avoid discrimination based on income or ethnicity

Priority – Tier 2

Whenever possible, work to ensure that demographic or ethnic groups are not impacted unfairly. New transmission lines should be sited according to electrical supply needs and not within areas that may offer less public resistance. Be sensitive to low-income demographics in areas where property is cheaper and permitting requirements may be easier.

Example Application

A low-income residential neighborhood appears to be an ideal location for a new transmission corridor. In order to protect the neighborhood, however, the transmission line is sited through a nearby industrialized area.

3I Avoid adverse aesthetic impacts on development

Priority – Tier 2

Electrical facilities are essential to meet communities' plans for growth and development. However, their location and design can influence how well they are integrated into the community. Task force members emphasized that the aesthetics of new facilities should not have a significant adverse effect on new development. Avoid areas where the facility would harm development potential.

3J Protect critical habitat, river and stream corridors

Priority - Tier 3

It is Rocky Mountain Power's policy to treat critical habitat, wetlands, rivers and stream corridors with extreme care and to avoid them where possible. Sites with potential for environmental issues should be evaluated for impacts and possible mitigation measures. Discussions with concerned parties should be made to identify locations with fewer adverse impacts.

3K Avoid existing trails

Priority – Tier 3

Transmission lines can sometimes be co-located with other infrastructure and rights-of-way. However, other criteria being met, avoid siting new transmission lines in existing trails. Steering clear of existing trails will reduce disruption to established recreation uses and also reduce community resistance to new infrastructure.

Communities are encouraged, however, to use the land beneath transmission lines as greenways or trails to take advantage of established rights-of-way and provide recreational amenities for the community.

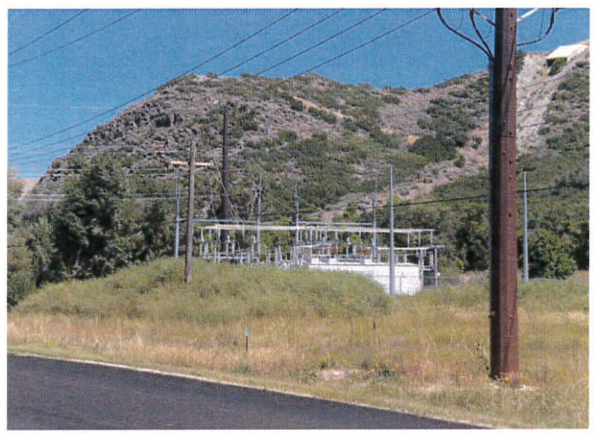
3L Select sites that allow operations and maintenance access

Priority – Tier 3

Access to transmission lines for emergency operations and regular maintenance is an important consideration and should be considered in conjunction with other siting criteria.

Example Application

A transmission line and trail are co-located through a wooded area. The trail is widened to accommodate vehicle access to the line and trees are cleared to meet electric safety code.



Jordanelle Substation

3M Utilize large-format (big-box) retail locations

Priority – Tier 3

Consider locations near large-format retail, such as big-box stores, in an effort to site infrastructure with other compatible uses. These locations present fewer conflicts than many other uses. Large parking lots associated with this type of retail would not be disturbed by overhead transmission lines. Community impacts would be minimal.

Example Application

A community chooses to site a new transmission line through an area of large-format retail stores. The transmission line runs parallel to the parking lot, thereby preserving land with other value for different purposes.

Transmission line running through a large car dealership parking lot

C. Scorecard

A scorecard was developed as a tool for local jurisdictions and Rocky Mountain Power to use in evaluating alternative locations for new facilities. It provides a means to compare specific locations in terms of how well each site meets the siting criteria established by the task force. It is not intended to replace careful consideration and debate about the relative benefits or impacts of specific locations. Rather, it is a tool to be used in combination with other information to facilitate comparative evaluation.

INSTRUCTIONS FOR USE

The scorecard is separated into two sections, one for substations and one for transmission lines. To score the potential site, ask yourself how well the location meets each criterion and enter an x in the corresponding line. Then multiply the score for each criterion by the corresponding criterion weight to produce a total score for that criterion. The weight assigned to each criterion corresponds to the priority it was given by the task force and shown in the Siting Criteria section of this document. Finally, sum the points in the last column to obtain a total score for the potential infrastructure location.

This example illustrates how to score a potential site. Blank scorecards can be found in appendix D and in spreadsheet form at:

www.rockymountainpower.net/planning

Summit Wasatch Electrical Plan SAMPLE Scorecard

SUBSTATIONS					
	Location Criteria	SCORE how well the criterion is met	Enter X where appropriate	Criterion WEIGHT	Criterion TOTAL = score X weight
2A	Maximize use of existing facilities and adjacent properties before building new facilities	Substantially (2 points)		3	3
		Partially (1 point)	x		
		Poorly (0 points)			
2B	Use topography to reduce visual impacts	Substantially (2 points)	x	3	6
		Partially (1 point)			
		Poorly (0 points)			
2C	Protect significant viewsheds	Substantially (2 points)		3	3
		Partially (1 point)	x		
		Poorly (0 points)			
2D	Build aesthetically pleasing facilities	Substantially (2 points)	x	3	6
		Partially (1 point)			
		Poorly (0 points)			
2E	Avoid dedicated open space and parks	Substantially (2 points)		2	0
		Partially (1 point)			
		Poorly (0 points)	x		
2F	Use areas with high development potential	Substantially (2 points)		2	2
		Partially (1 point)	x		
		Poorly (0 points)			
2G	Avoid residential neighborhoods	Substantially (2 points)	x	2	4
		Partially (1 point)			
		Poorly (0 points)			
2H	Avoid adverse aesthetic impacts on development	Substantially (2 points)		2	2
		Partially (1 point)	x		
		Poorly (0 points)			
2I	Avoid discrimination based on income or ethnicity	Substantially (2 points)	x	1	2
		Partially (1 point)			
		Poorly (0 points)			
2J	Utilize land adjacent to other infrastructure	Substantially (2 points)		1	1
		Partially (1 point)	x		
		Poorly (0 points)			
2K	Protect critical habitat, wetlands, rivers and stream corridors	Substantially (2 points)		1	0
		Partially (1 point)			
		Poorly (0 points)	x		
	SUBSTATION TOTAL				29

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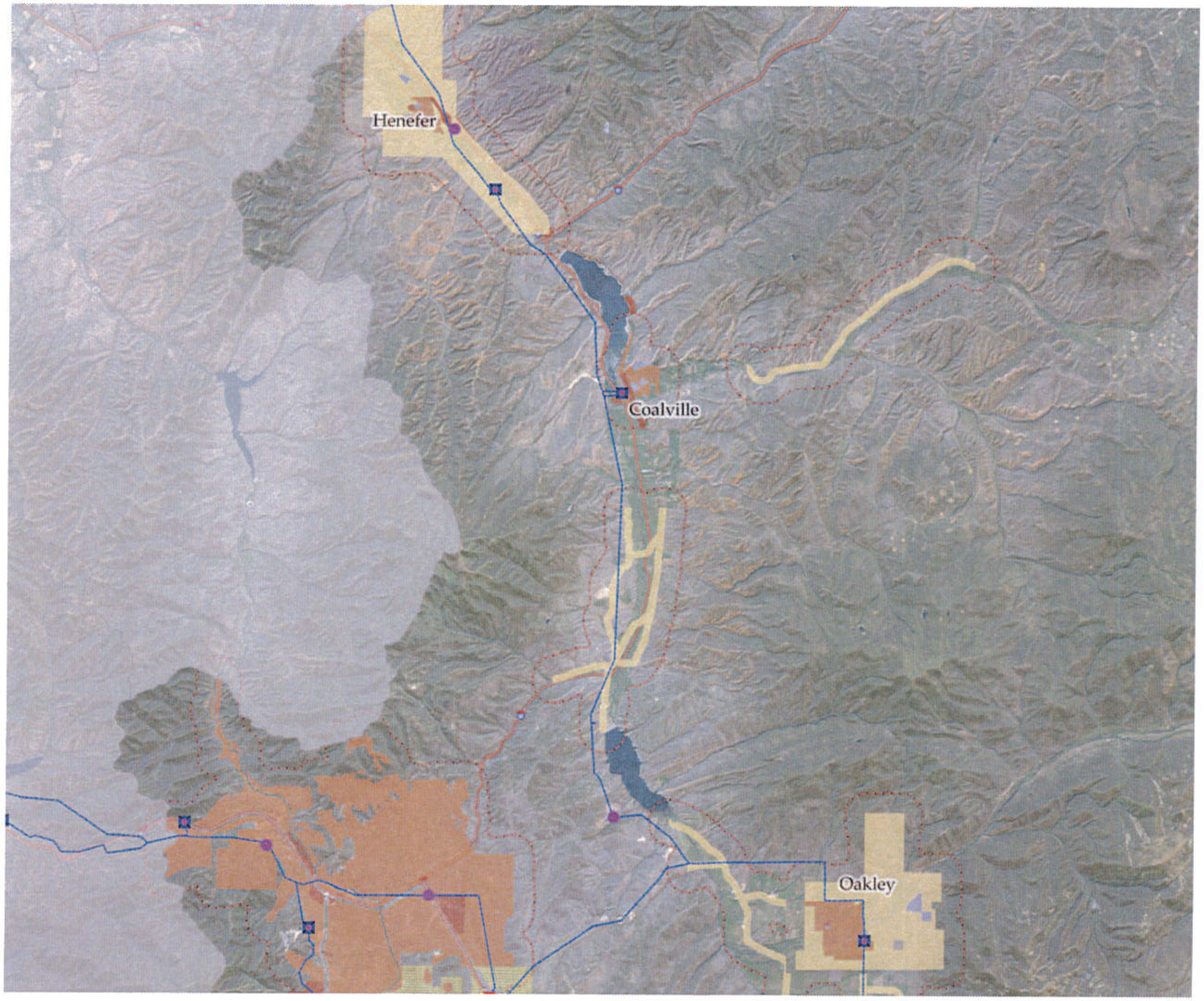
D. Map
NORTHERN SUMMIT AND WASATCH COUNTIES



GENERAL ELECTRICAL SYSTEM LEGEND

Substations

- Existing Substation
- New Substation
- Existing Substation; Subject to Change

Lines

- Existing Line
- New Line
- Existing Line; Subject to Change (Expand, widen, upgrade, remove, etc)

SOUTHERN SUMMIT AND WASATCH COUNTIES

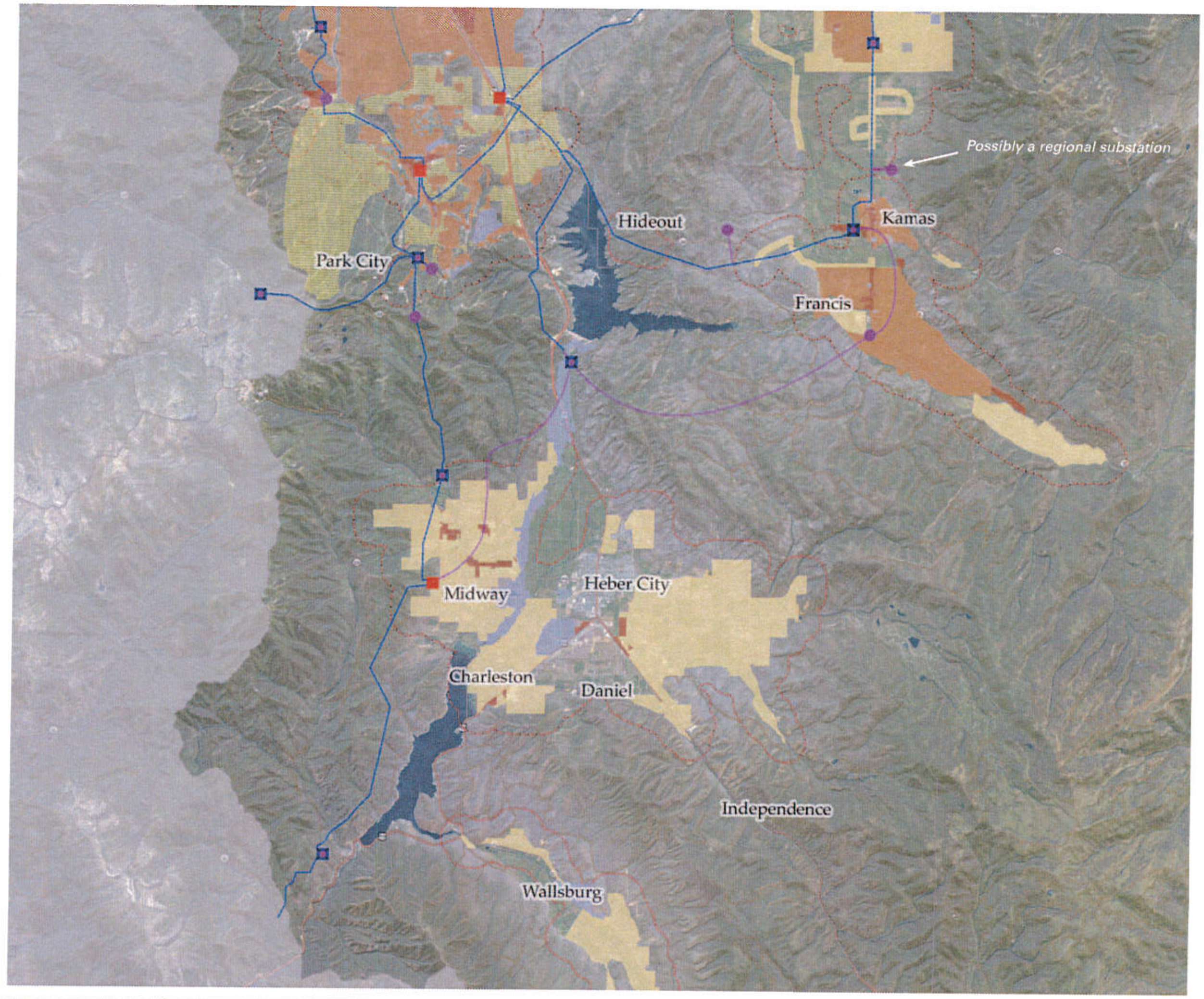
GENERAL ELECTRICAL SYSTEM LEGEND

Substations

- Existing Substation
- New Substation
- Existing Substation; Subject to Change

Lines

- Existing Line
- New Line
- Existing Line; Subject to Change (Expand, widen, upgrade, remove, etc)



E. How to use the plan in the future

The goal of the Summit Wasatch Electrical Plan is to facilitate cooperative planning by local government and Rocky Mountain Power for future electrical infrastructure needed for growing communities. It represents a shared understanding of the preferred locations of new electrical infrastructure and the process to be followed in making future siting decisions. It has no force of law; however communities and the utility can realize measurable benefits over time if is implemented voluntarily.

The effort can fulfill two important goals of long-range planning:

1. Define appropriate land uses and design characteristics for future electrical facilities
2. Let residents and property owners know what to expect as the community changes over time

Cities and counties are accustomed to working towards these aims within the transportation or mobility components of their general plans. Further, community development considerations such as land use, parks and recreation are typically integrated into their transportation plans. But most cities do not address electrical infrastructure with the same long-range view. The Summit Wasatch Electrical plan offers communities an opportunity to treat electrical infrastructure in a similar and thoughtful manner.

SUMMIT WASATCH ELECTRICAL PLAN UPDATES

It is important to revise the Summit Wasatch Electrical Plan periodically to reflect the changing geography of energy use, such as the location of a new data center, land-use changes, or to incorporate major local modifications.

Minor changes

Minor changes (those that affect only one jurisdiction and maintain the basic technical feasibility of the plan) should be shared with Rocky Mountain Power.

Contact Rocky Mountain Power representative:

Administrative Assistant
801-220-2660
rmpmasterelecplan@pacificorp.com

Major changes

Major changes (those that affect more than one jurisdiction or affect basic technical considerations) should be addressed by affected parties (jurisdictions and Rocky Mountain Power) on an as-needed basis. Rocky Mountain Power should record these changes in a modified Summit Wasatch Electrical Plan and send copies to all jurisdictions.

Overall updates

Planning officials of jurisdictions served by Rocky Mountain Power should meet every five years to update the Summit Wasatch Electrical Plan. It should include changes to the plan map, the siting criteria, and local implementation best practices.

LOCAL IMPLEMENTATION CHECKLIST: SUGGESTED NEXT STEPS

- Present plan as an informational item to planning commission, city or county council.
  - Discuss concept and approaches to address electrical infrastructure in your locality.
- Review the siting criteria and the maps in the Summit Wasatch Electrical Plan.
  - Identify compatibilities/ incompatibilities with your existing general plan.
- Develop a planning approach and schedule to address electrical infrastructure that considers:
  - Input from your elected and appointed officials. Approaches to consider include:
    - Developing an electrical infrastructure general plan element
    - Adopt as a stand-alone plan, referenced in relevant general plan elements
    - Note the plan as a reference document within the general plan
- Develop a schedule of anticipated general plan updates.
- Implement basic electrical infrastructure considerations in local plans and ordinances.
- Begin addressing substantive incompatibilities between local plans and ordinances and the Summit Wasatch Electrical Plan.

Inform Rocky Mountain Power, neighboring jurisdictions, and Summit and Wasatch Counties on an ongoing basis of any changes you make to plan elements to address incompatibilities.

A Rocky Mountain Power representative can assist in presenting the key components of the plan, how it was developed, and various approaches your jurisdiction might consider to implement the plan in your local long-range plans and ordinances.

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3. Local Planning Handbook

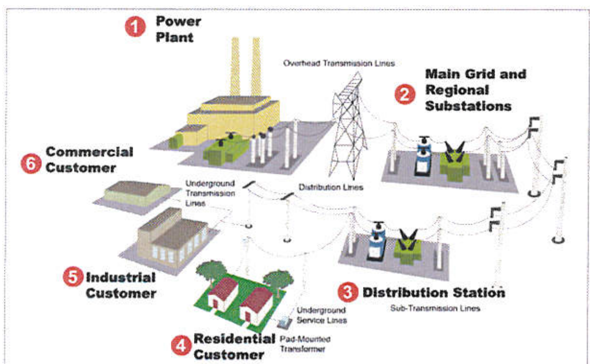
This handbook promotes a consistent ‘best practice’ approach to integrating electric substations and transmission lines into Utah’s communities. In doing so, it encourages citizens, community leaders, planners and utility representatives to actively participate in the utility siting process to improve the ability to efficiently coordinate future community growth, and recognizes the important role that electric utility service plays.

The electric utility transmission system is composed of electric power line corridors, which are linear routes through communities, and electric substations that are located on individual sites.

Electric power begins at power plants, transmitted through high voltage transmission lines, stepping down from higher to lower voltages through shorter-distance transmission lines and, ultimately, to distribution substations and distribution lines feeding residential and commercial users.

Electric substations and transmission lines should be sited in a way that is not only functional and cost-efficient, but also well-integrated into the community. Electric facilities should be part of a larger strategic plan that responds to community growth patterns and needs. Appropriate electric facility siting will ensure that safe, reliable electric services can be provided that also fits into the particular context. Siting decisions for electric facilities should consider impacts to natural systems like soils, drainage and habitat, and, with the aid of the community, address aesthetic considerations.

1. Proactive Planning
2. Best Management Practices
3. Sustainability
4. Communication
5. Multi-Purpose/Co-location
6. Neighborhood Integration



KEY QUESTIONS WHEN EVALUATING FACILITIES:

- Is this proposal consistent with the adopted electric service plan and corresponding siting criteria?
- Is this proposal compatible with existing land uses and the community's Comprehensive Plan?
- Can existing substations and transmission lines be utilized to meet the needs of the utility and the community?
- Does this proposal promote recreational use of utility corridors for trails, sports fields, and similar uses?
- Does this proposal limit the amount of site grading and vegetation, yet still meet adopted safety standards?
- Is proposed land development sited and screened in a manner that reduces the potential for conflicts with existing electrical facilities?
- Where feasible, are telecommunication facilities co-located with the proposal?
- Is the proposal screened with fences, walls, vegetation and/or topography or a combination thereof?
- Has the proposal included lighting designed to reduce impacts to the surrounding area yet meet safety and security requirements?
- Does this proposal's screening use color and materials minimizing aesthetic impacts?

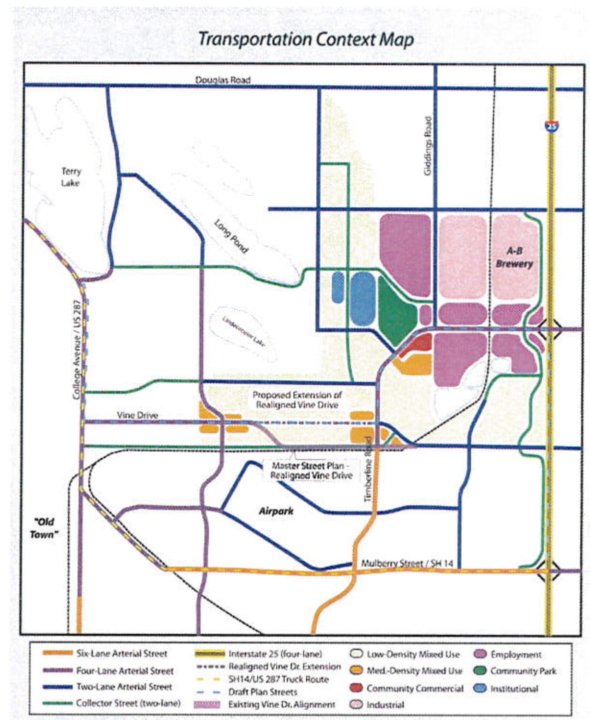
CORE CONCEPTS DISCUSSION

1. Proactive Planning

- Municipalities, counties and utilities should work together to appropriately site new substation and transmission facilities to maintain a reliable level of service and accommodate growth. Data and population projections should be generated to assist utilities in their growth planning.

  Comprehensive plans should include the siting of electric facilities, much as is done for a water or sewer master plan, transportation plan, or a parks, recreation and open space plan.

The siting of new substation and transmission facilities should be taken into consideration during the comprehensive planning process, at the time the desired location of residential, commercial and industrial areas is determined. Data collected during the comprehensive planning process should include forecast energy demand and the location and timing of growth based on several factors such as, historical electric usage by market sector, density of development, and historic and



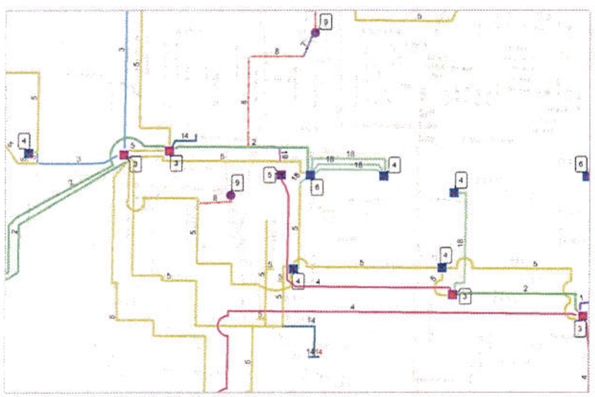
Integrate utilities with future transportation corridors forecasted market trends. Armed with this information, it will improve decision-making in forecasting electric demand relative to existing supply, predict facility need by general location, and determine transmission and distribution requirements. Once known, electric facilities can become an inclusive component of the planning process and adopted plan.

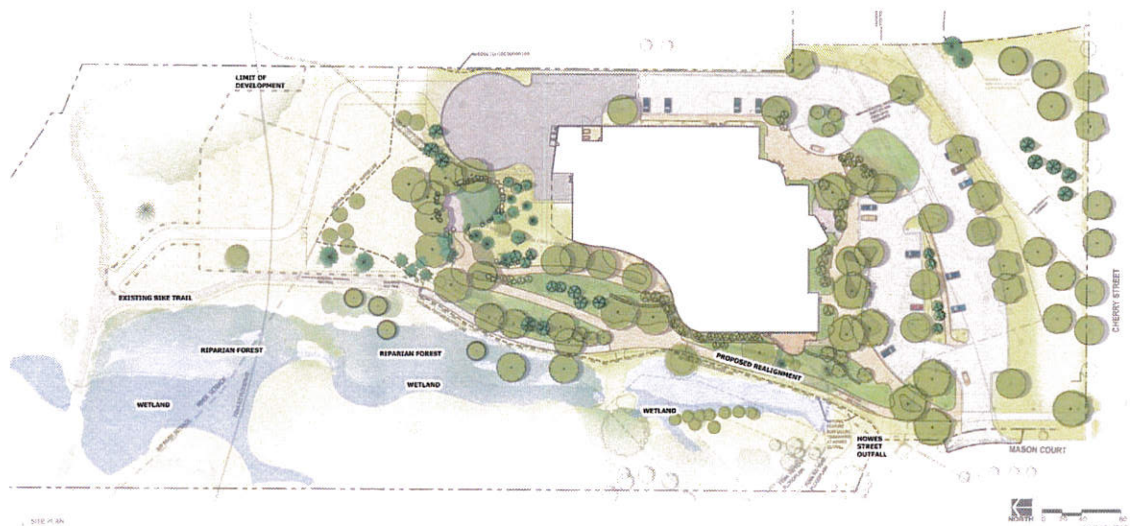
As with other Comprehensive Plan elements, communities should adopt utility policies that set a specific strategy to guide future decision-making. The following policies should be seen as a template for consideration by local municipalities:

- Develop siting and land use compatibility standards for electric facilities.
- Promote on-going coordination between municipalities and utility providers to ensure that electric transmission lines are provided in urban areas and can be coordinated with road right-of-way and other infrastructure.
- Consult the adopted Transportation Master Plan when designating new utility corridors.
- Consider utilizing new right-of-way corridors to minimize the need to tear up and replace existing roads.
- Secure new electric resources and transmission lines as necessary to meet projected demand levels.
- Require new development to dedicate sites and easements needed for substations, transmission, sub-transmission and distribution lines.
- Pursue reasonable and cost-effective energy efficiency, conservation, and load management programs.
- Develop and implement public education programs designed to increase the public's awareness of energy issues, including conservation measures and practices.

• Future facilities should follow the official electrical plan and corresponding siting criteria. The coordinated utilities plan suggests areas where expanded service may need to take place.
• Local jurisdictions should coordinate with the electrical provider when considering land use designations or new development in the vicinity of proposed transmission and substation facilities. Potential encroachments into proposed utility corridors and at substation sites should be evaluated during the land development review process. Some of the tools to preserve these areas include:

- Identify future potential transmission corridors and substation sites in new developments and require utility integration into the development plan and/or subdivision plat.
- Require dedication of a strip of land along existing transmission corridors for potential future right-of-way expansions.
- Prescribe building set-backs or lot sizes for properties adjacent to transmission lines so that buildings don't constrain future rights-of-way.
- If property adjacent to an existing transmission line is to be developed, require the developer to dedicate land for a parkway, bike path, or buffer area.





Development Plans identifying utility easements

2. Best Management Practices

- Require the use of those proven methods or techniques that consistently produce positive results, i.e. - "best practices" for future substation and transmission facilities.
- Limit the disturbance to vegetation within major utility transmission corridors and substation sites to actions that are necessary for the safety, operation and maintenance of the facilities. Care should be exercised to preserve the natural landscape and conduct construction operations so as to prevent any unnecessary destruction, scarring, or defacing of the natural surroundings in the vicinity of the work. Except where clearing is required for permanent construction and conductor clearances, approved construction roads, or excavation operations, all trees, native shrubbery, and vegetation should be preserved and shall be protected from damage by construction operations and equipment. The edges of clearings and cuts through tree, shrubbery or other vegetation might be irregularly shaped to alter the visual impact of straight lines.

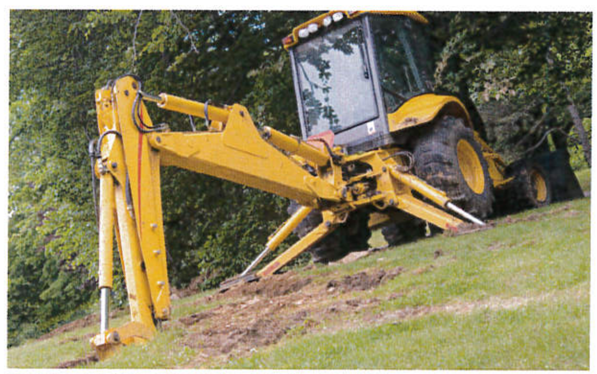
3. Sustainability

- Encourage conservation of electric resources to delay the need for additional transmission and substation facilities for electricity. Citizens and businesses can take advantage of electric conservation opportunities. Many conservation actions such as interior motion sensor lights that control lighting in response to room occupancy have minimal associated costs, making payback immediate and significant. Providing educational resources is a positive way that electric providers can inform the public about ways to improve energy efficiency that is both practical and economical.
- Consider cost-effective energy conservation technologies including, but not limited to, site planning, construction methods, materials used, and landscaping and development regulations. Such technologies for methods and materials should also promote practices that do not compromise human health conditions when occupied or used, reduce the need for future additional utility distribution facilities, and leave options for increasing conservation technologies in the future. Local jurisdictions can incorporate sustainability features directly into zoning and building codes. Minimum zoning standards should allow various energy saving uses such as wind turbines, solar access, photovoltaic solar panels, geothermal heat, and green roofs. Since more efficient energy use in buildings decreases energy costs, then a major focus should be on implementing "green building" practices.

4. Communication

Utility providers should prepare a detailed communications plan that highlights how information about future substation and transmission improvements can be shared with public agencies and customers. The following communications program elements should include:

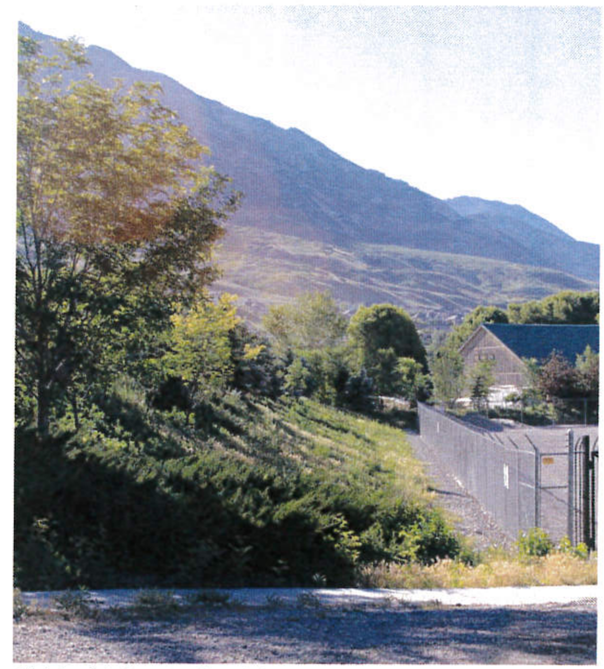
- Foster early and proactive communication between affected stakeholders
- Meet periodically with representatives of utility providers to ensure coordination of substation and transmission line plans.
- Coordinate with other jurisdictions in the planning and implementation of multi-jurisdictional substation and transmission improvements.
- Add transmission and substation information to the jurisdiction's geographical information system (GIS), where feasible, and coordinate regularly with private utility providers to obtain up-to-date systems information.



Exercise care during construction to protect vegetation

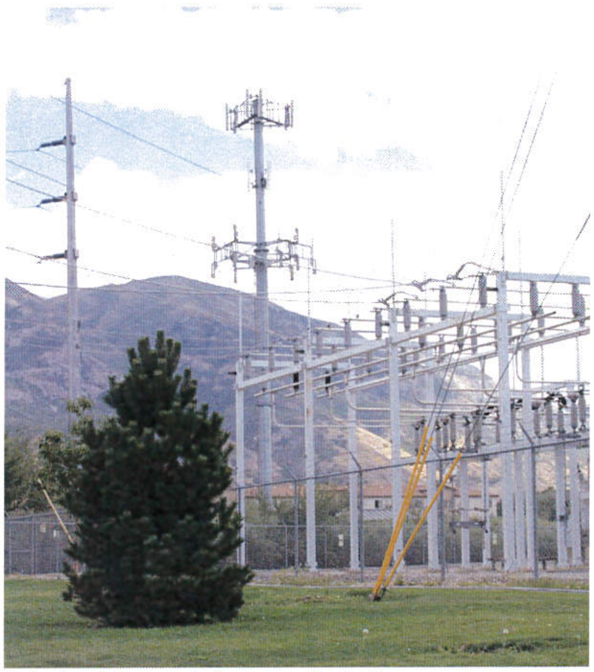
5. Multi-Purpose /Co-location

- Where economically feasible and allowed by law, promote co-location of major transmission facilities. Many major transmission facilities such as electric transmission lines, water, and natural gas main pipe lines can share utility corridors. This will minimize the amount of land allocated for this purpose and the tendency of such corridors to divide neighborhoods or districts.



Minimize disturbance to adjacent slopes

- Promote recreational use of utility corridors for trails, sports fields, and similar uses. Communities should be encouraged to utilize electric transmission line rights-of-way for bicycle/pedestrian paths, equestrian trails and sports fields. The local Parks & Recreation Master Plan should be consulted when developing the utility system, and future corridors should be coordinated with greenway trails when possible.
- Promote the co-location of telecommunication facilities adjacent to electric substations without undue burden on any single utility provider.



Co-location of telecommunication towers with substations

To the extent feasible antenna towers, and equipment structures should be co-located adjacent to substations and be designed to provide for the consolidation of future facilities to eliminate or minimize the visual clutter resulting from multiple communication structures.

6. Neighborhood Integration

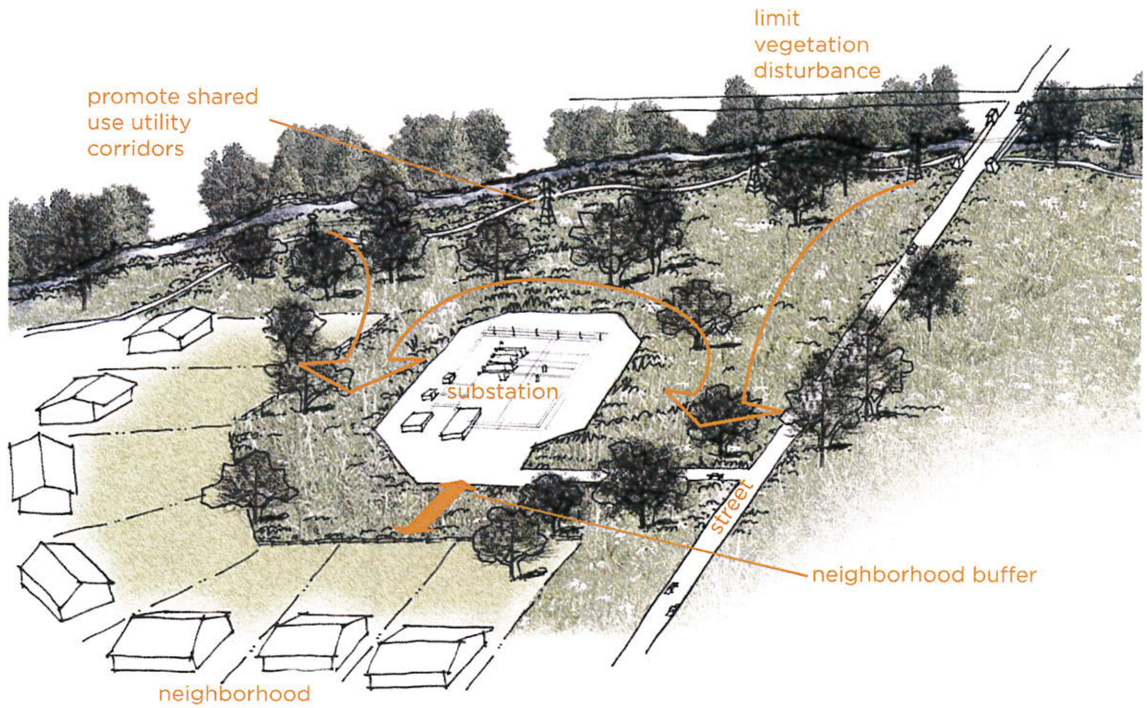
- Ensure that new transmission and substation facilities are designed in such a manner as to minimize adverse aesthetic impacts on the surrounding land uses.

Minimize disturbance of existing vegetation

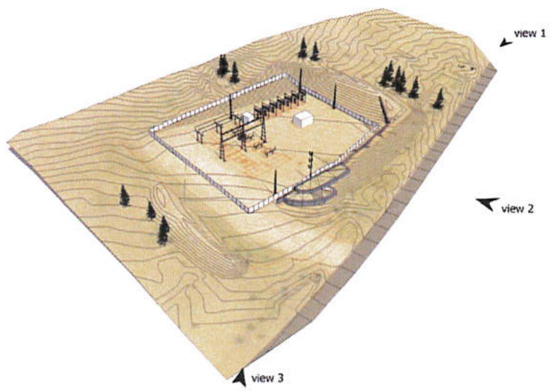
- Utilize buffer zones to integrate substations with surrounding neighborhoods and districts. Buffer zones can be defined through distance, land forms and plant material. Three types of landscaping options are currently available:
  1. **Hardscape** - Gravel, asphalt, decorative rock, paving etc.
  2. **Softscape** - Non-native trees, shrubs, grass, continual irrigation and maintenance required
  3. **Xeriscape** - Low watering intensity (waterwise), self sustaining shrubs and trees, native trees, shrubs and grasses
- If possible, move facilities behind natural landforms or vegetation to help screen them from view.
- Permanent exterior lighting must provide lighting adequate to meet safety and security needs, but should not be excessive. Dark sky practices should be utilized minimizing the impact of lighting to the adjacent properties.

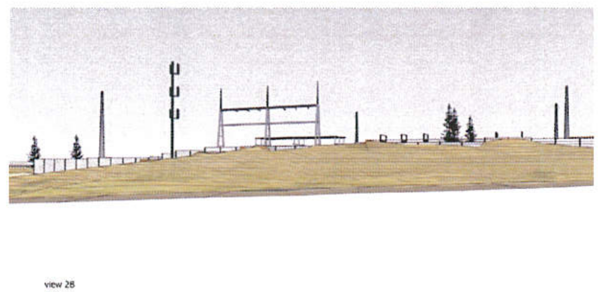
- Encourage the use of design guidelines to address the location and screening of electric substations.
- New development approved adjacent to existing substation facilities should provide vegetative screening or buffers. Buffer yards, including vegetative screening and/or berms could be created that separate new residential land uses from existing substations and similar electrical equipment in order to eliminate or minimize potential nuisances, or to provide spacing to reduce visual impacts.
- Use color and material finishes to blend into the surroundings. The colors and finishes should be based on the following considerations:
  - Utilize uniform and non-contrasting colors for substation walls to blend with the immediate natural environment.
  - Selected on the basis of their ability to blend with both the sky and the environment in which they are being used.
  - Transmission line conductors should, over time, be non-reflective, and the insulators non-reflective and non-refractive.

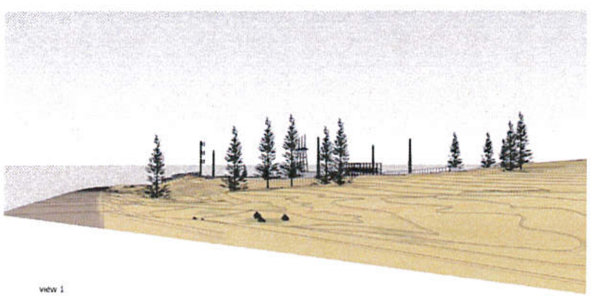
Vegetation acts as a buffer between a substation and the surrounding neighborhood

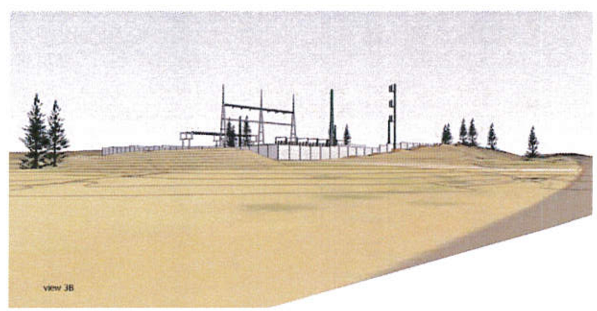


Techniques used to integrate substation into surrounding neighborhood









Example berming used to integrate substation into surrounding neighborhood

Resources

1. *The Case for New Electricity Transmission and Siting New Electricity Transmission Lines, Roger W. Gale, Mary O'Driscoll, GR Energy LLC, September, 2001, http://oharas.com/ET/Transmission_Case.pdf*

2. *The Neighborly Substation- Electricity, Zoning and Urban Design, Hope Cohen, Deputy Director, Center for Rethinking Development, December, 2008. http://www.manhattan-institute.org/html/crd_ neighborly_substation.htm*

3. *Visual Impact Analysis Methodology for Transmission Line Planning Corridors, EDAW, February 1977.*

4. Appendices

Appendix A: Glossary of terms

A

Alternating Current (AC) – An electrical current which alternates direction repeatedly due to a change in voltage. With power companies the alternating current creates a sinusoidal waveform.

Ampacity – The current-carrying capacity, expressed in amperes, of an electric conductor under stated thermal conditions. As ambient temperatures decrease the ampacity increases.

Ampere – A unit of measurement for electrical current produced by one volt applied across a resistance of one ohm. See Current.

B

Breaker –See Circuit Breaker.

Bus – An electrical connection that connects multiple electrical devices which is sometimes referred to as a bus bar.

Bushing – An insulated connection between the internal and external components of electrical equipment.

C

Capacitor – A device to store an electrical charge. In the field of electric power transmission and distribution, capacitors are devices used for power factor correction and voltage regulation. Power factor correction improves the ability to deliver useful power (real power) to loads and voltage regulation helps to maintain constant service voltage.

Capacity – The maximum amount of electrical power which a device can utilize at one time without causing damage to the device. Also, the amount of electric power that can be delivered at one time by a generating unit, generating station, or all the plants on an electric system.

Circuit – A conductor or system of conductors through which an electric current is intended to flow

Circuit Breaker – A device to open (de-energize) or close (energize) a circuit either during normal power system operation or during abnormal conditions. During abnormal conditions, when excessive current develops, a circuit breaker opens to protect equipment and surroundings from possible damage due to excess current.

Conductor – A material, usually in the form of a wire, cable, or bus bar capable of carrying an electric current, which allows an electric current to pass continuously along it.

Continuous Load – A sustained electrical load.

Current – The flow of electricity commonly measured in amperes. See also Ampere.

Cycles-per-Second – See Hertz.

D

Direct Current (DC) – Electrical current that normally flows in one direction only.

Demand – The rate at which electric energy is delivered to or by a system, expressed in kilowatts, or other suitable units at a given instant or averaged over a designated period of time. Demand varies from hour to hour, day to day, and season to season.

Distribution Substation – A substation where one or more transformers reduces the line voltage from a local transmission level between 46,000 volts and 161,000 volts (46 kV – 161 kV) to a distribution level (4.2 kV – 34.5 kV) in order to distribute power to customers.

Distribution Line – A combination of conductors connected together to deliver power to customers at distribution voltages (4.2 kV – 34.5 kV). Each distribution line can be composed of overhead or underground conductors and can serve hundreds of customers.

Distribution System – The distribution system includes all lines energized at voltages 34,500 volts (34.5 kV) and below.

DSM (Demand Side Management) – The planning and implementation of strategies designed to encourage consumers to improve energy efficiency, reduce energy costs, change the time of usage, or promote the use of a different energy source.

E

Easement – An easement is a right given to a person or entity to trespass upon land that the person or entity does not own. Easements are used for roads, for example or given to utility companies for the right to construct and access power lines

Energy – Energy is a measure of the amount of power usage over time and is measured in kilowatt-hours or megawatt-hours.

F

Fault – A problem on a power line that interrupts the normal flow of power, which usually causes a protective device (see circuit breaker and fuse) to operate.

Feeder – See distribution line

FERC (Federal Energy Regulatory Commission) – An independent U.S. government agency that regulates the interstate transmission of natural gas, oil, and electricity.

Franchise – A license or similar legal authority, granted to a utility by a jurisdiction, to provide service at retail in a given geographic area. An exclusive franchise is a monopoly to provide service in that area.

Frequency – The number of complete alternations or cycles per second of an alternating current measured in Hertz.

Fuse – A protective device that is designed to and de-energize a circuit when there is a fault on the circuit. The fuse can only operate once and must be replaced when it has operated.

G

Generator – A unit that converts thermal, mechanical, hydro, wind, chemical or nuclear energy into electric energy.

Generation Mix – A term used to describe the types of electrical generation a utility uses, or presently has on line – coal, wind, hydro, etc.

Giga-watt (GW) – 1,000 mega-watts, or 1,000,000 kilo-watts, or 1,000,000,000 watts.

Ground – The reference point in an electrical circuit from which other voltages are measured. Electric utilities use the earth or ground as the reference point. The potential or voltage of ground or earth is assumed to be zero volts.

Grounded – Connected to or in contact with earth or connected to some extended conductive body in place of the earth.

Guy Wire – A cable fastened to the pole to keep it in position.

H

Hertz (Hz) – A unit of frequency. One Hertz equals one complete cycle per second of an AC source. This unit replaces the former "cycles-per-second." The standard frequency in the US is 60 Hz. However, in some other countries the standard is 50 Hz

Horsepower – A measure of power used to define electric motors. For electricity one horsepower = 746 watts.

Hot – Energized (i.e., the line is hot or live).

I

IEEE (Institute of Electrical and Electronics Engineers) – A non-profit organization that is the world's leading professional association for the advancement of electrical technology. The IEEE promotes the engineering process of creating, developing, integrating, sharing and applying knowledge about electro and information technologies and sciences for the benefit of humanity and the profession. The IEEE sponsors the National Electrical Safety Code (NESC)

Insulator – Hardware or equipment made of porcelain, glass, or polymer used to isolate conductors from distribution poles or transmission structures that support them.

IOU (Investor Owned Utility) – A utility that is structured as a tax-paying business financed through sales of common stock. Rocky Mountain Power is an Investor Owned Utility.

IPP (Independent Power Producer) – A company that generates power but is not affiliated with an electric utility.

IRP (Integrated Resource Plan) – A method for looking ahead using environmental, engineering, social, financial and economic considerations; includes using the same criteria to evaluate both supply and demand options while involving customers and other stakeholders in the process. The IRP is the product of the process many utility companies and utility commissions use to select the generation resources needed to meet future demand for electricity.

J

Junction Box – An electrical junction box is a container for electrical connections, usually intended to conceal them from sight and deter public tampering

K

Kilovolt (kV) – A measurement of voltage. One kilovolt = 1,000 volts. This unit of measurement is most commonly used when describing transmission and distribution lines.

Kilowatt (kW) – A measurement of electric power. Ten 100 watt bulbs would use one kilowatt or 1,000 watts.

Kilowatt-Hour (kWh) – A measurement of electric energy equal to one kilowatt of power supplied for one hour. A kilowatt-hour could be used to light a 100-watt bulb for 10 hours.

L

Line Loss – The electrical energy lost in the process of transporting power over transmission and distribution lines. For a fixed amount of power going into a system:

> The greater the line length the greater the line loss
>
> The higher the voltage the less the line loss.

Load – The demand for power at a given point in time. The peak load is the highest amount of power drawn down at any time, or the utility's maximum demand. Load can be divided into three major classes – industrial load, commercial load, and residential load.

Load Curve – A graph showing power or demand against time

Load Factor – Load factor is the average power divided by the peak power, over a period of time. A high load factor is electricity used at a more constant rate without having peaks and valleys. A large business with a high load factor typically experiences a lower average cost per kWh and has a lower cost of service by the utility.

Load Forecasting – An estimate of future consumption of electricity. The estimates are used in planning for generation, transmission, and distribution facilities; in calculating future revenue from the sales of electricity; in determining cost allocations for the various rate classes; and in assessing the impact on load of changes in policies or underlying conditions such as the level of employment in the region.

M

Megawatt (MW) – 1,000 kilowatts or 1,000,000 watts.

Megawatt-hour (MWh) – 1,000 kilowatt-hours or 1,000,000 watt-hours.

Municipal Utility – An electric utility system owned by a municipality that serves retail customers generally within the boundaries of the municipality.

N

NEC (National Electrical Code) – A code for the safeguarding of people and property from hazards related to the use of electricity. Compliance with this code along with proper maintenance will result in an installation essentially free from hazard. The NEC does not cover installations under the exclusive control of an electric utility. The NEC is sponsored and updated by the National Fire Protection Association.

NERC (North American Electric Reliability Council) – An independent organization that works to ensure that the bulk electric system in North America is reliable, adequate, and secure.

NESC (National Electric Safety Code) – Rules published by the Institute of Electrical and Electronics Engineers (IEEE) applying to grounding, installation, maintenance and operation of electric supply, communication, utilization equipment, lines and facilities which have been adopted as standard by the American National Standards Institute. By law or statute electrical utilities are required to conform to the NESC.

Net Metering – A method of measuring the difference between the electricity the customer uses from the power company and the excess electricity given back by generating their own power. The net meter keeps track of power usage taken from the company and customer power provided back to the company.

Neutral Conductor – A system conductor other than a phase conductor that provides a return path for current to the source. It is intended to have approximately a zero voltage potential relative to earth or ground and such that the voltage differences between it and each of the phase conductors are approximately equal in magnitude.

O

Off-Peak – All times not identified as on-peak. See On-Peak.

Ohm – A unit of electrical resistance. A circuit resistance of one ohm will pass a current of one ampere with a voltage difference of one volt. Abbreviated using the Greek letter omega (Ω).

Ohm's Law – An equation that defines the relationship between voltage, resistance, and current. In 1828 the German physicist George Simon Ohm showed by experiment that the current in a conductor is equal to the difference of potential or voltage between any two points divided by the resistance between them. This may be written as $I = V / R$ where V is the voltage difference in volts, R is the resistance in ohms, and I is the current in amperes.

On-Peak – Those periods of time at which power is being delivered near the utility's maximum demand. Rocky Mountain Power's defined on-peak periods are:

October through April inclusive – 7:00 a.m. – 11:00 p.m., Monday through Friday except holidays

May through September inclusive – 7:00 a.m. – 9:00 p.m., Monday through Friday except holidays

Outage – Interruption in the delivery of electric service.

Overhead Service – Electric service supplied to the customer from the power company utilizing overhead conductors.

Overload – Operation of electrical equipment above its normal full-load rating, or of a conductor above its rated ampacity, that when it persists for a sufficient length of time, would cause damage to the equipment or conductor.

P

Partial Power – The loss of one or two energized conductors of a three-phase service or one energized conductor of a single phase service.

Peak Demand – The maximum demand imposed on a power system or component thereof.

Peak Load – See peak demand.

Phase – One wire or conductor of a two, three or four wire system.

Point of Delivery – The point where the electrical utility's circuit connects to the customer's system.

Potential – See voltage.

Power – The rate at which work is performed or that electric energy is converted to other forms of energy. Electric power is the product of voltage and current ($P = VI$) and is commonly measured in watts, kilowatts, or megawatts.

Power Grid – A network of power lines, transformers, generators, and associated equipment employed in distributing electricity over a geographical area. Rocky Mountain Power is part of a power grid that encompasses the western United States and parts of Canada and Mexico.

Power Plant – A complex of structures, machinery, and associated equipment for generating electric energy from another source of energy, such as nuclear reactions, coal, gas, wind, water, or sun.

PPE (Personal Protective Equipment) – Refers to protective clothing, helmets, goggles, or other garment designed to protect the wearer's body from injury by blunt impacts, electrical hazards, heat, chemicals, and infection, for job-related occupational safety and health purposes.

Primary – The high voltage part of the distribution system. In Rocky Mountain Power service territory the primary distribution power is between 4,160 volts (4.2 kV) and 34,500 volts (34.5 kV) with the majority at 12,500 volts (12.5 kV).

PSC (Public Service Commission) – A utility regulating authority.

PURPA (Public Utility Regulatory Policies Act) – A law passed in 1978 by the United States Congress as part of the National Energy Act, meant to promote greater use of renewable energy. This law created a market for non-utility electric power producers forcing electric utilities to buy power from these producers at the "avoided cost" rate, which was the cost the electric utility would incur were it to generate or purchase from another source. Generally, this is considered to be the fuel costs incurred in the operation of a traditional power plant.

Q

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R

Recloser – A switch that will automatically open a circuit if it detects electrical problems such as a fault, and then attempts to close the circuit at timed intervals. If the electrical problem falls to correct itself, the switch will remain open after a certain number of attempts to close the circuit.

RMP (Rocky Mountain Power) – An investor owned electric utility which serves customers in Utah, Idaho and Wyoming. A division of PacifiCorp which is a subsidiary of Mid-American Energy Holding Company (MEHC).

ROW (Right of Way) – Right-of-way is an interest in property either owned in fee or as an easement transferred through grant, prescription, dedication, or the right of Eminent Domain. Public utilities (regulated by the Public Utility Commission) have the right by State Statue to use a portion of the road right-of-way for installation and maintenance of their facilities.

S

SCADA (Supervisory Control & Data Acquisition) System – Rocky Mountain Power's SCADA system is a complex computer system that:

- Monitors frequency, generation, power, current, voltage and controlling device status on the utility's transmission and distribution systems.

- Controls (either automatically or via manual control) breakers, reclosers, and other controlling devices to maintain the integrity of the transmission and distribution systems.

Secondary – The low voltage part of the distribution system. In Rocky Mountain Power service territory the secondary distribution power is between 120 volts and 480 volts.

Sectionalize – To isolate a problem and restore as many customers to service as possible.

Single-phase – One phase of a three phase system. Single phase power is typically used to serve customers whose load characteristics are primarily lighting, heating, and small motors (typically residential and small commercial customers).

Single Phase Service – An overhead or underground service consisting of two "hot" wires and a neutral.

Smart Grid – A term used for an ever widening palette of utility applications that enhance and automate the monitoring and control of electrical use at the consumer level.

Structures – The poles or towers used to support transmission and distribution conductors.

Substation – An assembly of equipment in an electric power system through which electrical energy is passed for transmission, distribution, interconnection, voltage transformation, or switching. Substations can range in size from one acre to several hundred acres. A typical distribution substation whose primary purpose is to convert power from 138 kV to 12.5 kV is one acre inside the fence or wall. However, a main grid substation whose primary purpose is to convert power from 500 kV to 345 kV and connect to several 345 kV transmission lines may be 200 acres.

Sub-transmission – Lines that are typically energized between the voltages of 46,000 volts (46 kV) and 161,000 volts (161 kV). Sub-transmission lines are used to transfer power from transmission substations to regional and distribution substations.

Switch – A device that open or closes a circuit.

Switchyard – A substation that does not include voltage transformation.

T

Three - phase – The most common method used by electrical utilities worldwide to distribute power. In a three-phase system, three circuit conductors carry three alternating currents which reach their instantaneous peak values at different times. Three phase power is typically used to serve customers whose load characteristics include large motors, (typically industrial customers and large commercial customers).

Three Phase Service – An overhead or underground service usually consisting of three "hot" wires and a neutral.

Transformer – A transformer is an electrical device that takes electricity of one voltage and transforms it into another voltage.

Transmission System – An interconnected group of high voltage electric lines and associated equipment for transfer of electric energy between points of supply and points at which it is delivered to other utilities or transformed one or more times to lower voltages for delivery to consumers. Typically, at Rocky Mountain Power, transmission lines are energized at 230,000 volts (230 kV) and above.

Trip – A sudden shutdown of a piece of equipment or line. A trip is generally caused when a protective device (breaker, recloser) operates to isolate a portion of the system in order to protect the equipment or line.

U

Undergrounding – The act of converting the overhead transmission or distribution system to underground.

Underground Service – Electric service supplied to the customer from the power company utilizing underground cable.

V

Volt – A unit of measurement for voltage. The voltage difference across a one ohm resistance carrying a current of one ampere.

Voltage – The driving force, or "electrical pressure," that causes current to flow through a closed circuit. The force can be compared to the pressure of water in a pipe. Voltage is measured in volts (V) or kilovolts (kV).

Voltage Drop – Voltage drop is defined as the amount of voltage loss that occurs through all or part of a circuit due to the impedance of the lines and equipment on the circuit.

W

Watt – A unit of measurement of power. One watt equals the power dissipated by a current of 1 ampere flowing across a resistance of 1 ohm

X

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Y

\- - -

Z

\- - -

Appendix B: Facility diagrams and requirements

ELECTRICITY 101

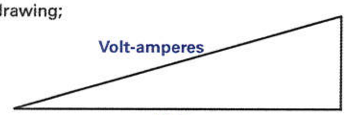
V = IR or Voltage (volts) = Current (amperes) X Resistance (ohms)

Voltage is a measure of electrical "pressure" (similar to water pressure in a hose).

Current is the movement of electrons through a conductor, (similar to water flow in a hose) measured in amperes or amps.

P = IV or Power (volt-amperes) = Current (amperes) X Voltage (volts)

Power (volt-amperes) has two components: Watts and Vars, as shown in the follow drawing;



Typically vars are not considered except with large customers and utility engineers. The remainder of this document will ignore vars and assume power only has one component, watts.

- 1,000 watts = 1 kilowatt = 1 kW
- 1,000,000 watts = 1 megawatt = 1 MW

The maximum amount of power a transmission line can carry is referred to as **capacity.**

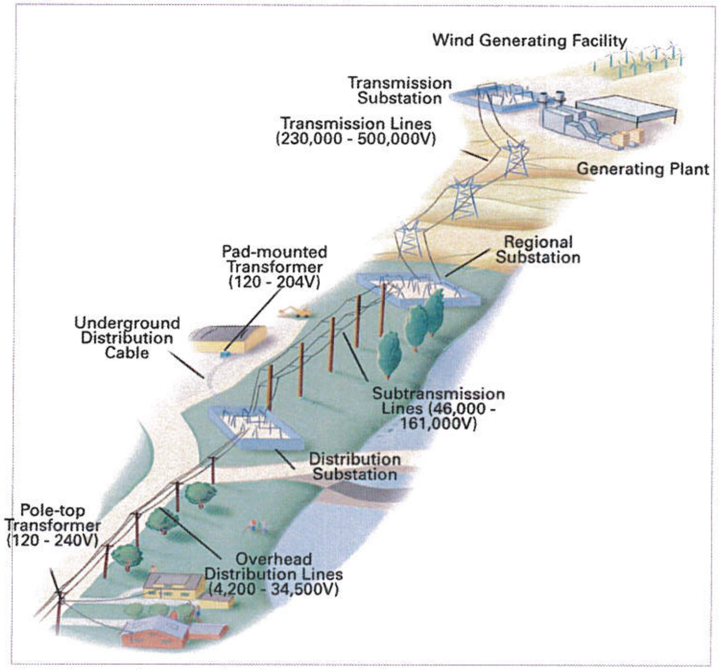
Energy represents the amount of power used or transmitted over a given period of time (energy = power x time). The basic unit of measure for electrical energy is the watt-hour.

- 1,000 watt-hours = 1 kilowatt-hour = 1 kWh
- 1,000,000 watt-hours = 1 megawatt-hour = 1 MWh

An electrical system is designed to accommodate Capacity (Demand (MW)) and Energy (MWh). Since capacity can be accommodated then Energy (MWh) will also be accommodated.

Load is power being used by customers. Instantaneous load represents capacity used. If customer load is greater than the electrical system capacity then load must be reduced or one or more components of the electrical system will fail.

Power System



Electricity moves from generation plants to transmission substations and distribution substation before being delivered to our homes

TRANSMISSION

Clearance

Minimum vertical and horizontal clearance is established by the National Electrical Safety Code (NESC). When a utility designs a transmission or distribution line they consider the maximum sag of the conductor (vertical component) and the maximum deflection of the conductor (horizontal component).

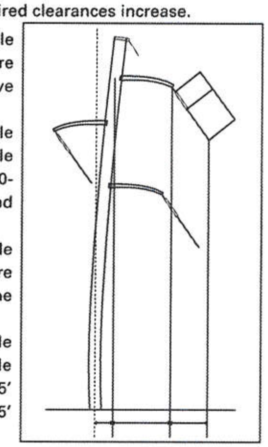
Vertical Clearance

Items that influence conductor sag include: (line loading, conductor capacity, line tension, ambient temperature, conductor weight, and conductor composition). The clearance required by code considers what the conductor crosses (roads, railroads, trails, water, structures, etc.) and the operating voltage of the line.

Clearance requirements are dependent on transmission line voltage.

As voltages increase, required clearances increase.

- Typical 345 kV single circuit H-frame structure will be 90-120' above the ground.
- Typical 345 kV double circuit single pole structure will be 130-170' above the ground (200' in some cases).
- Typical 138 kV single circuit H-frame structure will be 60-90' above the ground.
- Typical 138 kV double circuit single pole structure will be 70-95' above the ground (115' in some cases).

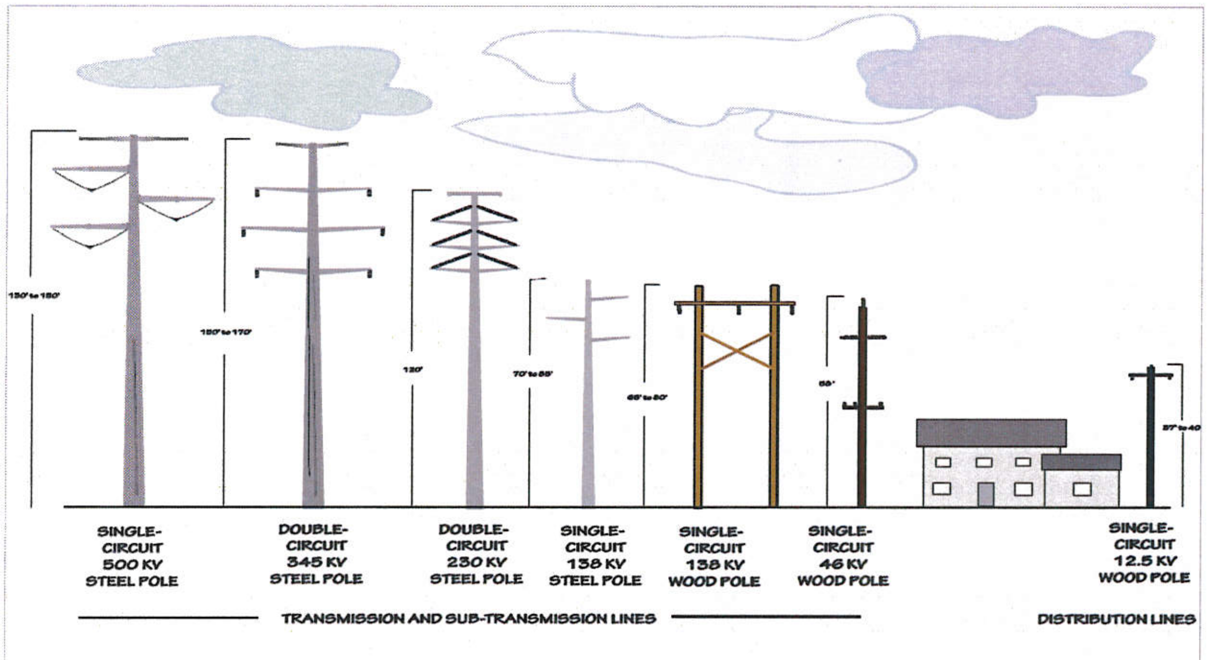


Horizontal Clearance and Right of Way

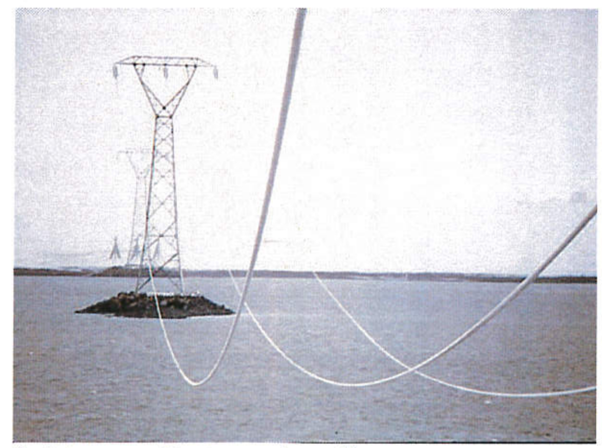
Horizontal clearance, like vertical clearance, increases as the voltage increases. As illustrated in the adjacent drawing, items that influence deflection include: pole structure design, pole material, wire size and span length, and maximum wind speed where the line is constructed. The horizontal clearance required by code considers what the conductor is passing by: tress, signs, buildings, etc.

Right of way width is determined by combining the maximum conductor deflection, the no wind conductor position (pole width and insulator length, and the minimum clearance required by code.

Single pole structures typically require less ROW width than lattice or multiple pole structures. Right of way can be shared with other infrastructure such as roads and pipelines.



Transmission and distribution line poles

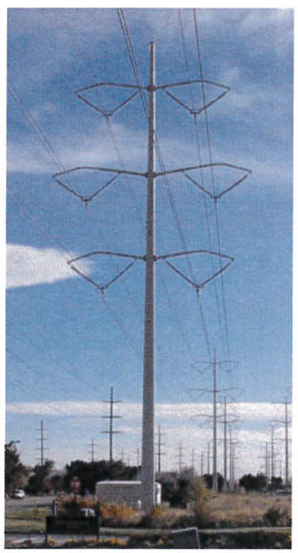


Conductor sag caused by extreme weather conditions

MAIN GRID

Main Grid lines typically operate at 230 kV and 345 kV

Energy is transmitted via high voltage lines (230kV, 345kV) from the power plants to major substations.



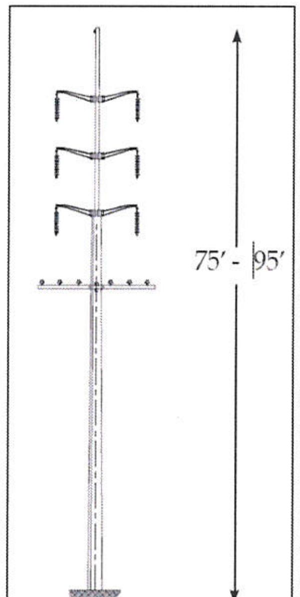
Left: Double circuit 345 kV line in a power line corridor with other lines. Monopole structure is the current typical design. Right: Single circuit 345 kV line in a power corridor with other lines.

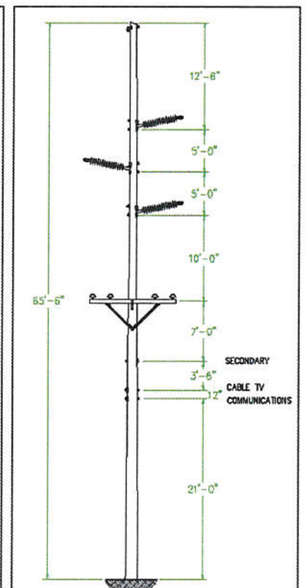
Sub-transmission Lines (Local Transmission)

46 kV and 138 kV – Used to transmit energy from main grid substations to regional and local substations.

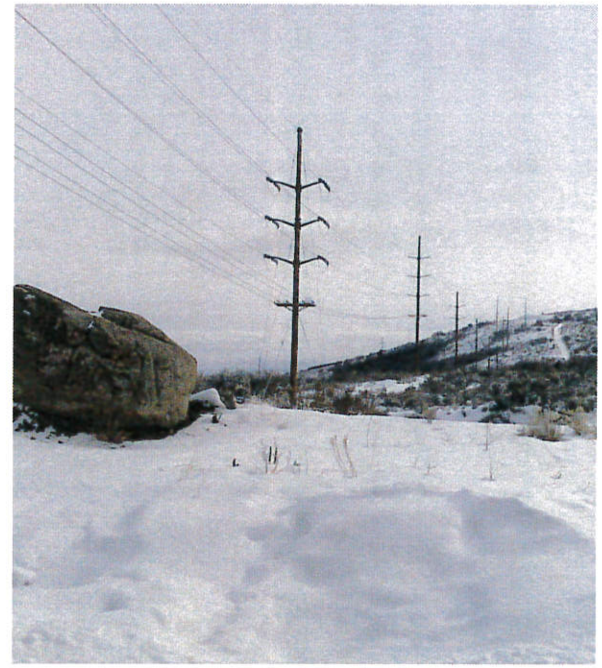
Double Circuit and Single Circuit 138 kV

Right-of-way is typically around 60 ft. with distances between structures around 300 ft.





138 kV line with 12.5 kV distribution underbuild. Monopole structures.



Double circuit 138 kV line in Summit county

Double Circuit and Single Circuit 46 kV

46 kV lines are similar to 138 kV lines. Older 46 kV lines are usually shorter, however, the current practice is to replace failing 46 kV structures with structures designed to accommodate future 138 kV conversion.

Distribution

4.16 kV to 12.47 kV

Typical distribution pole

SUBSTATIONS

A substation is used to transform or change voltage levels and contain equipment to protect power lines and substation equipment. Substations can contain the following: transformers, switches, capacitors, reactors, and circuit breakers. Generally power flows from a high voltage substation to a regional substation; then to a distribution substation.

Main Grid Transmission

Major substations (main grid): Convert power from high voltage transmission lines (230 kV, 345 kV) to sub-transmission voltages (46 kV, 138 kV)

Midvalley Substation. 345 kV to 138 kV

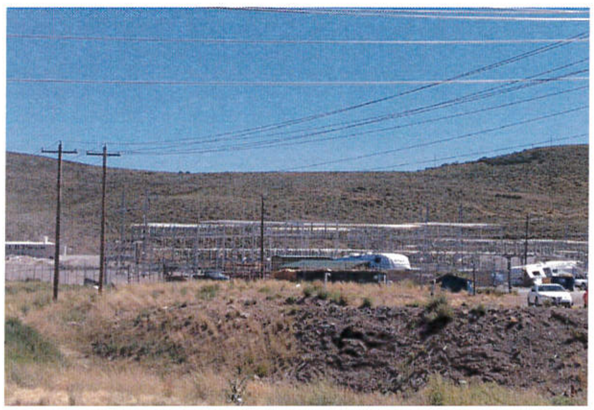
Main Grid collocated with Sub-Transmission and Distribution

Major substations (main grid): Convert power from high voltage transmission lines (230 kV, 345 kV) to sub-transmission voltages (46 kV, 138 kV) and distribution voltages (12.5 kV, 25 kV).

Above: Camp Williams Substation. 345 kV to 138 kV, 138 kV to 12.5 kV. Below: 90th South Substation 345 kV to 138 kV, 138 kV to 46 kV, 138 kV to 12.5 kV.

Regional Transmission collocated with Distribution

Regional substations (sub-transmission): Convert power from sub-transmission lines (46 kV, 138 kV) to other sub-transmission voltages and distribution voltages (12.5 kV, 25 kV)



Above: Southeast Substation Regional with Distribution. 138 kV to 12.5 kV Below: Silver Creek Substation 138 kV to 46 kV, 138 kV to 12.5 kV.

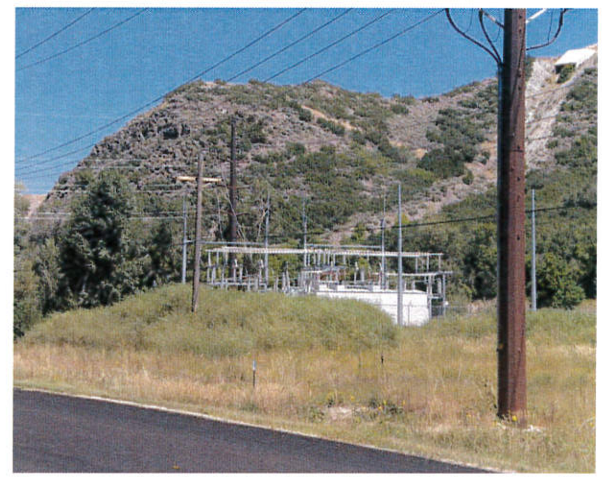
Distribution

Local substations convert power from sub-transmission lines (46 kV, 138 kV) to distribution voltages (12.5 kV, 25 kV).

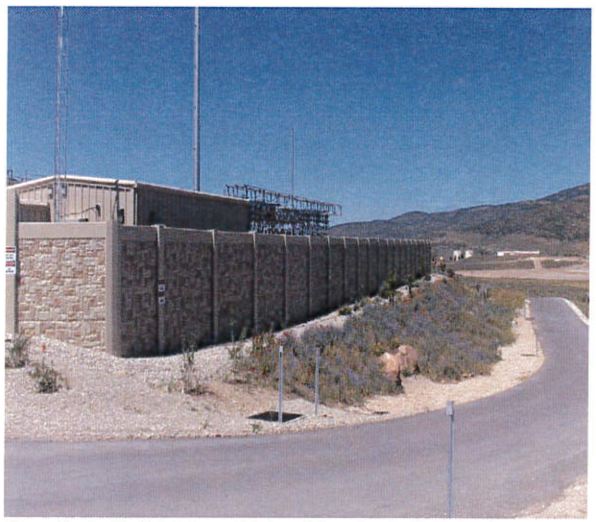
Ultimately serves up to 80 MW of load or:

- 1-3 square miles for industrial load
- 2-5 square miles for commercial load
- 6-8 square miles for typical urban residential load (8000 homes)

Above: Meadowbrook Substation aerial view. Below: Meadowbrook Substation street view. 138 kV to 12.5 kV.

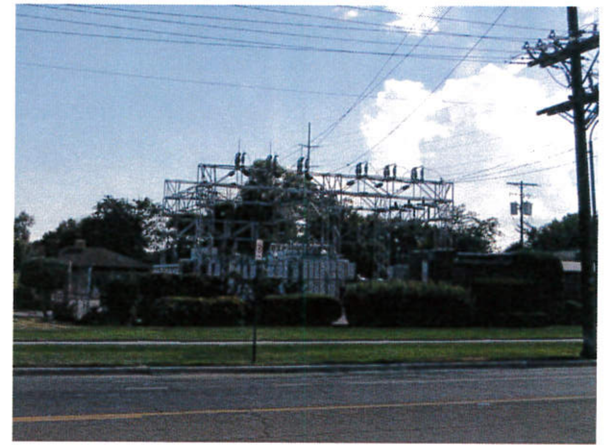


Above: Hammer Substation. 138 kV to 12.5 kV Below: Jordanelle Substation. 138 kV to 12.5 kV.



Above: Snyderville Substation aerial view. Below: Snyderville Substation street view. 138 kV to 12.5 kV.

Above: Capitol Substation 46kV to 12.5 kV. Below: East Millcreek Substation street view. 46 kV to 12.5 kV.



Above: Rose Park Substation 46 kV to 12.5 kV. Below: Park City Substation. 46 kV to 12.5 kV.

Appendix C: Growth assumptions

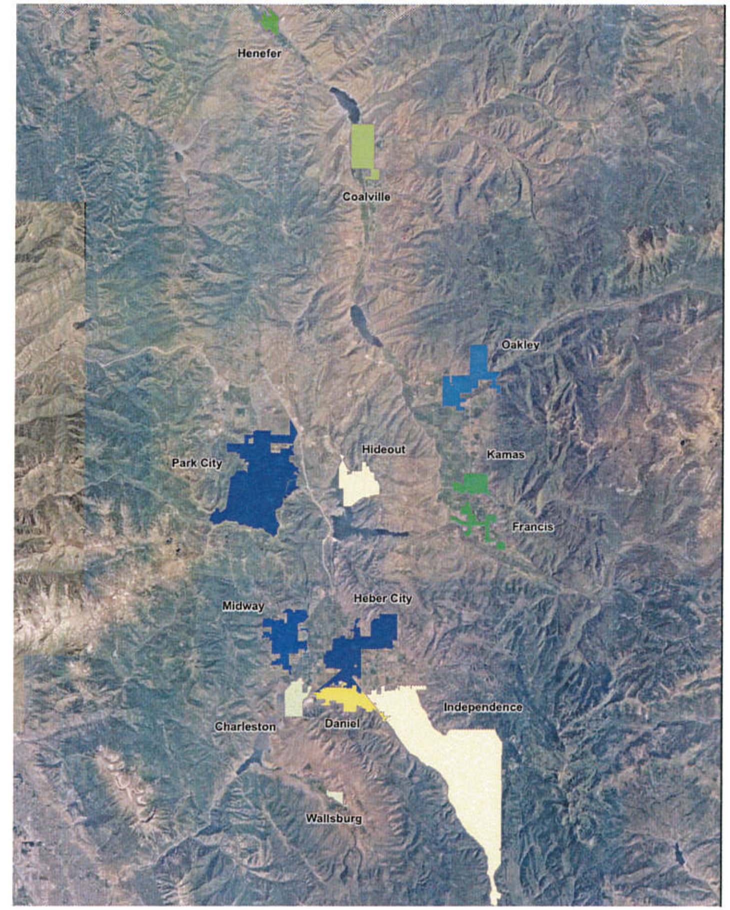
In order to establish a planning horizon year the task force was provided population projection by municipality at 2020 and 2030. The source data was provided by Mountainland Association of Governments.

POPULATION GROWTH LEGEND

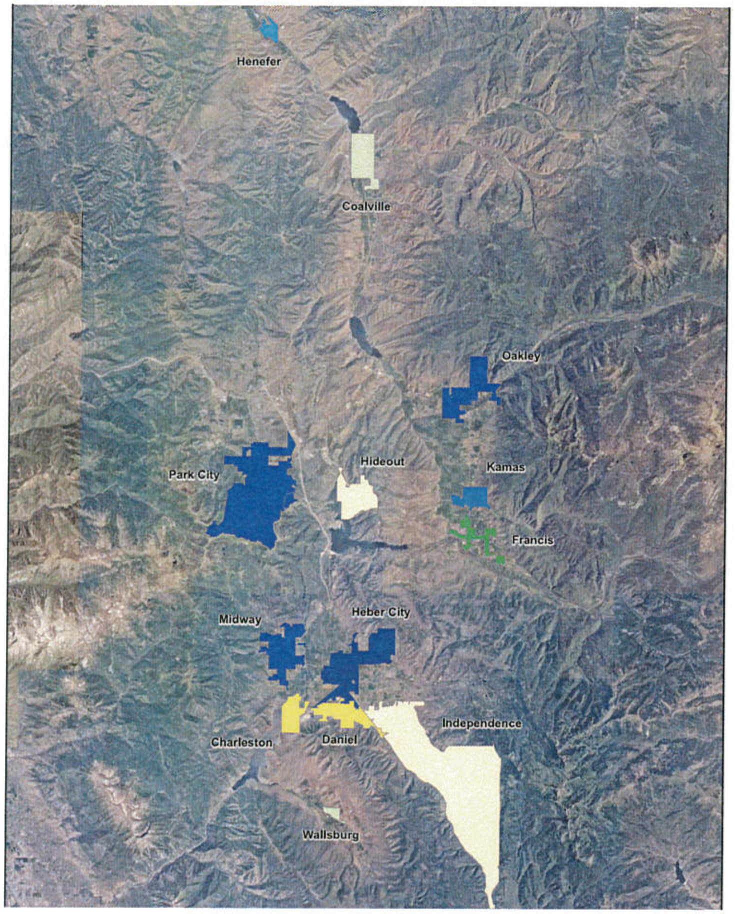
New Population by Municipality

- 0
- 1-250
- 251-400
- 401-600
- 601-800
- 801-1000
- 1001-1200
- 1201-2000
- 2001-3000
- 3001-4000
- 4001-5000
- 5001-8000

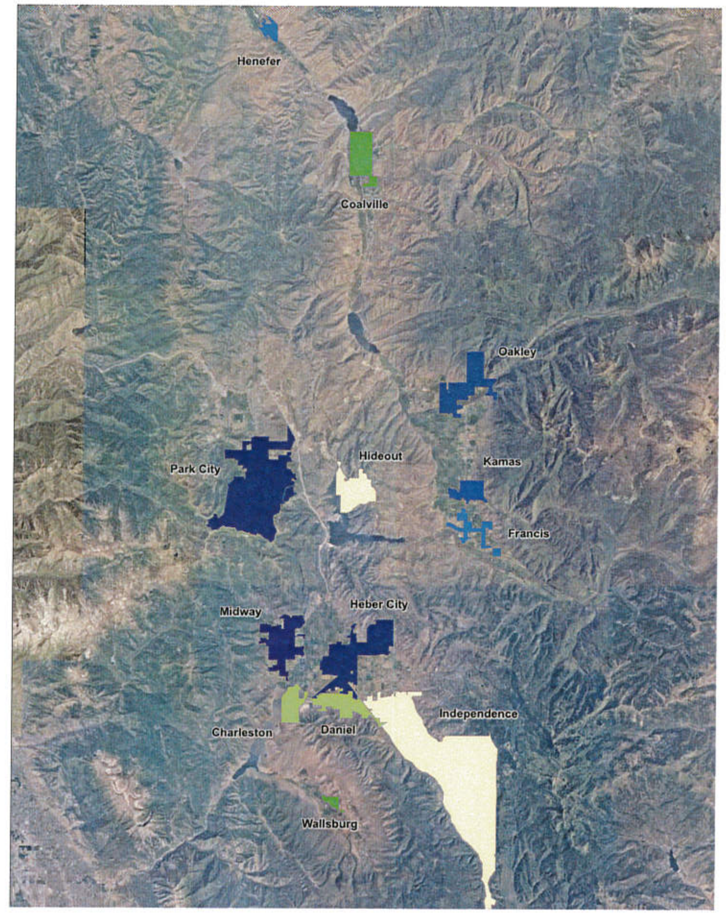
POPULATION GROWTH 2010-2020



POPULATION GROWTH 2020-2030



TOTAL POPULATION R 2010-2030



Appendix D: Scorecard

A scorecard was developed as a tool for local jurisdictions and Rocky Mountain Power to use in evaluating alternative locations for new facilities. It provides a means to compare specific locations in terms of how well each site meets the siting criteria established by the task force. It is not intended to replace careful consideration and debate about the relative benefits or impacts of specific locations. Rather, it is a tool to be used in combination with other information to facilitate comparative evaluation.

INSTRUCTIONS FOR USE

The scorecard is separated into two sections, one for substations and one for transmission lines. To score the potential site, ask yourself how well the location meets each criterion and enter an x in the corresponding line. Then multiply the score for each criterion by the corresponding criterion weight to produce a total score for that criterion. The weight assigned to each criterion corresponds to the priority it was given by the task force and shown in the Siting Criteria section of this document. Finally, sum the points in the last column to obtain a total score for the potential infrastructure location.

The scorecard spreadsheet can also be found at:

www.rockymountainpower.net/planning

Summit Wasatch Electrical Plan SAMPLE Scorecard

SUBSTATIONS					
Location Criteria	SCORE how well the criterion is met	Enter X where appropriate	Criterion WEIGHT	Criterion TOTAL = score X weight
2A Maximize use of existing facilities and adjacent properties before building new facilities	Substantially (2 points)			
	Partially (1 point)	x	3	3
	Poorly (0 points)			
2B Use topography to reduce visual impacts	Substantially (2 points)	x		6
	Partially (1 point)		3	
	Poorly (0 points)			
2C Protect significant viewsheds	Substantially (2 points)			
	Partially (1 point)	x	3	3
	Poorly (0 points)			
2D Build aesthetically pleasing facilities	Substantially (2 points)	x		6
	Partially (1 point)		3	
	Poorly (0 points)			
2E Avoid dedicated open space and parks	Substantially (2 points)			
	Partially (1 point)		2	
	Poorly (0 points)	x		0
2F Use areas with high development potential	Substantially (2 points)			
	Partially (1 point)	x	2	2
	Poorly (0 points)			
2G Avoid residential neighborhoods	Substantially (2 points)	x		4
	Partially (1 point)		2	
	Poorly (0 points)			
2H Avoid adverse aesthetic impacts on development	Substantially (2 points)			
	Partially (1 point)	x	2	2
	Poorly (0 points)			
2I Avoid discrimination based on income or ethnicity	Substantially (2 points)	x		2
	Partially (1 point)		1	
	Poorly (0 points)			
2J Utilize land adjacent to other infrastructure	Substantially (2 points)			
	Partially (1 point)	x	1	1
	Poorly (0 points)			
2K Protect critical habitat, wetlands, rivers and stream corridors	Substantially (2 points)			
	Partially (1 point)		1	
	Poorly (0 points)	x		0
	SUBSTATION TOTAL			29

Summit Wasatch Electrical Plan Scorecard

SUBSTATIONS				
Location Criteria	SCORE how well the criterion is met	Enter X where appropriate	Criterion WEIGHT	Criterion TOTAL = score X weight
2A Maximize use of existing facilities and adjacent properties before building new facilities	Substantially (2 points)		3	
	Partially (1 point)			
	Poorly (0 points)			
2B Use topography to reduce visual impacts	Substantially (2 points)		3	
	Partially (1 point)			
	Poorly (0 points)			
2C Protect significant viewsheds	Substantially (2 points)		3	
	Partially (1 point)			
	Poorly (0 points)			
2D Build aesthetically pleasing facilities	Substantially (2 points)		3	
	Partially (1 point)			
	Poorly (0 points)			
2E Avoid dedicated open space and parks	Substantially (2 points)		2	
	Partially (1 point)			
	Poorly (0 points)			
2F Use areas with high development potential	Substantially (2 points)		2	
	Partially (1 point)			
	Poorly (0 points)			
2G Avoid residential neighborhoods	Substantially (2 points)		2	
	Partially (1 point)			
	Poorly (0 points)			
2H Avoid adverse aesthetic impacts on development	Substantially (2 points)		2	
	Partially (1 point)			
	Poorly (0 points)			
2I Avoid discrimination based on income or ethnicity	Substantially (2 points)		1	
	Partially (1 point)			
	Poorly (0 points)			
2J Utilize land adjacent to other infrastructure	Substantially (2 points)		1	
	Partially (1 point)			
	Poorly (0 points)			
2K Protect critical habitat, wetlands, rivers and stream corridors	Substantially (2 points)		1	
	Partially (1 point)			
	Poorly (0 points)			
	SUBSTATION TOTAL			0

Summit Wasatch Electrical Plan Scorecard

TRANSMISSION LINES				
Location Criteria	SCORE how well the criterion is met	Enter X where appropriate	Criterion WEIGHT	Criterion TOTAL = score X weight
3A Protect significant viewsheds	Substantially (2 points)		3	
	Partially (1 point)			
	Poorly (0 points)			
3B Upgrade existing facilities before building new facilities	Substantially (2 points)		3	
	Partially (1 point)			
	Poorly (0 points)			
3C Avoid dedicated open space and parks	Substantially (2 points)		3	
	Partially (1 point)			
	Poorly (0 points)			
3D Build aesthetically pleasing facilities	Substantially (2 points)		3	
	Partially (1 point)			
	Poorly (0 points)			
3E Share rights-of-way with utilities, trails, railroads, canals, roads, etc.	Substantially (2 points)		2	
	Partially (1 point)			
	Poorly (0 points)			
3F Avoid residential neighborhoods	Substantially (2 points)		2	
	Partially (1 point)			
	Poorly (0 points)			
3G Use areas with high development potential	Substantially (2 points)		2	
	Partially (1 point)			
	Poorly (0 points)			
3H Avoid discrimination based on income or ethnicity	Substantially (2 points)		2	
	Partially (1 point)			
	Poorly (0 points)			
3I Avoid adverse aesthetic impacts on development	Substantially (2 points)		2	
	Partially (1 point)			
	Poorly (0 points)			
3J Protect critical habitat, river and stream corridors	Substantially (2 points)		1	
	Partially (1 point)			
	Poorly (0 points)			
3K Avoid existing trails	Substantially (2 points)		1	
	Partially (1 point)			
	Poorly (0 points)			
3L Select sites that allow operations and maintenance access	Substantially (2 points)		1	
	Partially (1 point)			
	Poorly (0 points)			
3M Utilize large format (big-box) retail	Substantially (2 points)		1	
	Partially (1 point)			
	Poorly (0 points)			
	TRANSMISSION TOTAL			0