BONNEVILLE POWER ADMINISTRATION

I-5 Corridor Reinforcement Project
Draft Environmental Impact Statement

Appendices A, B, D–F

November 2012

DOE/EIS-0436

Cooperating agencies: U.S. Army Corps of Engineers; Oregon Energy Facility Siting Council; Washington Energy Facility Site Evaluation Council; Cowlitz and Clark Counties, Washington

I-5 Corridor Reinforcement Project

Draft Environmental Impact Statement

Appendix A, B, D-F

Bonneville Power Administration

Cooperating Agencies:
U.S. Army Corps of Engineers, Oregon Energy Facility Siting Council,
Washington Energy Facility Site Evaluation Council, Cowlitz and Clark Counties, Washington

November 2012

Page intentionally left blank

Table of Contents

Volume 1: Chapters 1-13

Summary

Chapter 1 Purpose of and Need for Action

Chapter 2 Facility Siting, Route Segments, and Action Alternatives

Chapter 3 Project Components and Construction, Operation, and Maintenance Activities

Chapter 4 Proposed Action and Alternatives

Chapter 5 Land

Chapter 6 Recreation

Chapter 7 Visual Resources

Chapter 8 Electric and Magnetic Fields

Chapter 9 Noise

Chapter 10 Health and Safety

Chapter 11 Socioeconomics

Chapter 12 Transportation

Chapter 13 Cultural Resources

Volume 2: Chapters 14-33

Chapter 14 Geology and Soils

Chapter 15 Water

Chapter 16 Wetlands

Chapter 17 Vegetation

Chapter 18 Wildlife

Chapter 19 Fish

Chapter 20 Climate

Chapter 21 Air Quality

Chapter 22 Greenhouse Gases

Chapter 23 Intentional Destructive Acts

Chapter 24 Short-Term Uses versus Long-Term Productivity

Chapter 25 Irreversible or Irretrievable Commitment of Resources

Chapter 26 Cumulative Impacts

Chapter 27 Consultation, Review, and Permit Requirements

Chapter 28 Consistency with State Substantive Standards

Chapter 29 References

Chapter 30 List of Preparers

Chapter 31 Agencies, Organizations, and Persons Receiving this EIS

Chapter 32 Glossary and Acronyms

Chapter 33 Index

Appendices

Appendix A Washington Department of Natural Resources Lands Analysis

Appendix B Right-of-Way Tower Configuration Tables and Figures

Appendix C I-5 Corridor Reinforcement Project Photomap Book

Appendix D Underground Route Study

Appendix E Visual Assessment

Appendix F Electrical Effects

Appendix G Research on Extremely Low Frequency Electric and Magnetic Fields and Health

Appendix H Environmental Justice Tables

Appendix I Cultural Resource Sensitivity Scores

Appendix J Geologic Assessment – Geologic Hazards, Soil and Slope Gradient, Geology, Shallow Bedrock, Shallow Groundwater

Appendix K Fish Habitat and Fish Population Impacts

Appendix L Wetland Modeling

Appendix M Noxious Weed List

Appendix N NEPA Disclosure Forms

Appendix A

Washington Department of Natural Resources Lands Analysis

Appendix A Washington Department of Natural Resources Lands Analysis

The Washington State Energy Facility Site Evaluation Council (EFSEC) and the Oregon Department of Energy (ODOE) have provided Bonneville Power Administration (BPA) with state substantive standards that they believe are potentially applicable and should be addressed in this environmental impact statement (EIS). Inclusion of these standards in the EIS (Chapter 28, Consistency with State Substantive Standards) helps BPA and state agencies in their review of the project. By identifying and considering these standards as early as possible, the project can be designed to be consistent or compatible with them to the maximum extent practicable.

BPA recognizes that, when a state owns property that BPA proposes to cross with any facilities, the state agency managing that property may need to comply with certain state or local laws or regulations before it can agree to allow BPA use of their property. As discussed in Chapter 5, Land, Washington Department of Natural Resources (WDNR) is a state agency that manages property crossed by the action alternatives. To assist WDNR in its compliance efforts, BPA has included this Appendix A to provide additional information, where available, for these lands.

BPA and WDNR have signed a Mitigation Agreement that sets the foundation for future agreements specific to future projects or applicable to all land use actions between BPA and WDNR (May 2010). Section 4 of the agreement committed BPA and WDNR to enter into a Statewide Rights-of-Way Memorandum of Agreement (Statewide MOA) that covers all WDNR managed state lands in the state of Washington. This Statewide MOA covers specific issues related to all WDNR lands that are encumbered with BPA easements. Some of the information included in this appendix reflects agreements made in the MOA. The Statewide MOA addresses BPA transmission line operations and maintenance compatibility with trust land management and was signed by BPA and WDNR in March 2012. The Statewide MOA is formally titled Memorandum of Agreement between Washington State Department of Natural Resources and the Bonneville Power Administration, Department of Energy for Managing Impacts to State Lands from BPA Transmission Line and Access Road Easements. The following elements are addressed in the MOA:

- Integration of state and federal requirements
- Danger trees
- Vegetation management
- Noxious Weed Control and Management
- Access road management, maintenance, repair, and cost sharing
- Environmental and Resource Protection
- Dispute resolution
- Communications/notification
- Liability

- Situations where additional right-of-way and/or mitigation is needed for transmission operations, such as safety zones and vegetation removal for clear safe backlines
- Third party use (authorized and unauthorized)
- Safety

This appendix also reflects an Appraisal Memorandum of Understanding (Appraisal MOU) between BPA and WDNR. The Appraisal MOU was finalized on August 1, 2010 and describes the process BPA would use to appraise WDNR lands crossed by the proposed project.

The following sections of this appendix provide more detailed information on WDNR lands relevant to the I-5 project. Section A.1 describes WDNR land ownership that could be affected by the project; Section A.2 discusses potential impacts to WDNR land; and Section A.3 lists possible measures that could be undertaken before, during, or after project construction to lessen or avoid these potential impacts.

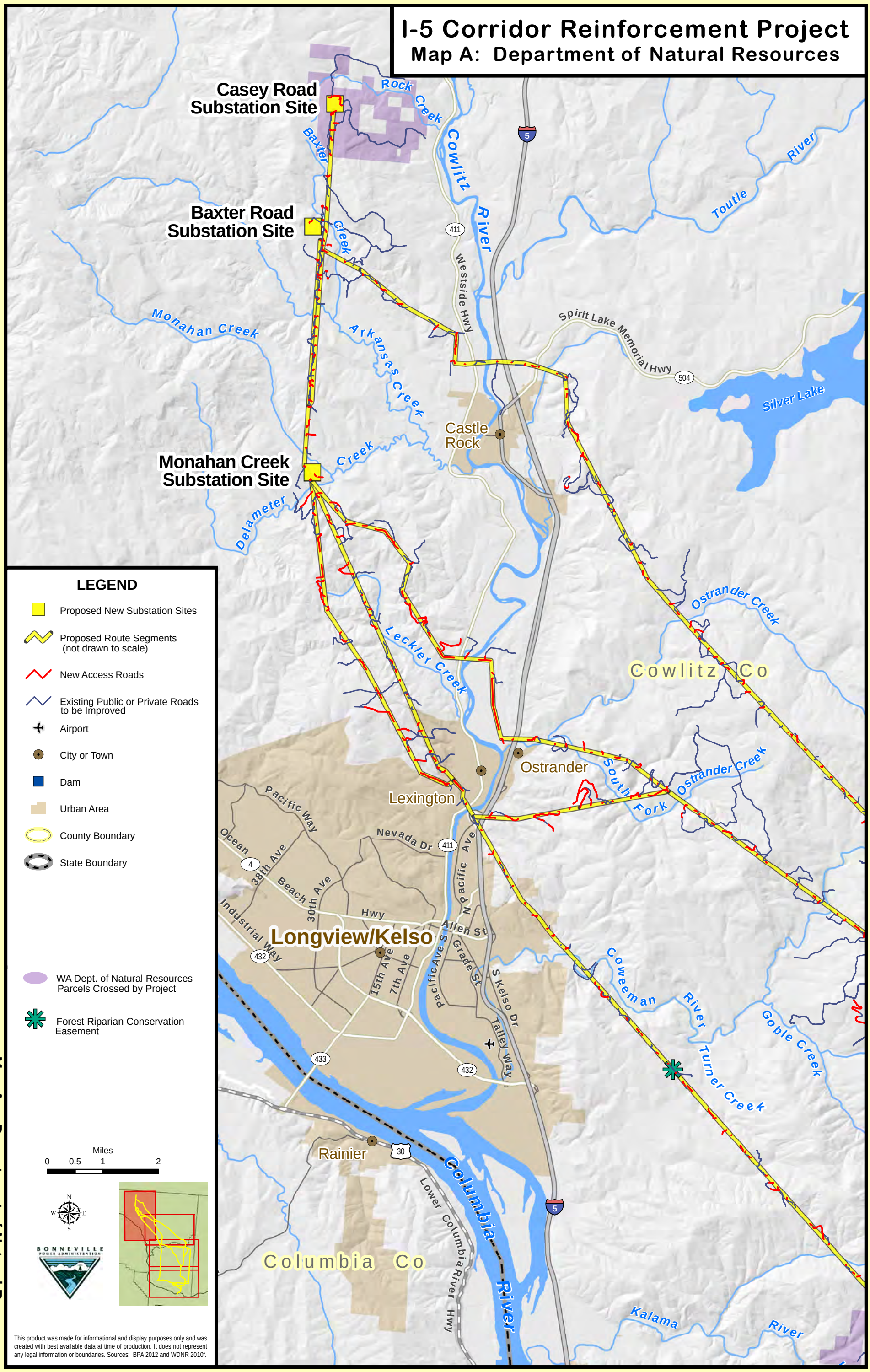
A.1 Washington Department of Natural Resources Land Potentially Affected

WDNR manages land in the project area, including land that would be crossed by the action alternatives (see Maps A through D and Table A-1). WDNR manages land for many purposes, including protection of state and federal threatened and endangered species, revenue for school construction, revenue for other state facilities, and environmental protection.

Table A-1 WDNR Parcels Potentially Crossed by Alternatives or Options in the Project Area[1]

WDNR Parcel Number	Alternative, Option, or Substation	Route Segment or Access Road
111253	Central	10
92	Central	10
11578	Central	12
11580	Central	12
13438	Central	12
11577	Central	12
11576	Central	12
15529	Crossover	14
11609	Central and Crossover	15
15253	Central and Crossover	15
11611	Central and Crossover	15
110022	Central and Crossover	18
11616	Central and Crossover	18
11649	Central and Crossover	18
11651	Central and Crossover	18
7925	Central and Crossover	18

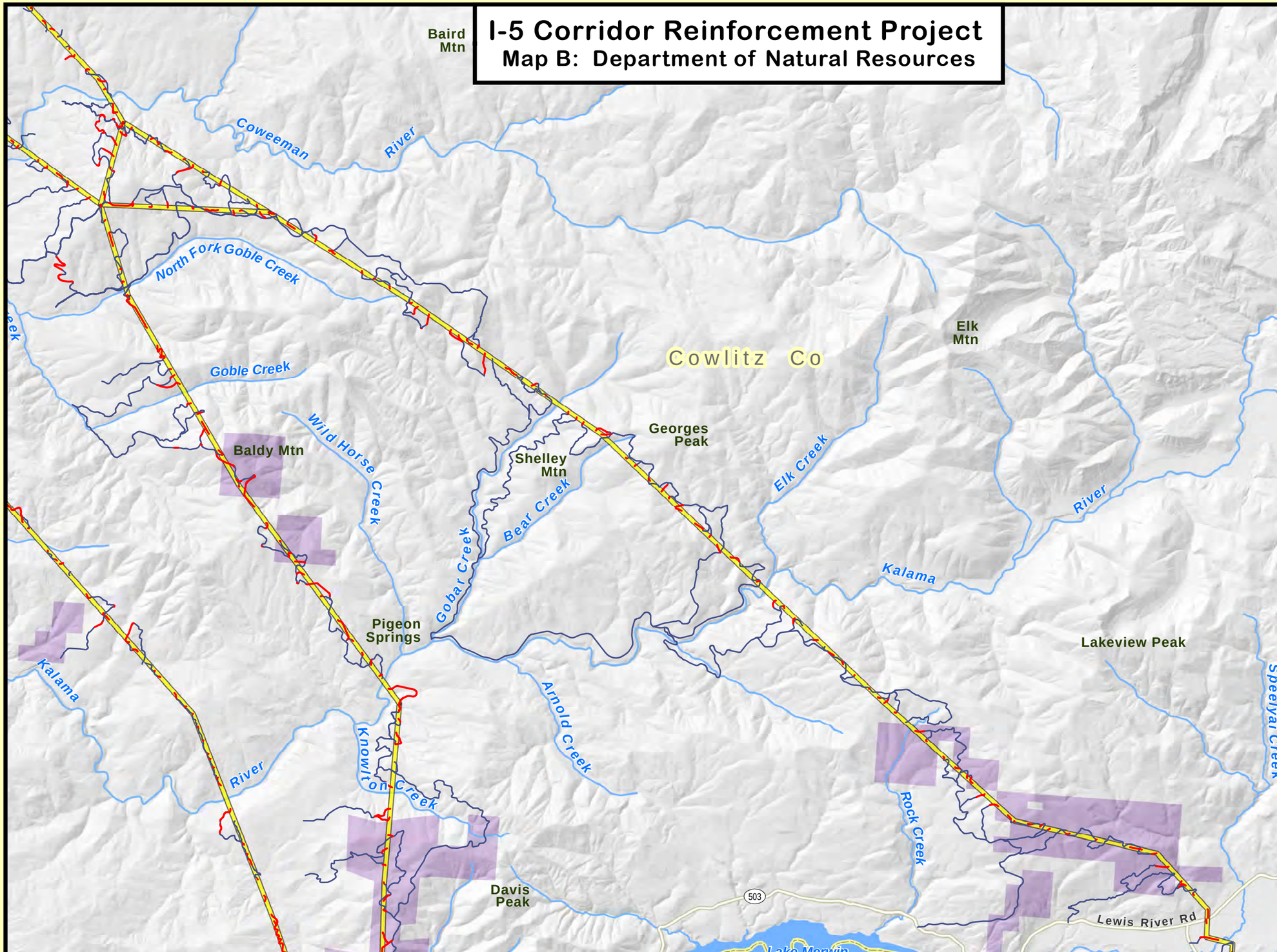
I-5 Corridor Reinforcement Project
Map A: Department of Natural Resources



This product was made for informational and display purposes only and was created with best available data at time of production. It does not represent any legal information or boundaries. Sources: BPA 2012 and WDNR 2010f.

Map A: Department of Natural Resources

I-5 Corridor Reinforcement Project
Map B: Department of Natural Resources

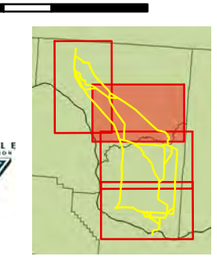


LEGEND

- Proposed New Substation Sites
- Proposed Route Segments (not drawn to scale)
- New Access Roads
- Existing Public or Private Roads to be Improved
- Airport
- City or Town
- Dam
- Urban Area
- County Boundary
- State Boundary
- WA Dept. of Natural Resources Parcels Crossed by Project

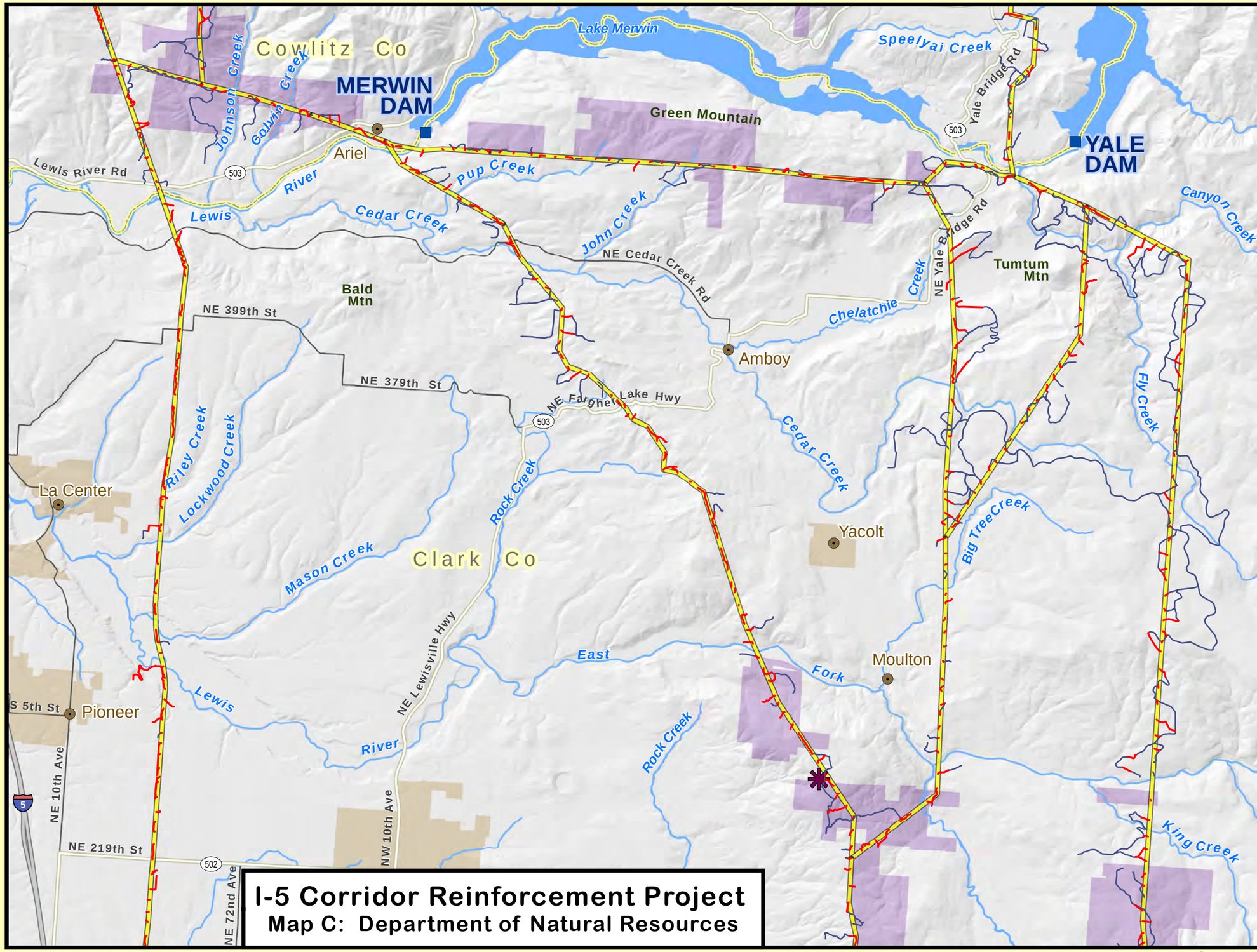
Miles
0 0.5 1 2

N W E S



This product was made for informational and display purposes only and was created with best available data at time of production. It does not represent any legal information or boundaries. Sources: BPA 2012 and WDNR 2010f.

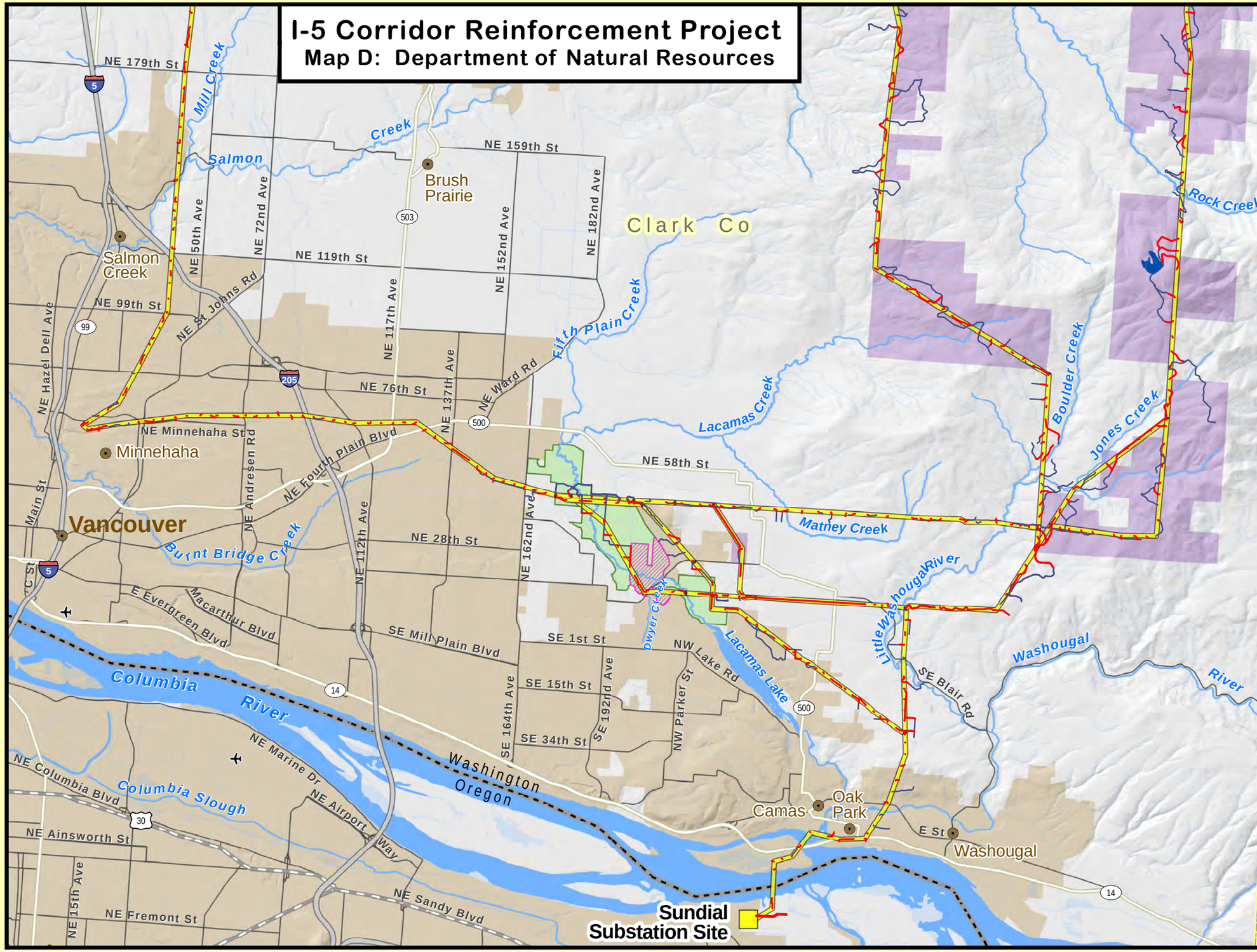
Map B: Department of Natural Resources



I-5 Corridor Reinforcement Project

Map C: Department of Natural Resources

I-5 Corridor Reinforcement Project
Map D: Department of Natural Resources



LEGEND

- Proposed New Substation Sites
- Proposed Route Segments (not drawn to scale)
- New Access Roads
- Existing Public or Private Roads to be Improved
- Airport
- City or Town
- Dam
- Urban Area
- County Boundary
- State Boundary
- WA Dept. of Natural Resources Parcels Crossed by Project
- Herbaceous Bald
- Lands Eligible for inclusion in National Resource Conservation Area (NCRA)
- Lands Eligible for inclusion in Natural Area Preserve (NAP)

Miles
0 0.5 1 2

N W E S

BONNEVILLE POWER ADMINISTRATION

This product was made for informational and display purposes only and was created with best available data at time of production. It does not represent any legal information or boundaries. Sources: BPA 2012 and WDNR 2010f.

WDNR Parcel Number	Alternative, Option, or Substation	Route Segment or Access Road
11648	Central and Crossover	18
11614	Central and Crossover	18
11656	Central and Crossover	18
7927	Central and Crossover	18
7930	Central and Crossover	18
10753	West	25
7911	Central Option 3	30
7905	Central Option 3	30
7923	Central Option 3	30
7910	Central Option 3	30
7921	Central Option 3	30
7913	Central Option 3	30
7918	Central Option 3	30
7915	Central Option 3	30
7879	West Option 2	43
56	Central Option 1, Casey Road Substation	A
11619	East	K
11628	East	K
8109	East	K
15535	East	K
11620	East	K
11627	East	K
11618	East	K
11624	East	K
11626	East	K
15108	Central and Crossover	L
11653	Crossover	N
54	Central, Casey Road Substation	new road to Casey Road Substation
53	Central, Casey Road Substation	new road to Casey Road Substation
7904	Central Option 3	new road on Segment 30
8023	East and Crossover	new road on Segment O
7982	East and Crossover	O
8001	East and Crossover	O
7947	East and Crossover	O
13030	East and Crossover	O

WDNR Parcel Number	Alternative, Option, or Substation	Route Segment or Access Road
111730	East and Crossover	O
7948	East and Crossover	O
7980	East and Crossover	O
8072	East and Crossover	O
7946	East and Crossover	O
8007	East and Crossover	O
7981	East and Crossover	O
7979	East and Crossover	O
8032	East and Crossover	O
8040	Central and East Option 2	P
15587	Central and East Option 2	P
7885	Central and East Option 2	P
7894	Central and East Option 2	P
7884	Central and East Option 2	P
7886	Central and East Option 2	P
8041	Central and East Option 2	P
7963	East and Crossover	Q
7951	East and Crossover	Q
7952	East Option 3	R
7962	East Option 3	R
8719	Central	improve road to Casey Road Substation
11556	Central	improve road to Casey Road Substation
50	Central	improve road to Casey Road Substation
51	Central	improve road to Casey Road Substation
52	Central	improve road to Casey Road Substation
111252	Central	improve road on Segment 10
11595	Central	improve road on Segment 12
11579	Central	improve road on Segment 12
11570	Central	improve road on Segment 12
7928	Central and Crossover	improve road on Segment 18
5	West and Crossover	improve road on Segment 9
58	Central	improve road on Segment A
60	Central	improve road on Segment A
57	Central	improve road on Segment A
15536	East	improve road on Segment K
11636	East	improve road on Segment K
11631	East	improve road on Segment K

WDNR Parcel Number	Alternative, Option, or Substation	Route Segment or Access Road
8073	East and Crossover	improve road on Segment O
13031	East and Crossover	improve road on Segment O
8033	East and Crossover	improve road on Segment O
7999	East and Crossover	improve road on Segment O
8024	East and Crossover	improve road on Segment O
8025	East and Crossover	improve road on Segment O
8042	East and Crossover	improve road on Segment O
8039	Central and East Option 2	improve road on Segment P
7961	East Option 3	improve road on Segment R
7960	East Option 3	improve road on Segment R
8067	Central and East Option 2	V
7919	Central and East Option 2	V

Notes:
1. Includes a 150-foot right-of-way that extends 75 feet on either side of the proposed centerline of the alternatives, a footprint for the substations, tower disturbance areas for towers outside the 150-foot right-of-way that would be removed or rebuilt, and a 30- and 20-foot easement for new and improved access roads outside of the transmission line right-of-way (some easements already exist with WDNR for existing access roads identified for improvement). Note that impacts from clearing beyond the 150-foot right-of-way would occur for danger tree and safety backline (see Chapter 3), but the impact to additional WDNR parcels is unknown at this time.

Source: WDNR 2010c

About 8 to 492 acres of WDNR land would potentially be crossed by the action alternatives (see Table A-2). Permanent impacts on WDNR land would occur from construction of towers, access roads, substations, and clearing of new right-of-way (see Table A-3). Clearing of additional vegetation for danger trees or safety backline outside of new and existing right-of-way could occur but the amount is unknown at this time. Temporary disturbance at pulling and tensioning sites outside of right-of-way and staging areas could occur on WDNR land although the locations are not known at this time.

Table A-2 WDNR Land Ownership in the Project Area[1] (Acres)

Alternatives and Options[2]	WDNR Land
West Alternative	**8**
West Option 1	N/C
West Option 2	+11
West Option 3	+8
Central Alternative	**492**
Central Option 1	+96
Central Option 2	N/C
Central Option 3	-90
East Alternative	**273**
East Option 1	N/C
East Option 2	+48

Alternatives and Options[2]	WDNR Land
East Option 3	+47
Crossover Alternative	**353**
Crossover Option 1	N/C
Crossover Option 2	N/C
Crossover Option 3	N/C

Notes:
N/C – No change from the action alternative.
1. Includes a 150-foot right-of-way that extends 75 feet on either side of the proposed centerline of the alternatives, a footprint for the substations, tower disturbance areas for towers outside the 150-foot right-of-way that would be removed or rebuilt, and a 30- and 20-foot easement for new and improved access roads outside of the transmission line right-of-way (some easements already exist with WDNR for existing access roads identified for improvement). Note that impacts from clearing beyond the 150-foot right-of-way would occur for danger tree and safety backline (see Chapter 3), but the exact amount and type of clearing is unknown at this time.
2. The value for each option represents the net change from the alternative. It was calculated as the acres of WDNR ownership added by the option minus the acres of WDNR ownership in the segments the option replaces.
Source: BLM 2009

Table A-3 Permanent Impacts to WDNR Land in the Project Area (Acres)

Alternatives and Options[1]	Substation[2]	Transmission Line Right-of-Way[3]	Towers[4]	New Access Roads[5]	Improved Access Roads[5]	Total Permanent Impacts
West Alternative	**0**	**7**	**0**	**1**	**<1**	**8**
West Option 1	N/C	N/C	N/C	N/C	N/C	N/C
West Option 2	N/C	+10	N/C	+<1	+1	+11
West Option 3	N/C	+6	N/C	+2	+<1	+8
Central Alternative	**0**	**411**	**0**	**23**	**58**	**492**
Central Option 1	+63	+15	+1	+2	+15	+96
Central Option 2	N/C	N/C	N/C	N/C	N/C	N/C
Central Option 3	N/C	-87	N/C	+1	-4	-90
East Alternative	**0**	**207**	**0**	**18**	**48**	**273**
East Option 1	N/C	N/C	N/C	N/C	N/C	N/C
East Option 2	N/C	+56	N/C	-4	-4	+48
East Option 3	N/C	+44	N/C	+1	+2	+47
Crossover Alternative	**0**	**295**	**0**	**21**	**37**	**353**
Crossover Option 1	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 2	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 3	N/C	N/C	N/C	N/C	N/C	N/C

Notes:
N/C – No change from the action alternative.
1. The value for each option represents the net change from the alternative. It was calculated as acres added by the option minus the acres in the segments the option replaces.
2. Includes towers and access roads within the substation footprint.
3. Includes area of existing and new transmission line right-of-way that would be needed for the project.
4. Includes towers outside of the substation footprint and 150-foot-wide right-of-way needing to be removed or rebuilt.
5. Based on an average 30- and 20-foot easement that would be needed for new or improved access roads. Includes access roads outside of the substation area and 150-foot right-of-way.
Source: BLM 2009

A.2 Resource Impacts

The following discussions address the environmental resources affected by the project to aid WDNR in its statutory and regulatory compliance efforts for its lands. General resource impacts from the project are described in Chapters 5 through 22 of this EIS, including impacts on environmental resources not specifically addressed in this appendix, including on WDNR land. The information below addresses the site-specific impacts on WDNR land, to the extent they have been identified. Once a preferred alternative is selected and focused field surveys are conducted, additional site-specific impacts may be identified.

A.2.1 Land Use

Chapter 5 of the EIS provides an analysis of potential project impacts on land use, including on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land. Existing land uses on WDNR land the project could cross include rural, timber production, agriculture, and open space (which includes both forested and non-forested areas) (see Table A-4).

Table A-4 Land Use on WDNR Land in the Project Area (Acres)

Alternatives and Options[1]	Urban/ Suburban	Rural	Timber Production	Open Space	Agriculture	Total
West Alternative	**0**	**0**	**1**	**7**	**0**	**8**
West Option 1	N/C	N/C	N/C	N/C	N/C	N/C
West Option 2	N/C	N/C	+11	N/C	N/C	+11
West Option 3	N/C	N/C	+8	+<1	N/C	+8
Central Alternative	**0**	**<1**	**480**	**11**	**<1**	**492**
Central Option 1	N/C	N/C	+59	+36	+<1	+96
Central Option 2	N/C	N/C	N/C	N/C	N/C	N/C
Central Option 3	N/C	N/C	-90	-<1	+1	-90
East Alternative	**0**	**1**	**262**	**10**	**<1**	**273**
East Option 1	N/C	N/C	N/C	N/C	N/C	N/C
East Option 2	N/C	+<1	+50	-1	-<1	+48
East Option 3	N/C	N/C	+36	+11	N/C	+47
Crossover Alternative	**0**	**<1**	**345**	**8**	**<1**	**353**
Crossover Option 1	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 2	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 3	N/C	N/C	N/C	N/C	N/C	N/C

Notes:
N/C – No change from the action alternative.
1. The value for each option represents the net change from the alternative. It was calculated as acres added by the option minus the acres in the segments the option replaces.
Sources: Herrera 2010, USGS 2011

Impacts on WDNR land include the creation of incompatible land uses related to conversion of active timber production lands to non-timber production land, use of open space land for project components, and disturbance to WDNR lands during maintenance and construction activities.

Use of WDNR land would be limited within the transmission line right-of-way and other uses would be eliminated at substations or under roads and tower footprints. Restrictions would include keeping the right-of-way clear of all structures, fire hazards, and tall-growing vegetation, and preventing any other use that may interfere with the safe operation or maintenance of the line. BPA would obtain the right, via its easements, to keep the right-of-way clear of vegetation and structures; BPA could also enter into agreements with WDNR for low-growing vegetation that does not interfere with BPA's safe operation and maintenance of its transmission facilities. WDNR would coordinate with BPA prior to planting to ensure that the use is safe, compatible, and does not create interference. Non-woody, non-structure supported (i.e., trellised) vegetation with a mature height not to exceed 4 feet could be grown safely under the transmission line. However, orchards, Christmas trees, tall-growing landscape or natural vegetation, and structure-supported crops would require special consideration.

Grazing land tends to be compatible with transmission lines, because livestock would be able to graze within the right-of-way. Although tower footprints and road beds would occupy land and remove that area of vegetation from grazing, livestock and wildlife could still walk around the towers and roads to access WDNR open space used for grazing that would be affected by the project.

Some uses of the right-of-way would not be restricted, but certain precautions would need to be taken. For example, in general, no object should be raised higher than 14 feet above the ground within the right-of-way (i.e., when moving timber harvest equipment underneath the right-of-way); ground elevation should not be altered (such as piling of dirt within the right of way); irrigation spray should not create a continuous stream onto the conductors or towers; fences should be grounded; and installing underground pipes or cables through the right-of-way needs to be coordinated with BPA so that they do not interfere with transmission line grounding systems. Vehicles and large equipment such as cranes, derricks and booms that do not extend more than 14 feet high could be operated safely under the line where it passes over roads, driveways, parking lots, cultivated fields or grazing lands.

BPA access roads could create an avenue for unauthorized access onto WDNR lands. At the request of WDNR, BPA would place gates at the entrance of access roads to prevent public access onto WDNR land and the project corridor. Locked gates at the entrances of BPA access roads and rights-of-way, which are installed for the life of the line and maintained by both BPA and WDNR, would help reduce trespassers, but could also cause a slight inconvenience to users of WDNR land.

There is the potential that, even with gates, unauthorized access and use of the right-of-way and adjacent properties could occur. WDNR has raised concerns about potential impacts to state lands from this unauthorized access and use. Because transmission line corridors are linear facilities that typically can be accessed fairly easily by the general public, WDNR is concerned that the project could contribute to unauthorized use and damage to state lands and public resources on these lands. WDNR also is concerned that gates by themselves are not sufficient to prevent unauthorized access and use to its lands where the project and associated roads

would be present. During construction and line maintenance, workers would need to ensure that gates are closed to prevent any livestock that may be grazing in the vicinity of WDNR land from escaping. Use of gates would also limit easy access to WDNR land by off-road vehicles.

In general, unauthorized public access and use could increase soil erosion and fire danger, introduce noxious weeds and illegal dumping, and disturb vegetation, wildlife, wildlife habitat, and cultural resources. Increased soil erosion could occur from unauthorized uses such as off road vehicles and other unmanaged recreational activities accessing areas and disturbing soils. Over time, unauthorized uses of gravel or dirt roads on WDNR land could lead to accelerated deterioration of these roads through disturbance and erosion. Increased fire danger can result from activities by unauthorized users on or near the project from a variety of means, such as campfires, discarded cigarettes, and vehicle exhaust systems coming into contact with vegetation.

The potential introduction of noxious weeds from unauthorized public access and use can occur from unauthorized vehicles inadvertently transporting and spreading seeds of noxious weeds into the project corridor and WDNR lands. Soil disturbance from these vehicles increases the potential for the introduced noxious weeds to become established in these disturbed areas. Such weed infestations would reduce the quality and value of WDNR land used for timber production, conservation, and preservation. They would also reduce forage quality of WDNR land, increase weed control costs, and threaten the integrity of native plant communities and habitats.

BPA would continue to work with WDNR concerning possible avenues for controlling or minimizing the potential for unauthorized public access and use on state lands to address WDNR's concerns about unauthorized access to its lands as a result of the project. Overall, maintenance impacts to WDNR land for the action alternatives would be low because the activities would not change land use; would be short term and limited to noise, dust and a small amount of vehicle traffic; and BPA would compensate for any damage that may occur. Timber harvest activities would not be affected by maintenance, other than possible minor scheduling conflicts that would be resolved by the parties involved through standard communication.

A.2.2 Recreation

Chapter 6 of the EIS provides an analysis of potential project impacts on recreation resources, including on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land.

Recreation facilities on WDNR lands include parks, campgrounds, motorized trails, and non-motorized trails. Recreational activities on WDNR land include sightseeing, nature appreciation, off-highway vehicle riding, target practice, fishing, and hunting. Dispersed recreation also takes place outside of designated recreation facilities, and can be authorized or unauthorized, as is the case with some off-highway motorized vehicle use and target practice at the Casey Road substation site.

Trails on WDNR land in the Yacolt Burn State Forest crossed by the project include the following:

- **Tarbell Trail**: This trail is a 35-mile non-motorized trail system that is open to hikers, equestrians, and mountain bikers year-round (WDNR 2010).

- **Larch Mountain Trail**: This trail is used by hikers, equestrians, and mountain bikers to reach the summit of Larch Mountain from the Tarbell Trail (WDNR 2010).
- **Jones Creek Trail and Jones Creek Trail Connector A**: This 14-mile-long stretch of double-track motorcycle and all-terrain vehicle motorized trail is open seasonally from May 1 to November 30.

The East and Crossover alternatives would cross or otherwise affect WDNR recreation resources within the Western Yacolt Burn State Forest (see Table A-5). The Casey Road substation site has no WDNR trails, but unauthorized activities such as target practice do occur. No other substation sites would affect WDNR recreation resources.

Table A-5 Permanent Impacts to Trails on WDNR Land in the Project Area[1]

Alternatives and Options[2]	Towers[3] (miles)	New Access Roads[4] (miles)	Improved Access Roads[4] (miles)
East Alternative	Tarbell Trail (<0.1)	Tarbell Trail (0.1)	Jones Creek Trail (0.2), Tarbell Trail (<0.1)
East Option 1	N/C	N/C	N/C
East Option 2	Tarbell Trail (-<0.1)	Tarbell Trail (-0.1)	Jones Creek Trail (-0.2), Tarbell Trail (-<0.1)
East Option 3	Jones Creek Trail (+<0.1)	Jones Creek Trail Connector A (+<0.1)	Jones Creek Trail Connector A (+0.3), Jones Creek Trail (-0.2)
Crossover Alternative	Tarbell Trail (<0.1)	Tarbell Trail (0.1)	Jones Creek Trail (0.2), Tarbell Trail (<0.1)
Crossover Option 1	N/C	N/C	N/C
Crossover Option 2	N/C	N/C	N/C
Crossover Option 3	N/C	N/C	N/C

Notes:
N/C – No change from the action alternative
1. The recreation study area is defined as the area within approximately 1,000 feet of the route.
2. The value for each option represents the net change from the action alternative. It was calculated as the total area added by the option minus the total area in the segments the option replaces.
3. Includes towers within and outside of the 150-foot right-of-way.
4. Includes access roads within and outside of the 150-foot right-of-way.
Source: Clark County 2011d

A.2.3 Socioeconomics

Chapter 11 of the EIS provides an analysis of potential project impacts on socioeconomic resources, including on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land. The socioeconomic conditions and resources potentially affected by the project on WDNR land include public services and utilities, government revenue from timber production, values associated with recreation and tourism, and ecosystems.

WDNR provides fire protection for more than 12 million acres in Washington, including their lands in the project area. WDNR has mutual aid agreements with rural fire districts in Clark and Cowlitz counties, and a master agreement for sharing fire protection resources among all state and federal agencies. In the event of a large or unusual emergency, they would likely be able to call in additional personnel and equipment from these districts and agencies.

WDNR manages state trust lands to provide revenue for several trusts, primarily by producing timber. The revenue generated for those trusts statewide ranged from $4 million to $65 million in 2009 (see Table A-6).

Table A-6 Washington State Trust Land, Beneficiaries, Acres, and Timber Sales, Statewide, 2009

Trust[1]	Beneficiaries	Total Acres[2]	Timber Sales[2] ($ millions)
Capitol Building Trust	State Capitol Campus	110,000	8
Charitable, Educational, Penal, and Reformatory Institutions Trust	WA State Institutions	69,000	4
Common School Trust	Public Schools (K-12)	1,800,000	34
Agricultural School Trust and Scientific School Trust	WA State University	84,000	4
State Forest Lands	County	625,000	65
Total		**2,688,000**	**115**

Notes:
1. Includes only trusts with land in the project area.
2. Statewide amounts; data specific to Cowlitz and Clark counties is not available.
Sources: WDNR 2009a, 2009b

The project would create a short-term increase in the trusts' revenue from these lands by triggering the harvest of the existing mature timber stock in and next to the new right-of-way and on any lands that would be occupied by a substation or access roads. Harvest of existing timber stock on existing right-of-way would likely not contribute to an increase in revenue for WDNR because this timber may be owned outright by BPA through fee-owned title or owned by BPA as reflected in existing easement agreements.

The value of short-term increases in government revenue for each action alternative has been quantified (see Table A-7). In some cases, additional trees would be cut next to but outside of the right-of-way for safety reasons, which would increase short-term revenue beyond the values reported here. Any increase in revenue would be offset if WDNR decided to reduce harvest on other lands. Additional revenue would come from BPA's payment of compensation for any state trust lands acquired for the project or for the easements themselves on trust lands. The appraisal process would also consider whether the transmission facilities would diminish the utility of a portion of the timberland property if the line effectively severs this area from the remaining property (called "severance damage").

Table A-7 Value of Timber Cleared on State Trust Lands (in 2011 dollars)[1]

Alternatives and Options[2]	Capitol Building	Institutions[3]	Common School	Agricultural	Scientific School	State Forest Lands	Total[4]
Value of Existing Timber							
West Alternative	**$0**	**$0**	**$2,390**	**$0**	**$0**	**$0**	**$2,390**
West Option 1	N/C	N/C	N/C	N/C	N/C	N/C	N/C
West Option 2	N/C	N/C	+$52,410	N/C	N/C	N/C	+$52,410
West Option 3	N/C	N/C	+$36,650	N/C	N/C	N/C	+$36,650
Central Alternative	**$167,100**	**$157,600**	**$753,400**	**$3,640**	**$110,600**	**$1,083,600**	**$2,276,000**
Central Option 1	N/C	N/C	+$12,490	N/C	+$74,850	+$168,300	+$255,600
Central Option 2	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Central Option 3	N/C	N/C	-$76,590	N/C	N/C	-$355,363	-$431,950
East Alternative	**$48,540**	**$0**	**$493,600**	**$0**	**$25,920**	**$697,300**	**$1,265,400**
East Option 1	N/C	N/C	N/C	N/C	N/C	N/C	N/C
East Option 2	+$53,590	N/C	-$11,750	N/C	-$25,920	+$244,100	+$260,000
East Option 3	N/C	N/C	+$66,260	N/C	N/C	+$104,600	+$170,900
Crossover Alternative	**$48,540**	**$0**	**$650,400**	**$0**	**$79,220**	**$839,500**	**$1,618,000**
Crossover Option 1	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 2	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 3	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Net Present Value of Revenue from Forgone Future Timber Harvests[5]							
West Alternative	**$0**	**$0**	**$1,860**	**$0**	**$0**	**$0**	**$1,860**
West Option 1	N/C	N/C	N/C	N/C	N/C	N/C	N/C
West Option 2	N/C	N/C	+$40,950	N/C	N/C	N/C	+$40,950
West Option 3	N/C	N/C	+$28,630	N/C	N/C	N/C	+$28,630
Central Alternative	**$130,500**	**$123,100**	**$588,600**	**$2,850**	**$86,390**	**$846,600**	**$1,778,000**
Central Option 1	N/C	N/C	+$9,760	N/C	+$58,470	+$131,500	+$199,700
Central Option 2	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Central Option 3	N/C	N/C	-$59,830	N/C	N/C	-$277,620	-$337,450

Alternatives and Options[2]	Capitol Building	Institutions[3]	Common School	Agricultural	Scientific School	State Forest Lands	Total[4]
East Alternative	**$37,920**	**$0**	**$385,600**	**$0**	**$20,250**	**$505,700**	**$949,500**
East Option 1	N/C	N/C	N/C	N/C	N/C	N/C	N/C
East Option 2	+$41,870	N/C	-$9,180	N/C	-$20,250	+$190,700	+$203,100
East Option 3	N/C	N/C	+$51,770	N/C	N/C	+$81,730	+$133,500
Crossover Alternative	**$37,920**	**$0**	**$508,100**	**$0**	**$61,890**	**$655,900**	**$1,264,000**
Crossover Option 1	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 2	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 3	N/C	N/C	N/C	N/C	N/C	N/C	N/C

Notes:
N/C – No change from the action alternative.
1. Calculated for timber that would be cleared from the right-of-way, substations, and access roads.
2. The value for each option represents the net change from the action alternative. It was calculated as the total value added by the option minus the total value in the segments the option replaces.
3. Includes charitable, educational, penal, and reformatory institutions.
4. Totals may not sum due to rounding.
5. Calculated in perpetuity.
Sources: Herrera 2010, USFS 2010, Warren 2009, WDNR, 2010c

Trees harvested on State Forest Lands Trust land would increase near-term revenue for the state.

The project would create long-term decreases in government revenue generated from state trust lands in three ways:

- Elimination or reduction of timber production on private timberlands that would be cleared in or next to the new right-of-way or for the substations and access roads
- Increase in the costs of managing private timberland near the new right-of-way, resulting, for example, from project-related restrictions on timber-harvest techniques, such as cable logging, or increases in risks to safety from logging near the right-of-way
- Reduction in the ability of private landowners to generate additional types of revenue, such as from growing trees to sequester carbon on the cleared lands

The long-term decreases in government revenue for each action alternative described in the first bullet are quantified in Table A-7. Measuring the impact entails converting the future impacts on timber-harvest revenue to an equivalent, single number, called the net present value, using a discount rate of 4 percent per year (Row, Kaiser, and Sessions 1981). The decrease in revenue is reported for the acres of trees within new right-of-way acquired for this project. For existing right-of-way, BPA likely has already negotiated compensation for forgone future revenue from timber production. Data are unavailable to quantify the decrease in government revenue resulting from the impacts described in the second and third bullet points above.

A.2.4 Transportation

Chapter 12 of the EIS provides an analysis of potential project impacts on transportation resources, including on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land. About 0.2 to 12 miles of new roads would be constructed and about 0.1 to 26 miles of road improvement would occur on WDNR lands for the alternatives (see Table A-8). Other existing roads on WDNR lands would be used to access the transmission line and substations during construction (see existing roads, Table A-8). Options would not change, increase or decrease the miles of roads required for each alternative.

Table A-8 New, Improved, and Existing Access Roads on WDNR Land in the Project Area

Alternatives and Options[1]	New Access Roads (miles)	Improved Access Roads (miles)	Existing Roads Potentially Used during Construction (miles)
West Alternative	**0.2**	**0.1**	**1**
West Option 1	N/C	N/C	-0.1
West Option 2	+0.3	+0.2	N/C
West Option 3	+0.8	+0.2	+1
Central Alternative	**12**	**26**	**20**
Central Option 1	+1	+7	+0.2
Central Option 2	N/C	N/C	-0.2
Central Option 3	-1	-2	-1
East Alternative	**7**	**21**	**30**
East Option 1	N/C	N/C	-0.2
East Option 2	+0.4	-1	-10
East Option 3	+0.2	+1	+4
Crossover Alternative	**9**	**16**	**29**
Crossover Option 1	N/C	N/C	+0.1
Crossover Option 2	N/C	N/C	N/C
Crossover Option 3	N/C	N/C	N/C

Notes:
N/C – No change from the action alternative.
1. The value for each option represents the net change from the action alternative. It was calculated as the miles added by the option minus the miles in the segments the option replaces.

A discussion of BPA's access road system is included in Section 3.9, Access Roads, of the EIS. This discussion includes a general description of the width, location, type of road improvement, and construction equipment that would be used. Use of temporary roads within agricultural fields is also discussed. For the WDNR parcels, BPA would acquire rights (easements for line access roads and fee title for substation access roads), and develop and maintain permanent access suitable for travel by wheeled vehicles to each transmission line structure site, substation

or other transmission facility. Existing public and private roads and transmission line rights-of-way would be used for access where reasonably possible.

Potential impacts to vehicle traffic flow would be short-term and moderate during the 30-month construction period if heavy equipment and supplies are transported on local roads to tower sites. Material transport amounts and specific routes are not defined to date, although existing roads that may be used during construction and do not need any improvement have been identified. A typical crew can construct 10 miles of line in about 3 months so construction traffic is likely to be present for 1-3 months before the next 10-mile section is constructed and other roads are used.

Maintenance traffic would not impact transportation modes along any of the action alternatives over the life of the line because it would normally require only a few maintenance vehicles several times a year and helicopters twice a year. Large vehicles such as flatbed trucks or a crane may occasionally be required to replace or repair the transmission line and towers, which could cause minor disruption to local traffic for brief periods of time. As part of BPA's Transmission Engineering Manual, BPA has an Access Road Planning and Design Manual (BPA 1987). This comprehensive manual includes BPA's access road policy and standards regarding the design and construction of access roads, including those on and next to WDNR land.

Environmental, engineering, economic, and maintenance factors are considered in locating and designing access roads. Access road planning, as described in the BPA Manual, takes into account many factors including seasonal constraints for construction, steep slopes, present and potential land uses, soil conditions, soil erosion potential, water quality impacts, visual impacts, and impacts to cultural resources. The BPA Manual also describes erosion and sediment control methods that are implemented. Erosion control is a very important factor in planning, designing, constructing and maintaining access roads. Erosion must be controlled during and after construction to prevent road damage, to avoid undue increases in stream turbidity and sedimentation, and soil deposition outside of the road right-of-way. Well designed and constructed erosion control measures would reduce road maintenance costs and provide a reliable road in the event of emergency work on the transmission line. Drainage structures including culverts, intercepting dips, water bars, and gravel surfacing are elements of erosion control, as is seeding.

Access road planning and design are important elements of transmission project development and, to be effective, must begin at the earliest stage of project planning. Well-developed access road plans and designs minimize construction and maintenance costs, environmental impacts, and costly delays because of late changes in access road routing. Access road plans and designs are developed using landowner, environmental, construction, and maintenance input. For WDNR land, access road plans and designs would also be coordinated with the appropriate WDNR engineer.

As discussed in the introduction to this appendix, BPA and WDNR expect to negotiate a Statewide MOA with the goal of addressing BPA transmission line operations and maintenance compatibility with WDNR trust land management. Among other things, this MOA is expected to provide mutually agreeable definitions, classifications, and responsibilities for BPA sole and joint use access roads located on WDNR lands, to provide for mutually agreeable maintenance and operation of these roads. Although a statewide approach to BPA access roads on WDNR lands

will be addressed in the Statewide MOA, discussion has occurred between BPA and WDNR on this issue. While these discussions have not concluded, they provide an indication of the likely language concerning definitions, classifications, and best practices for BPA access roads located on WDNR lands that BPA and WDNR expect may be included in the easement documents for the project, and in any project-specific maintenance and operation agreement negotiated if the project is approved. Based on current, in-progress discussions between BPA and WDNR, any such language likely will be similar to, or possibly largely the same as, the following:

A.2.4.1 Definitions

1. Road Maintenance: Periodic work performed on a road so that the road prism remains usable and costly repairs are not needed. Activities include but are not limited to shaping the roadway, vegetation control, cleaning catch basins, installation of cross-drain culverts and culvert maintenance, water bars, ditches, roadside brushing, and spot rocking. Road maintenance may be required because of traffic use or non-traffic relayed conditions such as vegetation growth.
2. Road Improvement: Includes any work that increases the overall value of the road and requires a significant expenditure of resources and specifically excludes road maintenance and road abandonment. Activities include but are not limited to: new road and bridge construction, bridge and culvert replacement, significant road surface improvement or changing the surface of a road, widening, ditch construction, abandonment, decommissioning and road realignments or rerouting. It does not include any of the specific activities listed in road maintenance.
3. Road Abandonment: Includes all work to put a road in a condition that no longer requires maintenance. The following work is required to exempt a road from maintenance:
    a. Roads are out-sloped, water barred, or otherwise left in a condition suitable to control erosion and sediment transport and maintain water movement within a wetland or a natural drainage
    b. All disturbed slopes, including ditches, are left in a suitable condition to control or limit erosion
    c. The road is blocked, or other reasonable measures are taken, when equally effective, to prevent four wheel highway vehicles from passing the point of closure at the time of abandonment
    d. Water crossing structures and fills on all typed waters are removed, except where State determines other measures would provide adequate protection to public resources
4. Sole Use Road: A road on state-managed uplands within and outside the transmission corridor that is used almost exclusively by BPA, including roads built for the original line construction, patrol, maintenance, upgrades, emergency repairs, and vegetation management. General characteristics of this type of road include:
    a. Road does not currently, nor in the foreseeable future, provide needed access to state-managed lands for the purpose of resource management.
    b. Road is not generally used, identified, or necessary for administrative use by State purchasers, lessees, or permittees.

c. No additional easement holder user of the road has been identified.

d. State rarely uses the road administratively. Such State use includes, but is not limited to easement administration.

e. State does not have a designated recreational trail or promote other authorized recreational use of the road.

f. State does not consider the road part of the State funded transportation system.

5. Joint Use Road: A joint use road is a road on WDNR-managed land that is used by both BPA and WDNR. General characteristics of this type of road include:

   a. State uses or has immediate plans to use the road, or a portion of the road, to access WDNR-managed lands.

   b. State's purchasers, lessees or permittees require use of the road.

   c. An additional easement holder user of the road may have been identified.

   d. State has designated sections of the road as a recreation trail or has invited recreational use onto the road.

   e. State maintains the road and considers the road part of the State funded transportation system.

A.2.4.2 Best Practices To Maintain and Improve Joint and Sole Use Roads on State-Managed Lands

WDNR and BPA agree to produce and maintain a safe, cost effective, environmentally friendly, and practical road program that is supported by and meets the needs of the sole and joint use roads. Instead of complying with specific roads standards, the agencies will identify and implement best practices to accomplish the following objectives:

- Protect water quality and avoid sediment loading into water bodies
- Protect sensitive areas and reduce ecosystem impacts
- Maintain natural channels, natural stream flow, and maintain passage for aquatic organisms
- Control surface water on the road
- Stabilize the driving surface
- Evaluate unauthorized use that may damage the road and take steps to curtail such use
- Implement needed slope stabilization measures and reduce mass wasting
- Establish compatible vegetation on disturbed areas
- Avoid and control the spread of noxious weeds

A.2.5 Cultural Resources

Chapter 13 and Appendix I of the EIS provides an analysis of potential project impacts on cultural resources, including on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land. Sites have been identified by using a variety of methods including archaeology, oral history and history. Many of the pre-contact sites recorded in the project area are near major waterways including Lacamas Lake, the Washougal River, and the Columbia River. None of these major waterways are crossed by the project on WDNR land. Fewer archaeological sites have been identified in upland areas in the eastern and northern portions of the project area, where WDNR lands are most dense. Six historic sites are potentially eligible for listing and have been identified on WDNR parcels. Two of these sites are crossed by the project. One site, a historic road, is located between two tower sites and would be spanned by the new line. The other site, a historic road and bridge, is just within the proposed right-of-way.

During construction, BPA attempts to avoid known sites whenever possible and uses trained cultural resource monitors on large-scale projects to ensure unidentified sites are not inadvertently impacted. Known archaeological sites would be delineated both by surface observations and subsurface testing before construction to avoid physically impacting sites during construction. For unknown sites, appropriate mitigation procedures would be in place to stop construction activities and determine protective measures (e.g., avoidance) if artifacts are found (see Chapter 13). Impacts should not occur to unknown sites with these procedures in place.

If towers, substations, and access roads are sited to avoid sensitive areas, their subsequent maintenance and operation would not affect known resources. If any maintenance activities would need to occur outside of tower locations, outside of the substation fence, or off access roads, a review of sensitive areas would be required to avoid impacting resources. An on-the-ground survey and inventory of cultural resources would occur once a Preferred Alternative has been identified.

A.2.6 Geology and Soils

Chapter 14 and Appendix J of the EIS provides an analysis of potential project impacts on geology and soils, including on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land. The analysis in Chapter 14 includes a general assessment of geologic hazards including WDNR parcels potentially affected by the project, and the identified measures to lessen or avoid potential geologic hazards would also apply to WDNR land. Maps in Appendix I display the liquefaction risks and faults found within the project area, including WDNR parcels.

WDNR lands in the project area are located in the hilly topography of the South Cascades and Willapa Hills physiographic provinces where residual soil overlays igneous bedrock. Potential impacts to soils that may result on WDNR lands from the project include increased soil erosion, soil compaction, and increased landslide activity.

Soil Erosion. Almost all (about 99 percent) of the WDNR lands in the project area have a severe or very severe hazard of erosion. Increased soil erosion could lead to increased sedimentation

into water bodies, which in turn would impact water resources (such as drinking water), fish (such as salmon and steelhead), and plants, as well as degradation of air quality from blowing dust. Although the soils on WDNR land may be susceptible to erosion, with implementation of mitigation measures as described in Chapters 3 and 14, the impact from erosion would be low.

Soil Compaction: Similar to other areas of the project, WDNR lands in the project area would be subjected to permanent soil compaction where roads, towers, and substations are constructed, and temporary soil compaction would occur in areas disturbed during project construction, such as near roads, towers, and substations. Impacts from compacted soils could include restricted infiltration and root depth, and reduced water available for plant growth. When infiltration is reduced, runoff may occur and lead to erosion, nutrient loss, and potential water quality problems. These impacts would be reduced, but not eliminated, through the implementation of the mitigation measures described in Chapters 3 and 14.

Landslide Areas: Two mapped landslides occur on WDNR land in the project area; one north of the Lewis River, the other south of Yacolt. Potential impacts resulting from landslides triggered or exacerbated by the project on WDNR land include damage to roads, disruption of utilities (such as transmission lines or pipelines), damage to plant and wildlife habitats, and sedimentation or damming of water bodies. These potential impacts would be avoided or reduced through implementation of mitigation measures described in Chapters 3 and 14, such as siting towers and roads to avoid potentially unstable locations, or designing towers and roads specifically to avoid destabilizing landslide areas. Additionally, BPA monitors towers for signs of distress due to slope movement. Potential active slide-caused problems would likely be observed at towers during the annual maintenance crew tower inspections and twice-a-year helicopter inspections.

Because road development also has the potential to cause erosion or landslides, road grades on all lands crossed by the proposed project would be varied depending on the erosion potential of the soil and roads would be rocked where needed for dust abatement, stability, load bearing, and seasons of use. Final design measures would take slopes, soil types, bedrock, the presence of bedrock hollows or inner gorges, and other factors into account based on site-specific information.

Seismic Risks and Volcanic Activity: The risk to the project on WDNR land from earthquakes and volcanic eruptions is low. While all of the project including those portions potentially on WDNR lands could be subjected to shaking from an earthquake, all facilities would be built to applicable seismic standards and combined wind- and ice-loading tower design criteria typically exceed earthquake-induced loads.

Seismically induced liquefaction risk is also low; WDNR lands in the project area are mostly underlain by igneous bedrock with a small area underlain by glacial deposits. Generally, transmission towers are likely to survive settlement associated with liquefaction with only minor structural damage. It is BPA's policy to avoid placing towers in areas where liquefaction might occur, such as stream crossings. If a potential liquefaction hazard is found, the liquefiable soils would most likely be excavated to bedrock and replaced with non-liquefiable backfill. In addition, no mapped active faults cross the project on WDNR lands.

Portions of the project potentially on WDNR lands could be subjected to ashfall from an eruption of a nearby volcano, but none of the WDNR land in the project area are mapped as

being located within a proximal (e.g., lava flows, pyroclastic flows) or distal (i.e., lahar) hazard zone.

Additional geology and soils information would be obtained from updated geologic hazard assessments, including on-the-ground field assessments of the Preferred Alternative. BPA would likely not use certain models suggested by WDNR as part of its geologic hazard assessments because field assessments would essentially cover the outcomes the models would produce. An update of the geologic hazard assessments in Appendix J would include another review of liquefaction hazard mapping, geologic maps for fault locations, and aerial photographs combined with surface condition assessments at proposed tower locations and surrounding terrain for landslide hazard assessment. Geological soil testing would continue to be done at representative tower locations to help determine appropriate tower footings for a given soil type or hazard. Geologic and soil hazard areas are avoided where possible, and where avoidance is not possible, towers and roads would be designed to address the applicable hazard.

A.2.7 Water and Fish

Chapters 15 and 19 and Appendix K of the EIS provide an analysis of potential project impacts on water and fish resources, including on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land.

Rights-of-way and new and improved access roads would not cross any FEMA designated 100-year floodplains on WDNR land. None of the new towers on WDNR land or Casey Road Substation are in floodplains. No stream segments listed on the Washington State 303(d) list would be crossed by rights-of-way and new and improved access roads on WDNR land. Access roads would cross some streams on WDNR land (see Table A-9). Clearing of riparian vegetation would occur along these streams.

Table A-9 Access Roads and Right-of-Way Stream Crossings on WDNR Land in the Project Area

Alternatives and Options[1]	New and Improved Roads that Cross Any Stream[2] (number)	Right-of-Way Stream Crossings (number)
West Alternative	**0**	**2**
West Option 1	N/C	N/C
West Option 2	N/C	N/C
West Option 3	+3	+2
Central Alternative	**69**	**81**
Central Option 1	+22	+4
Central Option 2	N/C	N/C
Central Option 3	-4	-19
East Alternative	**42**	**33**
East Option 1	N/C	N/C
East Option 2	+13	+14
East Option 3	+8	+15

Alternatives and Options[1]	New and Improved Roads that Cross Any Stream[2] (number)	Right-of-Way Stream Crossings (number)
Crossover Alternative	**31**	**55**
Crossover Option 1	N/C	N/C
Crossover Option 2	N/C	N/C
Crossover Option 3	N/C	N/C

Notes:
N/C – No change from the action alternative.
1. The net change for each option represents the net change from the action alternative. It was calculated as the total number added by the option minus the total number removed by the option.
2. Includes ephemeral, intermittent and perennial streams.
Source: WDNR 2006

WDNR manages 2.4 million acres of state-owned aquatic lands beneath many project area water bodies including the Columbia, Cowlitz, Coweeman, Lewis, and Kalama rivers. Easements or permits on these state-owned aquatic lands may be required where alternatives or options cross (see Table A-10)

Special status and resident fish species that may be present in project area streams on WDNR land include resident cutthroat trout, rainbow trout, Lower Columbia River steelhead (listed as threatened under the Endangered Species Act [ESA]), and Lower Columbia River coho (ESA threatened).

Table A-10 WDNR State-Owned Aquatic Lands Potentially Crossed by Alternatives or Options in the Project Area

State-Owned Aquatic Lands	Segment	Alternative or Option
Columbia River	52	East, Central, West, Crossover
Cowlitz River	F, 3, 4	East, Central, West, Crossover, East Option 1, Central Option 2
Coweeman River	9	West, Crossover
Lewis River	25, M, L, K	West, Central, Crossover, East, Central Option 3
Kalama River	9, 10	West, Central, Crossover
Washougal	52	East, Central, West, Crossover

A.2.8 Wetlands

Chapter 16 and Appendix L of the EIS provides an analysis of potential project impacts on wetlands, including on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land.

Although no substations, access roads, or towers would be built in wetland areas on WDNR land, impacts from right-of-way clearing would occur in forested and scrub-shrub wetlands on WDNR land (see Table A-11). As described in Section 16.2.4, West Alternative, clearing and fill

of emergent and scrub-shrub wetlands along West Option 1 (Segment 40) would occur within the Lacamas Creek floodplain. Some of this area has recently been designated as a natural area by the Washington State Commissioner of Public Lands (see Sections 17.1.1.5, Herbaceous, and 17.1.2.1, WDNR Protected Areas, and Figure 17-1). These areas are not included in Table A-11 because WDNR does not currently own the parcels. WDNR does anticipate the purchase and transfer of these parcels to WDNR ownership by the time this DEIS is released.

Table A-11 Potential Clearing of Wetlands on WNDR Land in the Project Area

Alternatives and Options[1]	Right-of-Way Clearing (acres)[2,3]	
	Forested	Scrub-Shrub
West Alternative	**0.02[3]**	**0.1**
West Option 1	N/C	N/C
West Option 2	N/C	N/C
West Option 3	+0.2	N/C
Central Alternative	**23.7**	**0.6**
Central Option 1	+0.2	N/C
Central Option 2	N/C	N/C
Central Option 3	-5.4	-0.3
East Alternative	**13.6**	**0.6**
East Option 1	N/C	N/C
East Option 2	+4.8	+0.4
East Option 3	+2.7	+1.7
Crossover Alternative	**18.3**	**0.3**
Crossover Option 1	N/C	N/C
Crossover Option 2	N/C	N/C
Crossover Option 3	N/C	N/C

Notes:
N/C – No change from the action alternative,
1. The value for each option represents the net change from the action alternative. It was calculated as the acres added by the option minus the acres in the segments the option replaces.
2. Cleared wetland within the right-of-way.
3. All acreages are based on wetlands mapped from available data.
Sources: DEA 2009; Herrera 2011a, 2011b, 2012

A.2.9 Vegetation

Chapter 17 of the EIS provides an analysis of potential project impacts on vegetation, including on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land. Vegetation types present on WDNR lands where the project would cross include forest, shrubland, herbaceous, and rural landscaped (see Table A-12). No special-status plants are present on WDNR land crossed by the project, although four special-status plant habitats that are managed or proposed for management by WDNR could be affected.

Table A-12 Vegetation Types on WDNR Land in the Project Area

Alternatives and Options[1,3]	Vegetation Type (acres)[2]						
	Mature Forest	Forest	Production Forest	Shrubland	Herbaceous	Rural Landscaped	Urban/ Suburban Landscaped
West Alternative	**0**	**4**	**1**	**3**	**0**	**0**	**0**
West Option 1	N/C	N/C	N/C	N/C	N/C	N/C	N/C
West Option 2	N/C	N/C	+11	N/C	N/C	N/C	N/C
West Option 3	N/C	+<1	+8	+<1	N/C	N/C	N/C
Central Alternative	**0**	**1**	**480**	**5**	**<1**	**4**	**0**
Central Option 1	N/C	+1	+59	+29	+<1	+6	N/C
Central Option 2	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Central Option 3	N/C	N/C	-90	-1	+1	N/C	N/C
East Alternative	**0**	**2**	**262**	**6**	**<1**	**2**	**0**
East Option 1	N/C	N/C	N/C	N/C	N/C	N/C	N/C
East Option 2	N/C	-1.2	+50	-<1	+<1	-<1	N/C
East Option 3	N/C	N/C	+36	+4	N/C	N/C	N/C
Crossover Alternative	**0**	**2**	**345**	**4**	**<1**	**1**	**0**
Crossover Option 1	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 2	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Crossover Option 3	N/C	N/C	N/C	N/C	N/C	N/C	N/C

Notes:

N/C – No change from the action alternative.

1. The value for each option represents the net change from the action alternative. It was calculated as the acres added by the option minus the acres in the segments the option replaces.
2. Total acres mapped within 150-foot transmission line right-of-way, access roads, and substations for each action alternative.
3. Clearing for danger trees outside the right-of-way is unknown at this time and not included in these calculations.

Source: Herrera 2010

The West Alternative and Options (segments 36, 36A, 36B, 40, 41, 45, 46, and 50) cross the Lacamas Prairie Natural Area, which has been identified as a potential Natural Area Preserve and Natural Resource Conservation Area by WDNR (see Section 17.1.2.1, WDNR Protected Areas, and Figure 17-1). Approximately 33 acres of the Natural Area would be crossed by new and existing right-of-way; and 11 acres would be affected by towers and access roads, including less than 1 acre of WNHP Oregon white oak woodland priority ecosystems. Special-status species that have documented occurrences in the Natural Area include Bradshaw's lomatium (ESA endangered), Hall's aster (WA sensitive), Oregon coyote-thistle (WA threatened), small-flowered trillium (WA sensitive), dense sedge (WA threatened), and Nuttall's quillwort (WA sensitive).

The West and Crossover alternatives also cross a WDNR forest riparian conservation easement along Segment 9 and a WDNR genetic research plot along Segment 30 of Central Option 3 (see Maps A and C). These areas could be impacted by right-of-way clearing, tower and road construction, and danger tree removal.

Approximately 0.5 acre of existing access road crosses the southern edge of an herbaceous bald on WDNR land along Segment O of the East and Crossover alternatives (see Section 17.1.2.2, WNHP Priority Ecosystems, and Map D). Although species composition is unknown at this time, it could qualify as a Washington Natural Heritage Program (WNHP) North Pacific herbaceous bald and bluff priority ecosystem (it is not currently documented as such by WNHP).

Noxious weeds could also be present on WDNR lands where the project would cross. The project could cause the spread of noxious weeds, especially along newly constructed access roads (see Chapter 17 and Appendix M). To control or contain noxious weeds on WDNR parcels potentially crossed by the proposed project, BPA would undertake actions in coordination with WDNR at four stages of the project: pre-construction, construction, immediate post-construction, and maintenance.

Pre-Construction: The MOA between WDNR and BPA and/or easement document for any WDNR lands affected would outline measures for weed control. As part of BPA's noxious weed management, BPA would conduct a noxious weed survey once a Preferred Alternative is chosen and before construction to help determine infestation locations and appropriate mitigation measures needed before and during construction. If noxious weeds are found on WDNR land, BPA and WDNR could decide to apply herbicides prior to construction to help reduce spread during construction. Construction specifications would contain provisions stating how the noxious weeds would be controlled or contained including provisions outlined in the Statewide MOA.

All proposed actions to control or eradicate noxious weeds would comply with the Carson-Foley Act (P.L. 90-583), the Federal Noxious Weed Act (P.L. 93-629), and other applicable state and federal regulations, and all applicable state and county noxious weed control regulations and guidelines to the extent practicable.

Construction: During construction, BPA would implement noxious weed control measures specified in the construction specifications which would include establishing vehicle and equipment washing stations in strategic locations to reduce the possibility of seed being carried to areas that do not have infestations, and reseeding disturbed areas with desirable species to limit the spread of noxious weeds. To ensure that the desired level of noxious weed control is

being carried out, the BPA field inspector and the land liaison representative would monitor the program. For WDNR land, BPA would coordinate these efforts with WDNR as specified in the Statewide MOA or easement agreement.

Immediate Post-Construction: Upon completion of construction, the maintenance of the transmission line and its access roads and rights-of-way would become the responsibility of BPA Transmission Line Maintenance with the assistance of the BPA Regional Natural Resource Specialist. Before the line is released for future maintenance, a detailed post-construction field review would be conducted with WDNR, the BPA field inspector, and the BPA Regional Natural Resource Specialist. Specific noxious weed control measures would be agreed upon and responsibilities, including funding, assigned to the participating organization.

Maintenance: Over the long-term, vegetation (including noxious weeds) on WDNR land would be managed by the BPA Regional Natural Resource Specialist along the right-of-way as guided by BPA's Transmission System Vegetation Management Program EIS, agreements made with WDNR, and input from the county weed boards.

Noxious weed control on BPA easements across WDNR land and other lands would be coordinated through the BPA Regional Natural Resource Specialist. Prior to conducting any such weed control, BPA's usual practice is to develop a noxious weed management plan within an overall Vegetation Management Prescription, followed by preparation of a Supplement Analysis (SA) to BPA's Transmission System Vegetation Management Program EIS. The SA provides a review of the control activities and ensures they are consistent with the vegetation maintenance activities contained in that EIS. BPA would coordinate preparation of the noxious weed management plan on WDNR managed trust lands with WDNR staff. Examples of maintenance policies that are defined in BPA's Transmission System Vegetation Management Program EIS, and that likely would be included in a noxious weed management plan and considered in SAs relevant to WDNR, include the following:

- Apply herbicides to the rights-of-way
- Provide herbicides to landowners
- Contract with the owners or county weed control districts to apply herbicides to BPA rights-of-way
- Contract with the county weed control district to apply herbicides to specific identified noxious weeds
- Initiate additional control measures as recommended by local jurisdictions or responsible governmental agencies
- Where required by state or local agencies or in agricultural areas where noxious weeds are present, pressure or steam wash all vehicles used in that location before entering another location

A.2.10 Wildlife

Chapter 18 of the EIS provides an analysis of potential project impacts on wildlife, including impacts on WDNR land, and identifies measures to lessen or avoid impacts that would also apply to WDNR land. Special-status species that may be present on WDNR land crossed by project

include marbled murrelet (ESA threatened) and northern spotted owl (ESA threatened). Central Option 1 and the access road to Casey Road Substation may cross near marbled murrelet habitat on WDNR land. The Central, Crossover, and East alternatives may cross WDNR land that is within a 1.8-mile radius of known spotted owl activity and management areas. Additionally, WDNR has a Habitat Conservation Plan (HCP) that covers all the upland and riparian trust land on the westside and the east slope of the Cascades within the range of the spotted owl. This HCP provides multiple species' protection on all forested WDNR lands including those that may be impacted by the alternatives or options that cross WDNR land.

The West Alternative and Options cross westside prairie and Oregon white oak woodland habitats in the Lacamas Prairie Natural Area, which are both considered WDFW priority habitats (see Section 18.1.2.3, Westside Prairie). About 0.5 acre of existing access road crosses the southern edge of an herbaceous bald habitat along Segment O of the East and Crossover alternatives (see Section A.2.9). Located on WNDR land, this herbaceous bald has been documented by WDFW as priority habitat (see Section 18.1.2.2, Herbaceous Balds).

Other species that may have special status on WDNR land in the project area include elk and deer. Habitat may include winter range for different herds of Columbian black-tailed deer, Roosevelt elk, and Rocky Mountain elk in the Yale Valley and Rock Creek areas (East, Crossover, and Central alternatives). The Casey Road site is also within the winter range for the Willapa Herd of Roosevelt elk.

A.3 Measures for WDNR Lands

In addition to mitigation measures identified in Chapters 3 and 5 through 22 of the EIS, the measures outlined in Table A-13 would be implemented to further reduce or avoid potential impacts on WDNR lands.

Table A-13 Measures for WDNR Lands

Measure	Implementation
Implement the MOA with WDNR that reduces noxious, invasive and undesirable species including tall-growing woody plants and works towards compatible and native low-growing species vegetation on WDNR lands. The MOA outlines coordination between WDNR and BPA for the use of herbicides on lands where WDNR uses herbicides and minimizes the use of herbicides on lands where WDNR does not use herbicides.	Washington Statewide Rights-of-Way MOA/WDNR Easement Document
Implement the MOA that defines, classifies, and designates responsibilities for BPA sole and joint use access roads for the proposed project that would be located on WDNR lands, with the goal of addressing operations and maintenance compatibility of the proposed transmission line with WDNR trust land management.	Washington Statewide Rights-of-Way MOA/WDNR Easement Document
For any noxious weed management plans prepared for proposed weed control and other vegetation maintenance on WDNR managed trust lands as part of future line maintenance activities, coordinate preparation of these management plans with WDNR staff.	Noxious Weed Management Plans

Measure	Implementation
Commit to coordinating with WDNR regarding the 1989 WDNR Agricultural and Grazing lands Policy Plan and related Resource Management Plans for individual parcels during construction and maintenance of the line and access roads over WDNR trust lands. Provide WDNR with notice of potential impacts to affected lands enrolled in the Conservation Reserve Program. Request permission to disturb ground cover as needed to complete the project and agree to restore impacted lands outside of lands developed for tower pads and access roads to the same type of cover at no expense to any applicable WDNR lessee or to WDNR as landowner.	Washington Statewide Rights-of-Way MOA
Implement the Appraisal MOU with WDNR to pay fair market value for impacts any easement conveyances granted to BPA to on trust lands.	Appraisal MOU
Utilize the Appraisal MOU with WDNR to assess the value for any reduction in CRP acreage due to construction of access roads or towers.	Appraisal MOU
Work with WDNR concerning a possible cooperative agreement for the control of unauthorized public access and use on state lands that could result from the proposed project. The agreement could address various provisions related to unauthorized access, such as additional measures to be taken to discourage unauthorized use of the project corridor and associated access roads, periodic inspection for unauthorized access and any resulting damage, and repair of any damage from unauthorized access. BPA will strive to design the corridor to prevent trespass and provide signs that discourage unauthorized use of the corridor.	Washington Statewide Rights-of-Way MOA/WDNR Easement Document
Mark the easement corridor in strategic locations on WDNR land so that BPA, contractors, adjacent landowners and the public can clearly recognize when they are within the corridor to prevent uncompensated corridor expansion, vegetation management conflicts, and to reduce trespass.	Washington Statewide Rights-of-Way MOA/WDNR Easement Document
Develop a mutually agreeable fire prevention and suppression plan with WDNR that addresses managing and controlling the risks associated with wildland fire due to construction, operation, and maintenance of the transmission line.	Washington Statewide Rights-of-Way MOA/WDNR Easement Document

Page intentionally left blank

Appendix B

Right-of-Way Tower Configuration Tables and Figures

Table B-1 West Alternative Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
2	6.0	2/1-2/18	0	Lexington-Delameter No. 1 SC 115-kV line Longview-Chehalis No. 1 SC 230-kV line	Remove about 28 wood H-Frame structures of the Lexington-Delameter No. 1 SC 115-kV line to accommodate new 500-kV line.	New 500-kV line Longview-Chehalis No. 1 SC 230-kV line	B-2
		2/18-2/27	0	Lexington-Longview No. 2 SC 230-kV line Lexington-Delameter No. 1 SC 115-kV line Lexington-Longview No. 1 SC 115-kV line	Remove about 15 wood pole structures of the Lexington-Delameter No. 1 SC 115-kV line to accommodate new 500-kV line.	New 500-kV line Lexington-Longview No. 2 SC 230-kV line Lexington-Longview No. 1 SC 115-kV line	
		2/27-2/28	150	Lexington-Delameter No. 1 SC 115-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	Remove about 2 wood pole structures of the Lexington-Delameter No. 1 SC 115-kV line 150 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	
4	0.8	4/1-4/2	Varies	Lexington-Delameter No. 1 SC 115-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	Remove about 2 wood pole structures of Lexington-Delameter No. 1 SC 115-kV line 150 feet new right-of-way needed 250 feet east of Tower 4/1 to accommodate new 500-kV line	New 500-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	B-3
		4/2-4/3	0	BPA Lexington Substation		New 500-kV line around Lexington Substation	B-1
		4/3-4/5	0	Ross-Lexington No. 1 230-kV line		New 500-kV line Ross-Lexington No. 1 230-kV line	B-3
9	18.7	9/1-9/11	0	Cowlitz PUD SC 115-kV line Ross-Lexington No. 1 SC 230-kV line	Remove about 11 wood pole structures of the Cowlitz PUD SC 115-kV line to accommodate new 500-kV line	New 500-kV line Ross-Lexington No. 1 SC 230-kV line	B-4
		9/11-9/20	0	Ross-Lexington No. 1 SC230-kV line		New 500-kV line Ross-Lexington No. 1 SC 230-kV line	
		9/20-9/21	22.5	Ross-Lexington No. 1 SC 230-kV line	22.5 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line Ross-Lexington No. 1 SC 230-kV line	
		9/21-9/82	0	Ross-Lexington No. 1 SC 230-kV line		New 500-kV line Ross-Lexington No. 1 SC 230-kV line	
25	29.8	25/1-25/18	0	Ross-Lexington No. 1 SC 230-kV line		New 500-kV line Ross-Lexington No. 1 SC 230-kV line	B-6
		25/18-25/19	12.5	Ross-Lexington No. 1 SC 230-kV line	12.5 feet new right-of-way needed on east side of existing right-of-way to accommodate new 500-kV line	New 500-kV line Ross-Lexington No. 1 SC 230-kV line	
		25/19-25/106	0	Ross-Lexington No. 1 SC 230-kV line		New 500-kV line Ross-Lexington No. 1 SC 230-kV line	
		25/106-25/110	0	Sifton-Ross No. 1/Bonneville PH1-Alcoa No. 2 DC 115-kV line		New 500-kV line Sifton-Ross No. 1/Bonneville PH1-Alcoa No. 2 DC 115-kV line	
		25/110-25/141	0	McNary-Ross No. 1 SC 345-kV line Sifton-Ross No. 1/Bonneville PH1-Alcoa No. 2 DC 115-kV line	Rebuild about 32 towers on the McNary-Ross No. 1 345-kV line to narrower 345-kV line configuration to accommodate new 500-kV line	New 500-kV line McNary-Ross No. 1 SC 345-kV line Sifton-Ross No. 1/Bonneville PH1-Alcoa No. 2 DC 115-kV line	
		25/141-25/151	30	McNary-Ross No. 1 SC 345-kV line Sifton-Ross No. 1/Bonneville PH1-Alcoa No. 2 DC 115-kV line	30 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line McNary-Ross No. 1 SC 345-kV line Sifton-Ross No. 1/Bonneville PH1-Alcoa No. 2 DC 115-kV line	
		25/151-25/152	30	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	30 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	

Table B-1 West Alternative Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
36B	1.4	36B/1-36B/7	155	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	New 500-kV line crosses from North to South side of right-of-way. 155 feet new right-of-way needed on south side of existing right-of-way to accommodate new 500-kV line	McNary Ross 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line New 500-kV line	B-9
		36B/7-36B/8	155	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	New 500-kV line parallels existing DC 115-kV line at 36B/7, then replaces DC 115-kV line at 36B/8 with TC 500-kV line	McNary Ross 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1/ New 500-kV TC line	
41	1.3	41/1-41/8	50	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	Remove about 8 towers of DC 115-kV line. 25 feet new right-of-way needed on each side of existing right-of-way to accommodate new TC 500-kV line.	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 / New 500-kV TC line	B-14
45	0.7	45/1-45/3	50	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	Remove about 3 towers of DC 115-kV line. 25 feet new right-of-way needed on each side of existing right-of-way to accommodate new TC 500-kV line.	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1/ New 500-kV TC line	B-16
		45/3-45/6	150			New 500-kV line	B-1
50	4.1	50/1-50/5	150			New 500-kV line	B-1
		50/5-50/13	130	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	130 feet new right-of-way needed on south side of existing right-of-way to accommodate new 500-kV line	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line New 500-kV line	B-21
		50/13-50/21	50	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	Remove about 8 towers of existing DC 115-kV line. 25 feet new right-of-way needed on each side of existing right-of-way to accommodate new TC 500-kV line.	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1/ New 500-kV TC line	
		50/21-50/26	130	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	130 feet new right-of-way needed on south side of existing right-of-way to accommodate new 500-kV line	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line New 500-kV line	
52	4.8	52/1-52/2	0	North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 4 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	B-23
		52/2-52/9	0	North Camas-Oak Park SC 115-kV line North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 14 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Camas-Oak Park SC 115-kV line North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	
		52/9-52/17		North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 16 existing 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	
		52/17-52/24	150		Towers 52/20-52/22 are special tall river crossing towers (Figure B-23)	New 500-kV line	B-1 B-23

SC - Single Circuit
DC - Double Circuit
TC - Triple Circuit

Table B-2 West Option 1 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
36	0.2	36/1-36/2	30	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	30 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	B-7
40	2.7	40/1-40/11	150			New 500-kV line	B-1
		40/11-40/14	0	North Bonneville-Ross No. 2 SC 230-kV line North Bonneville-Ross No. 1 SC 230-kV line	Remove about 3 existing North Bonneville-Ross No. 1 230-kV towers and replace with 3 new DC 500-kV towers. Some new right-of-way needed at south end of existing right-of-way to accommodate tower 40/11.	North Bonneville-Ross No. 2 SC 230-kV North Bonneville-Ross No. 1 /New 500-kV DC line	B-13
46	0.5	46/1-46/3	0	North Bonneville-Ross No. 2 SC 230-kV line North Bonneville-Ross No. 1 SC 230-kV line	Remove about 2 existing North Bonneville-Ross No. 1 230-kV towers and replace with 3 new DC 500-kV towers	North Bonneville-Ross No. 2 SC 230-kV line North Bonneville-Ross No. 1 /New 500-kV DC line	B-17

Table B-3 West Option 2 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
36	0.2	36/1-36/2	30	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	30 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	B-7
36A	1.0	36A/1-36A/4	30	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	30 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	B-8
		36A/4-36A/6	0-30	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	Rebuild about 3 towers on McNary-Ross No. 1 345-kV line to narrower 345-kV line configuration to accommodate new 500-kV line.	New 500-kV line McNary-Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	
37	0.7	37/1-37/2	0	McNary-Ross No. 1 SC 345-kV line Sifton-Ross No. 1/Bonneville PH1-Alcoa No. 2 DC 115-kV line	Rebuild about 2 towers on the McNary-Ross No. 1 SC 345-kV line to narrower 345-kV line configuration to accommodate new 500-kV line.	New 500-kV line McNary Ross No. 1 SC 345-kV line	B-10
		37/2-37/4	0	McNary-Ross No. 1 SC 345-kV line	New 500-kV line constructed on north side of existing right-of-way	New 500-kV line McNary-Ross No. 1 SC 345-kV line	
38	0.7	38/1-38/5	0	McNary-Ross No. 1 SC 345-kV line	New 500-kV line constructed on north side of existing right-of-way	New 500-kV line McNary-Ross No. 1 SC 345-kV line	B-11
43	1.9	43/1-43/9	150			New 500-kV line	B-1
		43/9-43/10	Varies	North Bonneville-Ross No. 2 SC 230-kV line North Bonneville-Ross No. 1 SC 230-kV line	Remove and replace 1 tower on existing North Bonneville-Ross No. 1 SC 230-kV line with new DC 500-kV line	North Bonneville-Ross No. 2 SC 230-kV line North Bonneville-Ross No. 1 /New 500-kV DC line	B-15
48	2.5	48/1-48/14	0	North Bonneville-Ross No. 1 SC 230-kV line North Bonneville-Ross No. 2 SC 230-kV line	Remove about 14 towers of North Bonneville-Ross No. 1 line and replace with new DC 500-kV towers. About 100 feet new right-of-way needed between towers 48/13 and 48/14.	North Bonneville-Ross No. 2 SC 230-kV line North Bonneville-Ross No. 1/New 500-kV DC 500-kV line	B-19

Table B-3 West Option 2 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
51	2.1	51/1-51/11	0	North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 22 existing 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	B-22

Table B-4 West Option 3 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Final Right-of-Way Configuration	Figure
36	0.2	36/1-36/2	30	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	30 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	B-7
36A	1.0	36A/1-36A/4	30	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	30 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	B-8
		36A/4-36A/6	0-30	McNary Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	Rebuild about 3 towers on McNary-Ross No. 1 345-kV line to narrower 345-kV line configuration to accommodate new 500-kV line.	New 500-kV line McNary-Ross No. 1 SC 345-kV line Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	
37	0.7	37/1-37/2	0	McNary-Ross No. 1 SC 345-kV line Sifton-Ross No. 1/Bonneville PH1-Alcoa No. 2 DC 115-kV line	Rebuild about 2 towers on the McNary-Ross No. 1 SC 345-kV line to narrow 345-kV line configuration to accommodate new 500-kV line.	New 500-kV line McNary Ross No. 1 SC 345-kV line	B-10
		37/2-37/4	0	McNary-Ross No. 1 SC 345-kV line	New 500-kV line constructed on north side of existing right-of-way	New 500-kV line McNary-Ross No. 1 SC 345-kV line	
38	0.7	38/1-38/5	0	McNary-Ross No. 1 SC 345-kV line	New 500-kV line constructed on north side of existing right-of-way	New 500-kV line McNary-Ross No. 1 SC 345-kV line	B-11
39	5.3	39/1-39/20	0	McNary-Ross No. 1 SC 345-kV line	New 500-kV line constructed on north side of existing right-of-way	New 500-kV line McNary-Ross No. 1 SC 345-kV line	B-12
		39/20-39/23	105	McNary-Ross No. 1 SC 345-kV line	105 feet new right-of-way needed on south side of existing right-of-way to accommodate new 500-kV line.	McNary-Ross No. 1 SC 345-kV line New 500-kV line	
		39/23-39/27	105	McNary-Ross No. 1 SC 345-kV line North Bonneville-Ross No. 1/North Bonneville Ross No. 2 DC 115-kV line	105 feet new right-of-way needed on south side of existing right-of-way to accommodate new 500-kV line	McNary-Ross No. 1 SC 345-kV line North Bonneville-Ross No. 1/North Bonneville Ross No. 2 DC 115-kV line New 500-kV line	
T	0.3	T/1-T/3	150			New 500-kV line	B-1
49	2.7	49/1-49/7	150			New 500-kV line	B-1
		49/7-49/10	105	North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	105 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	B-20
		49/10-49/15	0	North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	About 4 towers on North Bonneville-Troutdale No. 2 SC 230-kV line removed and replaced with DC 500-kV line.	North Bonneville-Troutdale No. 2/New 500-kV DC line North Bonneville-Troutdale No. 1 SC 230-kV line	
51	2.1	51/1-51/11	0	North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 22 existing 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	B-22

Table B-5 Central Alternative Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
B	0.8	B/1-B/5	150			New 500-kV line	B-1
F	15.8	F/1-F/75	150			New 500-kV line	B-1
G	1.4	G/1-G/8	150			New 500-kV line	B-1
H	1.5	H/1-H/8	150			New 500-kV line	B-1
10	7.9	10/1-10/34	150			New 500-kV line	B-1
12	5.0	12/1-12/20	150			New 500-kV line	B-1
15	1.9	15/1-15/9	150			New 500-kV line	B-1
23	1.3	23/1-23/7	150			New 500-kV line	B-1
L	1.7	L/1-L/5	150			New 500-kV line	B-1
		L/5-L/9	150		150 feet new right-of-way on south side of existing Pacificorp right-of-way to accommodate new 500-kV line.	Pacificorp SC 115-kV line on Pacificorp right-of-way New 500-kV line	B-28
18	7.2	18/1-18/22	150		150 feet new right-of-way on south side of existing Pacificorp right-of-way to accommodate new 500-kV line.	PacifiCorp SC 115-kV line on PacifiCorp right-of-way New 500-kV line	B-5
		18/22-18/32	150			New 500-kV line	B-1
28	5.9	28/1-28/27	150			New 500-kV line	B-1
V	6.0	V/1-V/27	150			New 500-kV line	B-1
P	8.6	P/1-P/39	150			New 500-kV line	B-1
35	2.5	35/1-35/15	150			New 500-kV line	B-1
T	0.3	T/1-T/3	150			New 500-kV line	B-1
49	2.7	49/1-49/7	150			New 500-kV line	B-1
		49/7-49/10	105	North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	105 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	B-20
		49/10-49/15	0	North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	About 4 towers on North Bonneville-Troutdale No. 2 SC 230-kV line removed and replaced with DC 500-kV line.	North Bonneville-Troutdale No. 2/New 500-kV DC line North Bonneville-Troutdale No. 1 SC 230-kV line	
51	2.1	51/1-51/11	0	North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 22 existing 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	B-22
52	4.8	52/1-52/2	0	North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 4 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	B-23
		52/2-52/9	0	North Camas-Oak Park SC 115-kV line North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 14 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Camas-Oak Park SC 115-kV line North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	
		52/9-52/17		North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 16 existing 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	
		52/17-52/24	150		Towers 52/20-52/22 are special tall river crossing towers (Figure B-23)	New 500-kV line	B-1 B-23

SC - Single Circuit
DC - Double Circuit
TC - Triple Circuit

Table B-6 Central Option 1 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
A	2.5	A/1-A/9	125	Longview-Chehalis No. 1 SC. 230-kV line Napavine-Allston No. 1 SC 500-kV line Longview-Chehalis No. 3 SC 230-kV line Paul-Allston No. 2 SC 500-kV line	125 new right-of-way needed on east side of existing right-of-way to accommodate new 500-kV line	New 500-kV line Longview-Chehalis SC. 230-kV line Napavine-Allston No. 1 SC 500-kV line Longview-Chehalis No. 3 SC 230-kV line Paul-Allston No. 2 SC 500-kV line	B-24
		A/9-A/12	150	Napavine-Allston No. 1 SC 500-kV line Longview-Chehalis No. 1 SC. 230-kV line Longview-Chehalis No. 3 SC 230-kV line Paul-Allston No. 2 SC 500-kV line	150 feet new right-of-way needed on east side of existing right-of-way to accommodate new 500-kV line and adequate separation distance between existing and proposed 500-kV lines.	New 500-kV line Napavine-Allston No. 1 SC 500-kV line Longview-Chehalis SC. 230-kV line Longview-Chehalis No. 3 SC 230-kV line Paul-Allston No. 2 SC 500-kV line	

Table B-7 Central Option 2 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
1	6.4	1/1-1/28	150			New 500-kV line	B-1
4	0.8	4/1-4/2	Varies	Lexington-Delameter No. 1 SC 115-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	Remove about 2 wood pole structures of Lexington-Delameter No. 1 SC 115-kV line 150 feet new right-of-way needed 250 feet east of Tower 4/1 to accommodate new 500-kV line	New 500-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	B-3
		4/2-4/3	0	BPA Lexington Substation		New 500-kV line around Lexington Substation	B-1
		4/3-4/5	0	Ross-Lexington No. 1 230-kV line		New 500-kV line Ross-Lexington No. 1 230-kV line	B-3
5	1.9	5/1-5/10	150		Line is on existing BPA right-of-way 850 feet east of Tower 5/1 before requiring 150 feet of new right-of-way. Line crosses I-5 and heads east.	New 500-kV line	B-1
8	1.6	8/1-8/9	150			New 500-kV line	B-1
11	5.0	11/1-11/21	150			New 500-kV line	B-1

Table B-8 Central Option 3 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
M	2.4	M/1-M/11	150			New 500-kV line	B-1
26	6.5	26/1-26/35	150			New 500-kV line	B-1
30	6.0	30/1-30/31	150			New 500-kV line	B-1

Table B-9 East Alternative Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
B	0.8	B/1-B/5	150			New 500-kV line	B-1
F	15.8	F/1-F/75	150			New 500-kV line	B-1
I	2.8	I/1-1/13	150			New 500-kV line	B-1
K	22.8	K/1-K/94	150			New 500-kV line	B-1
W	1.3	W/1-W/6	150			New 500-kV line	B-1
O	19.4	O/1-O/83	150			New 500-kV line	B-1
Q	2.6	Q/1-Q/13	150			New 500-kV line	B-1
S	0.4	S/1-S/3	150			New 500-kV line	B-1
49	2.7	49/1-49/7	150			New 500-kV line	B-1
		49/7-49/10	105	North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	105 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	B-20
		49/10-49/15	0	North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	About 4 towers on North Bonneville-Troutdale No. 2 SC 230-kV line removed and replaced with DC 500-kV line.	North Bonneville-Troutdale No. 2/New 500-kV DC line North Bonneville-Troutdale No. 1 SC 230-kV line	
51	2.1	51/1-51/11	0	North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 22 existing 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	B-22
52	4.8	52/1-52/2	0	North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 4 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	B-23
		52/2-52/9	0	North Camas-Oak Park SC 115-kV line North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 14 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Camas-Oak Park SC 115-kV line North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	
		52/9-52/17		North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 16 existing 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	
		52/17-52/24	150		Towers 52/20-52/22 are special tall river crossing towers (Figure B-23)	New 500-kV line	B-1 B-23

SC - Single Circuit
DC - Double Circuit
TC - Triple Circuit

Table B-10 East Option 1 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
3	7.8	3/1-3/38	150			New 500-kV line	B-1
7	2.1	7/1-7/10	150			New 500-kV line	B-1
11	5.0	11/1-11/21	150			New 500-kV line	B-1
J	2.7	J/1-J/13	150			New 500-kV line	B-1

Table B-11 East Option 2 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
35	2.5	35/1-35/15	150			New 500-kV line	B-1
P	8.6	P/1-P/39	150			New 500-kV line	B-1
T	0.3	T/1-T/3	150			New 500-kV line	B-1
U	6.1	U/1-U/26	150			New 500-kV line	B-1
V	6.0	V/1-V/27	150			New 500-kV line	B-1

Table B-12 East Option 3 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Final Right-of-Way Configuration	Figure
R	3.7	R/1-R/10	150			New 500-kV line	B-1
		R/10-R/19	105	McNary-Ross No. 1 SC 345-kV line North Bonneville-Ross No. 1&2 DC 230-kV line	105 feet of new right-of-way needed on north side of existing BPA right-of-way to accommodate new 500-kV line	New 500-kV line McNary-Ross No. 1 SC 345-kV line North Bonneville-Ross No. 1 and 2 DC 230-kV line	B-29

Table B-13 Crossover Alternative Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
2	6.0	2/1-2/18	0	Lexington-Delameter No. 1 SC 115-kV line Longview-Chehalis No. 1 SC 230-kV line	Remove about 28 wood H-Frame structures of the Lexington-Delameter No. 1 SC 115-kV line to accommodate new 500-kV line.	New 500-kV line Longview-Chehalis No. 1 SC 230-kV line	B-2
		2/18-2/27	0	Lexington-Longview No. 2 SC 230-kV line Lexington-Delameter No. 1 SC 115-kV line Lexington-Longview No. 1 SC 115-kV line	Remove about 15 wood pole structures of the Lexington-Delameter No. 1 SC 115-kV line to accommodate new 500-kV line.	New 500-kV line Lexington-Longview No. 2 SC 230-kV line Lexington-Longview No. 1 SC 115-kV line	
		2/27-2/28	150	Lexington-Delameter No. 1 SC 115-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	Remove about 2 wood pole structures of the Lexington-Delameter No. 1 SC 115-kV line 150 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	
4	0.8	4/1-4/2	Varies	Lexington-Delameter No. 1 SC 115-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	Remove about 2 wood pole structures of Lexington-Delameter No. 1 SC 115-kV line 150 feet new right-of-way needed 250 feet east of Tower 4/1 to to accommodate new 500-kV line	New 500-kV line Lexington-Longview No. 1 SC 115-kV line Lexington-Longview No. 2 SC 230-kV line	B-3
		4/2-4/3	0	BPA Lexington Substation		New 500-kV line around Lexington Substation	B-1
		4/3-4/5	0	Ross-Lexington No. 1 230-kV line		New 500-kV line Ross-Lexington No. 1 230-kV line	B-3
9	18.7	9/1-9/11	0	Cowlitz PUD SC 115-kV line Ross-Lexington No. 1 SC 230-kV line	Remove about 11 wood pole structures of the Cowlitz PUD SC 115-kV line to accommodate new 500-kV line	New 500-kV line Ross-Lexington No. 1 SC 230-kV line	B-4
		9/11-9/20	0	Ross-Lexington No. 1 SC230-kV line		New 500-kV line Ross-Lexington No. 1 SC 230-kV line	
		9/20-9/21	22.5	Ross-Lexington No. 1 SC 230-kV line	22.5 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line Ross-Lexington No. 1 SC 230-kV line	
		9/21-9/82	0	Ross-Lexington No. 1 SC 230-kV line		New 500-kV line Ross-Lexington No. 1 SC 230-kV line	
14	1.5	14/1-14/7	150			New 500-kV line	B-1
15	1.9	15/1-15/9	150			New 500-kV line	B-1
23	1.3	23/1-23/7	150			New 500-kV line	B-1
L	1.7	L/1-L/5	150			New 500-kV line	B-1
		L/5-L/9	150		150 feet new right-of-way on south side of existing Pacificorp right-of-way to accommodate new 500-kV line.	Pacificorp SC 115-kV line on Pacificorp right-of-way New 500-kV line	B-28
18	7.2	18/1-18/22	150		150 feet new right-of-way on south side of existing Pacificorp right-of-way to accommodate new 500-kV line.	PacifiCorp SC 115-kV line on PacifiCorp right-of-way New 500-kV line	B-5
		18/22-18/32	150			New 500-kV line	B-1
N	1.6	N/1-N/9	150			New 500-kV line	B-1
W	1.3	W/1-W/6	150			New 500-kV line	B-1
O	19.4	O/1-O/83	150			New 500-kV line	B-1
Q	2.6	Q/1-Q/13	150			New 500-kV line	B-1
S	0.4	S/1-S/3	150			New 500-kV line	B-1

Table B-13 Crossover Alternative Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
49	2.7	49/1-49/7	150			New 500-kV line	B-1
		49/7-49/10	105	North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	105 feet new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line	New 500-kV line North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	B-20
		49/10-49/15	0	North Bonneville-Troutdale No. 2 SC 230-kV line North Bonneville-Troutdale No. 1 SC 230-kV line	About 4 towers on North Bonneville-Troutdale No. 2 SC 230-kV line removed and replaced with DC 500-kV line.	North Bonneville-Troutdale No. 2/New 500-kV DC line North Bonneville-Troutdale No. 1 SC 230-kV line	
51	2.1	51/1-51/11	0	North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 22 existing 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	B-22
52	4.8	52/1-52/2	0	North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 4 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	B-23
		52/2-52/9	0	North Camas-Oak Park SC 115-kV line North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 14 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Camas-Oak Park SC 115-kV line North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	
		52/9-52/17		North Bonneville-Troutdale No. 1 SC 230-kV line North Bonneville-Troutdale No. 2 SC 230-kV line	Remove about 16 existing 230-kV towers and replace with DC 230-kV line parallel to new 500-kV line	North Bonneville-Troutdale No. 1&2 DC 230-kV line New 500-kV line	
		52/17-52/24	150		Towers 52/20-52/22 are special tall river crossing towers (Figure B-23)	New 500-kV line	B-1 B-23

SC - Single Circuit
DC - Double Circuit
TC - Triple Circuit

Table B-14 Crossover Option 1 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
47	0.7	47/1-47/4	0	North Bonneville-Ross No. 2 SC 230-kV line North Bonneville-Ross No. 1 SC 230-kV line	Remove about 4 towers on North Bonneville-Ross No. 1 SC 230-kV line and replace with a DC 500-kV line	North Bonneville-Ross No. 2 SC 230-kV line North Bonneville-Ross No. 1/New 500-kV DC line	B-18
48	2.5	48/1-48/14	0	North Bonneville-Ross No. 1 SC 230-kV line North Bonneville-Ross No. 2 SC 230-kV line	Remove about 14 towers of North Bonneville-Ross No. 1 line and replace with new DC 500-kV towers. About 100 feet new right-of-way needed between towers 48/13 and 48/14.	North Bonneville-Ross No. 2 SC 230-kV line North Bonneville-Ross No. 1/New 500-kV DC 500-kV line	B-19
50	4.1	50/1-50/5	150			New 500-kV line	B-1
		50/5-50/13	130	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	130 feet new right-of-way needed on south side of existing right-of-way to accommodate new 500-kV line	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line New 500-kV line	B-21
		50/13-50/21	50	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	Remove about 8 towers of existing DC 115-kV line. 25 feet new right-of-way needed on each side of existing right-of-way to accommodate new TC 500-kV line.	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1/New 500-kV TC line	
		50/21-50/26	130	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line	130 feet new right-of-way needed on south side of existing right-of-way to accommodate new 500-kV line	Bonneville PH1-Alcoa No. 2/North Camas-Sifton No. 1 DC 115-kV line New 500-kV line	

Table B-15 Crossover Option 2 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Proposed Right-of-Way Configuration	Figure
C	3.0	C/1-C/17	0	Napavine-Allston No. 1 SC 500-kV line Longview-Chehalis No. 1 SC. 230-kV line Longview-Chehalis No. 3 SC 230-kV line Paul-Allston No. 2 SC 500-kV line	About 26 existing 230-kV towers removed and rebuilt with DC 230-kV line. Build new 500-kV line at location of Longview-Chehalis No. 1 SC 230-kV line. New 500-kV line will operate as Napavine-Allston No. 1 SC 500-kV line. Old Napavine-Allston No. 1 SC 500-kV line will operate as new proposed 500-kV line .	Napavine-Allston No. 1 500-kV line (operate as new 500-kV line) New 500-kV line (operate as Napavine-Allston No. 1 SC 500-kV line) Longview-Chehalis No. 1&3 DC 230-kV line Paul-Allston No. 2 SC 500-kV line	B-25
E	1.3	E/1-E/6	0	Napavine-Allston No. 1 SC 500-kV line Longview-Chehalis No. 1 SC. 230-kV line Longview-Chehalis No. 3 SC 230-kV line Paul-Allston No. 2 SC 500-kV line	About 10 existing 230-kV towers removed and rebuilt with DC 230-kV line. Build new 500-kV line at location of Longview-Chehalis No. 1 SC 230-kV line. New 500-kV line will operate as Napavine-Allston No. 1 SC 500-kV line. Old Napavine-Allston No. 1 SC 500-kV line will operate as new proposed 500-kV line.	Napavine-Allston No. 1 500-kV line (operate as new 500-kV line) New 500-kV line (operate as Napavine-Allston No. 1 SC 500-kV line) Longview-Chehalis No. 1&3 DC 230-kV line Paul-Allston No. 2 SC 500-kV line	B-27
		E/6-E/7	0	Longview-Chehalis No. 1 SC. 230-kV line		New 500-kV line Longview-Chehalis No. 1 SC. 230-kV line	

Table B-16 Crossover Option 3 Tower Configurations

Segment	Segment Length (miles)	Section (Tower to Tower)	Additional Right-of-Way Required (Feet)	Existing BPA Right-of-Way Configuration	Proposed Action	Final Right-of-Way Configuration	Figure
D	2.9	D/1-D/17	125	Napavine-Allston No. 1 SC 500-kV line Longview-Chehalis No. 1 SC. 230-kV line Longview-Chehalis No. 3 SC 230-kV line Paul-Allston No. 2 SC 500-kV line	125 new right-of-way needed on east side of existing right-of-way to accommodate new 500-kV line. New 500-kV line crosses Napavine-Allston No. 1 SC 500-kV line between towers D/16 and D/17 on existing BPA right-of-way.	New 500-kV line Napavine-Allston No. 1 SC 500-kV line Longview-Chehalis No. 1SC. 230-kV line Longview-Chehalis No. 3 SC 230-kV line Paul-Allston No. 2 SC 500-kV line	B-26
E	1.3	E/1-E/6	0	Napavine-Allston No. 1 SC 500-kV line Longview-Chehalis No. 1 SC. 230-kV line Longview-Chehalis No. 3 SC 230-kV line Paul-Allston No. 2 SC 500-kV line	About 10 existing 230-kV towers removed and rebuilt with DC 230-kV line. Build new 500-kV line at location of Longview-Chehalis No. 1 SC 230-kV line. New 500-kV line will operate as Napavine-Allston No. 1 SC 500-kV line. Old Napavine-Allston No. 1 SC 500-kV line will operate as new proposed 500-kV line.	Napavine-Allston No. 1 500-kV line (operate as new 500-kV line) New 500-kV line (operate as Napavine-Allston No. 1 SC 500-kV line) Longview-Chehalis No. 1&3 DC 230-kV line Paul-Allston No. 2 SC 500-kV line	B-27
		E/6-E/7	0	Longview-Chehalis No. 1 SC. 230-kV line		New 500-kV line Longview-Chehalis No. 1 SC. 230-kV line	

Page intentionally left blank

Figure B-1 Route Segments Requiring New Right-of-Way 1, 3, 5, 7, 8, 10, 11, 12, 14, 15, 23, 26, 28, 30, 35, B, F, G, H, I, J, K, M, N, O, P, Q, S, T, U, V, W

Proposed. New Single-Circuit Tower on New Right-of-Way

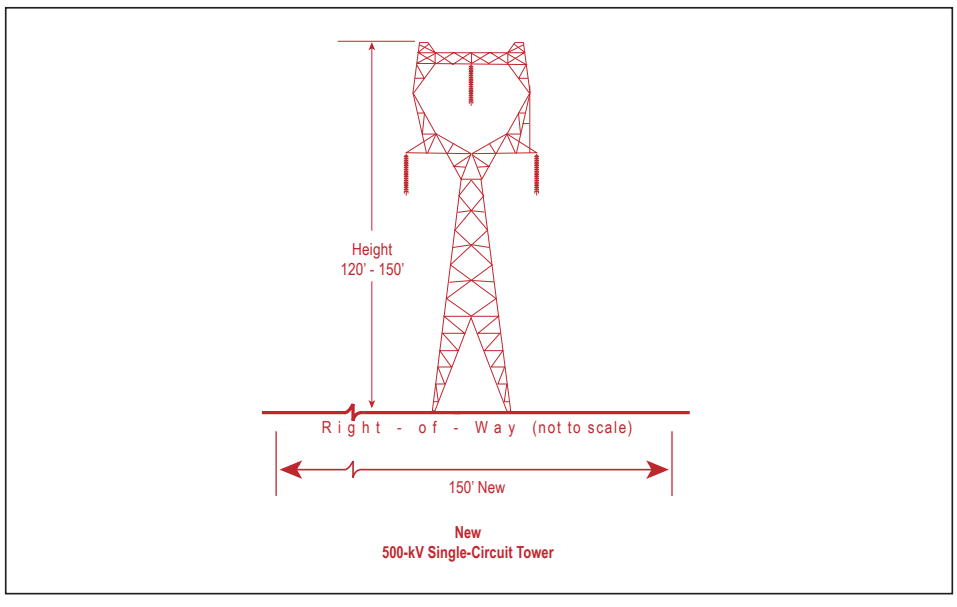
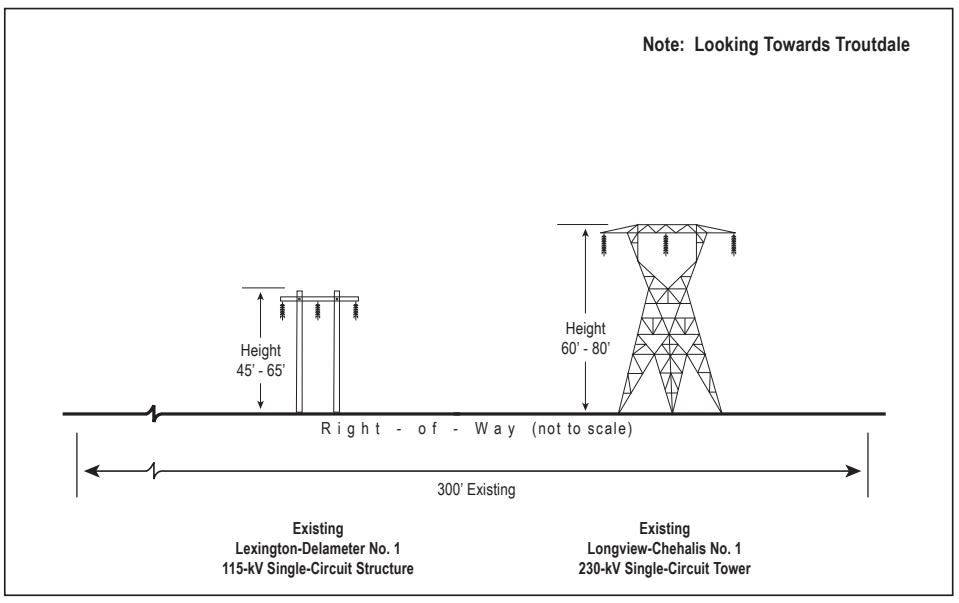


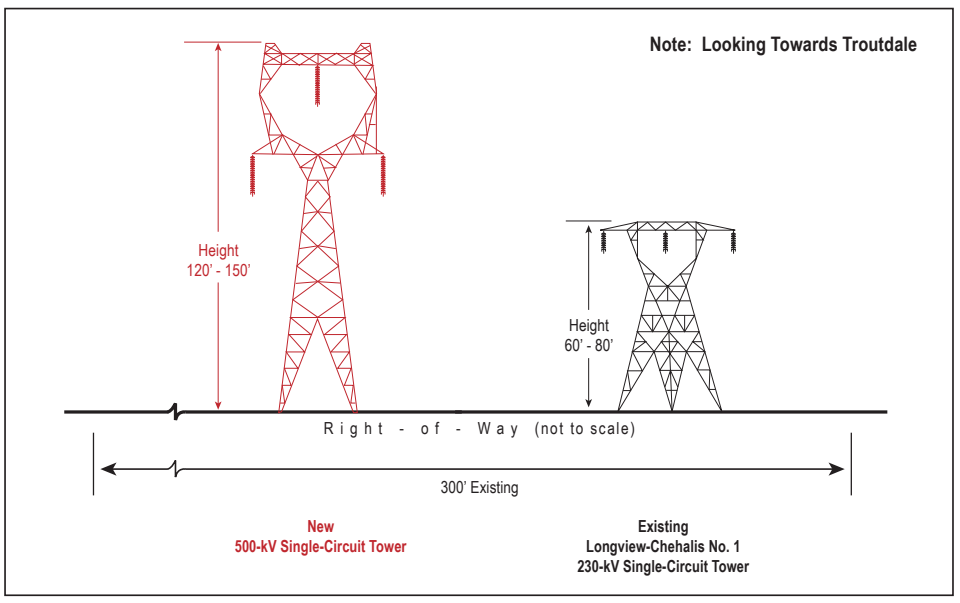
Figure B-2 Route Segment 2

Towers 2/1-2/18

Existing. Single-Circuit Structure Lexington-Delameter No. 1 Line Parallel to the Longview-Chehalis No. 1 Line

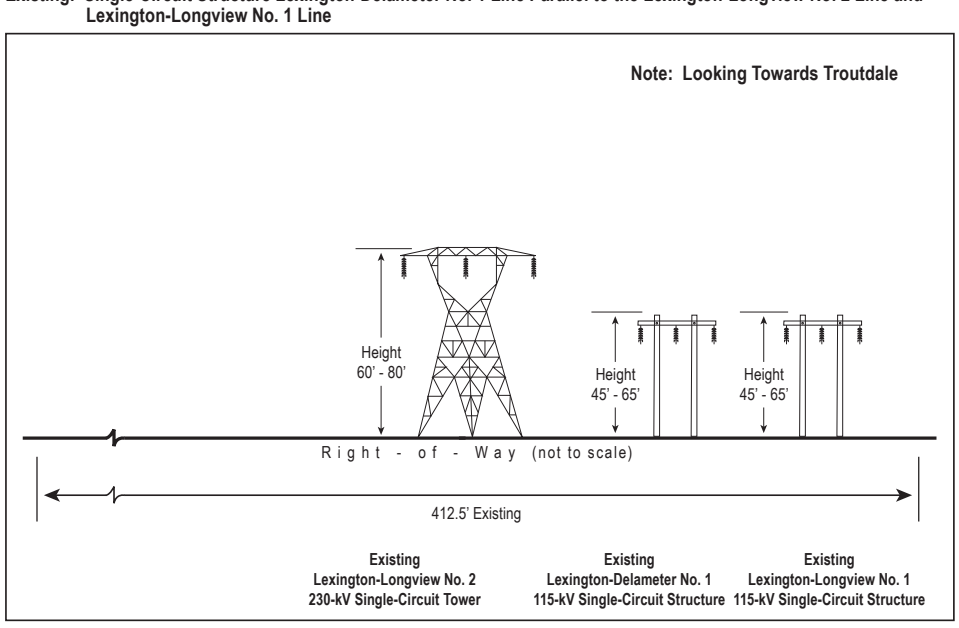


Proposed. New Single-Circuit Tower Replacing Lexington-Delameter No. 1 Line Parallel to the Longview-Chehalis No. 1 Line

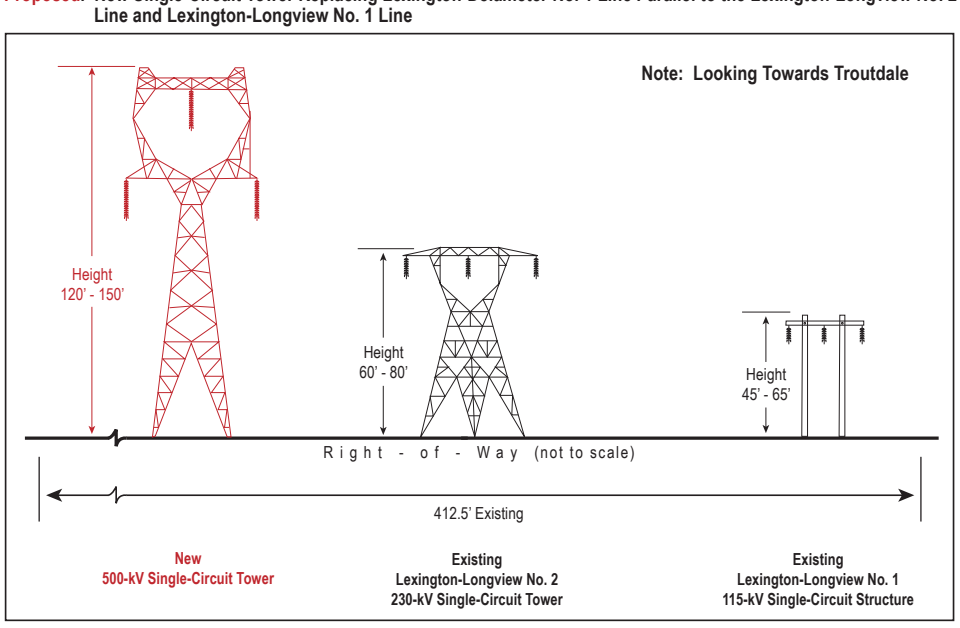


Towers 2/18-2/27

Existing. Single-Circuit Structure Lexington-Delameter No. 1 Line Parallel to the Lexington-Longview No. 2 Line and Lexington-Longview No. 1 Line

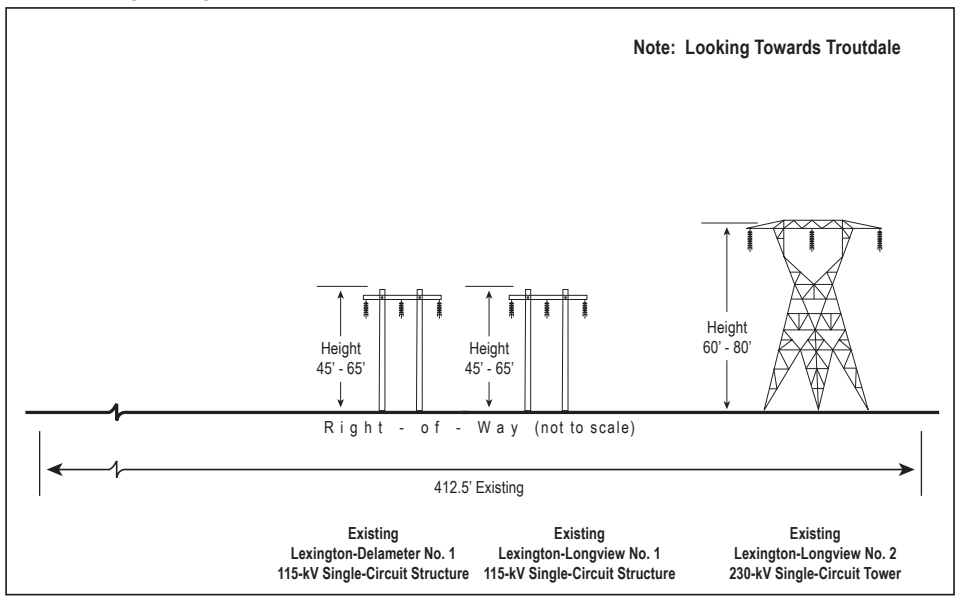


Proposed. New Single-Circuit Tower Replacing Lexington-Delameter No. 1 Line Parallel to the Lexington-Longview No. 2 Line and Lexington-Longview No. 1 Line



Towers 2/27-2/28

Existing. Single-Circuit Structure Lexington-Delameter No. 1 Line Parallel to the Lexington-Longview No. 2 Line and Lexington-Longview No. 1 Line



Proposed. New Single-Circuit Tower Replacing Lexington-Delameter No. 1 Line Parallel to the Lexington-Longview No. 2 Line and Lexington-Longview No. 1 Line

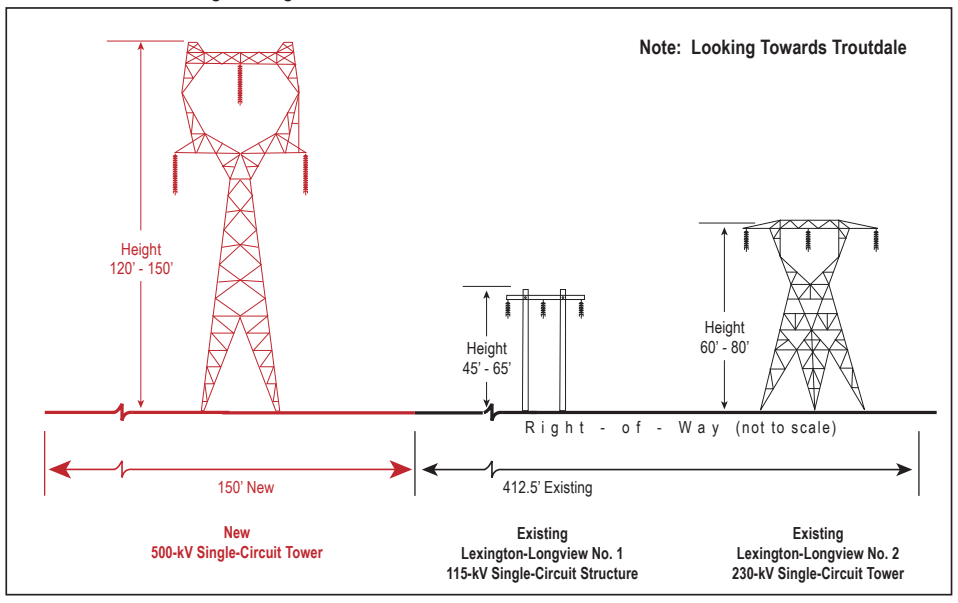
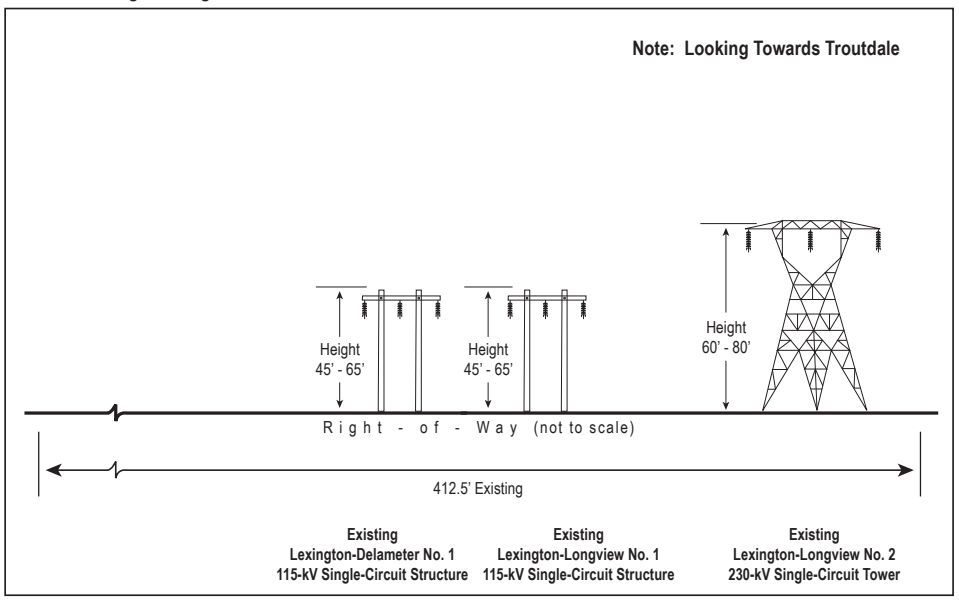


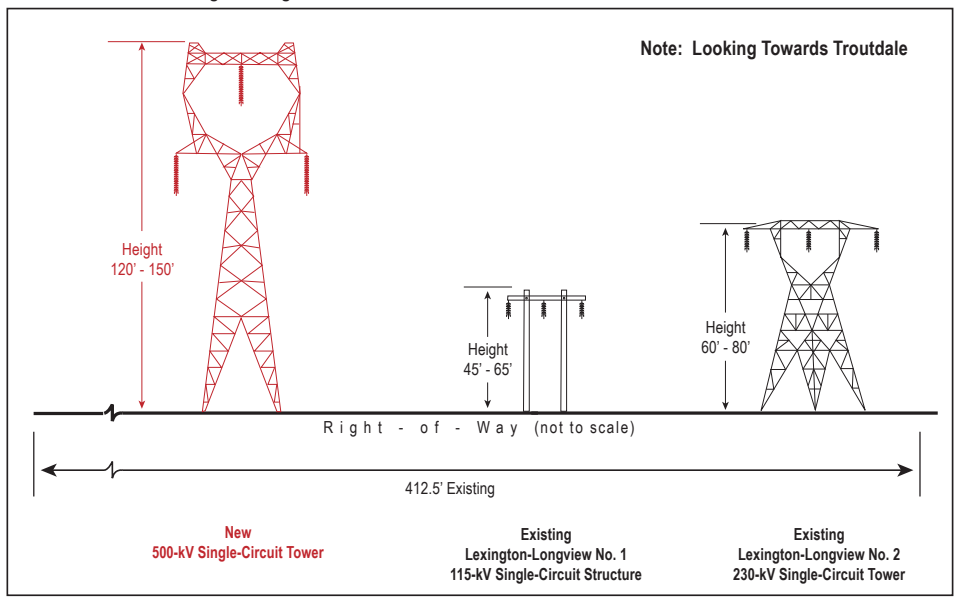
Figure B-3 Route Segment 4

Towers 4/1-4/2*

Existing. Single-Circuit Structure Lexington-Delameter No. 1 Line Parallel to the Lexington-Longview No. 2 Line and Lexington-Longview No. 1 Line



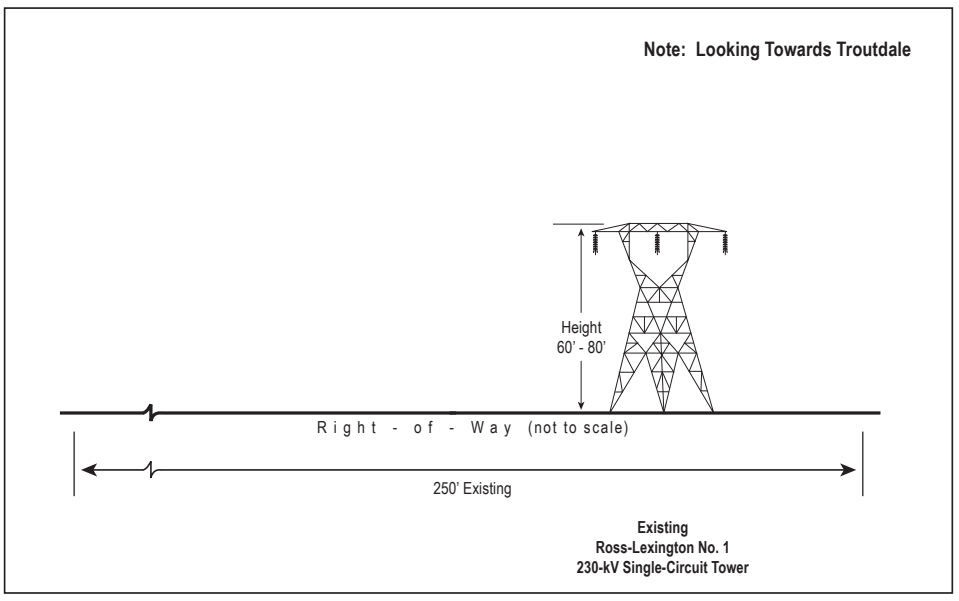
Proposed. New Single-Circuit Tower Replacing Lexington-Delameter No. 1 Line Parallel to the Lexington-Longview No. 2 Line and Lexington-Longview No. 1 Line



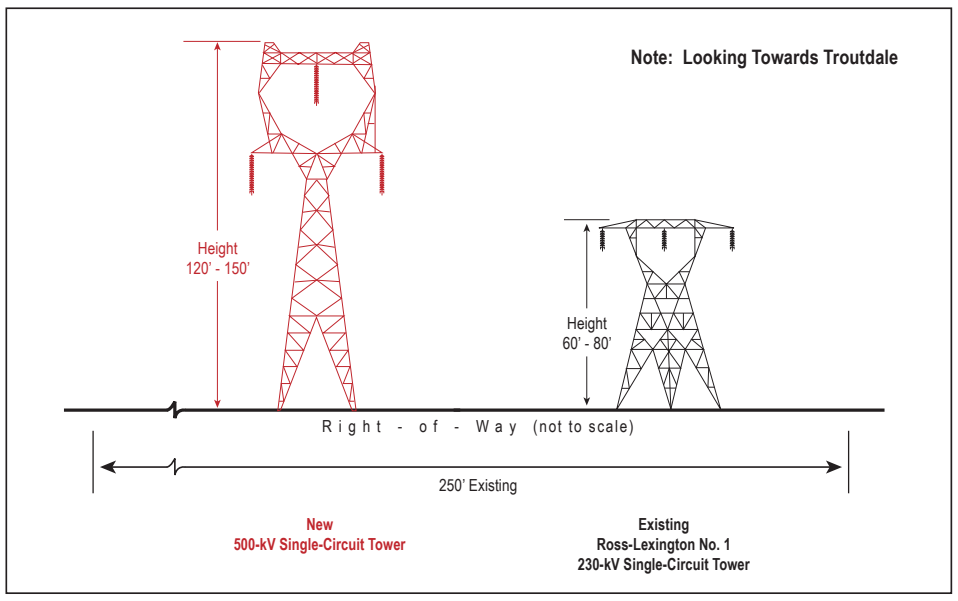
* Note: 150 feet of additional right-of-way is needed from tower 4/1 to approximately 250 feet east where existing right-of-way is not currently available. See Table B-1 for more information.

Towers 4/2-4/5*

Existing. Single-Circuit Tower Ross-Lexington No. 1 Line



Proposed. New Single-Circuit Tower Parallel to the Ross-Lexington No. 1 Line

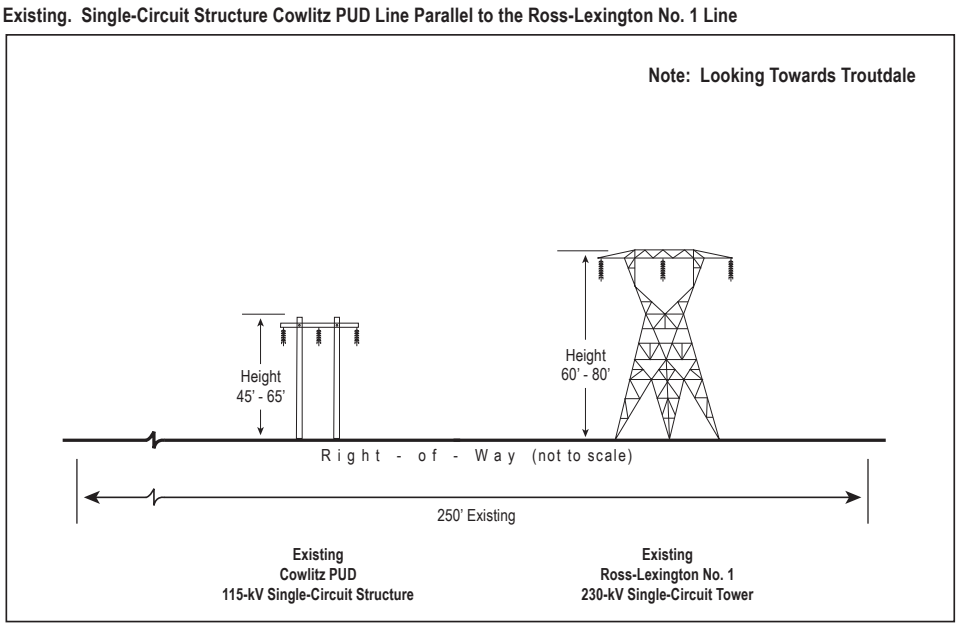


* Note: From towers 4/2-4/3 the proposed 500-kV line will cross over BPA fee-owned land near the existing Lexington Substation before it parallels the Ross-Lexington No. 1 230-kV line. See Table B-1 for more information.

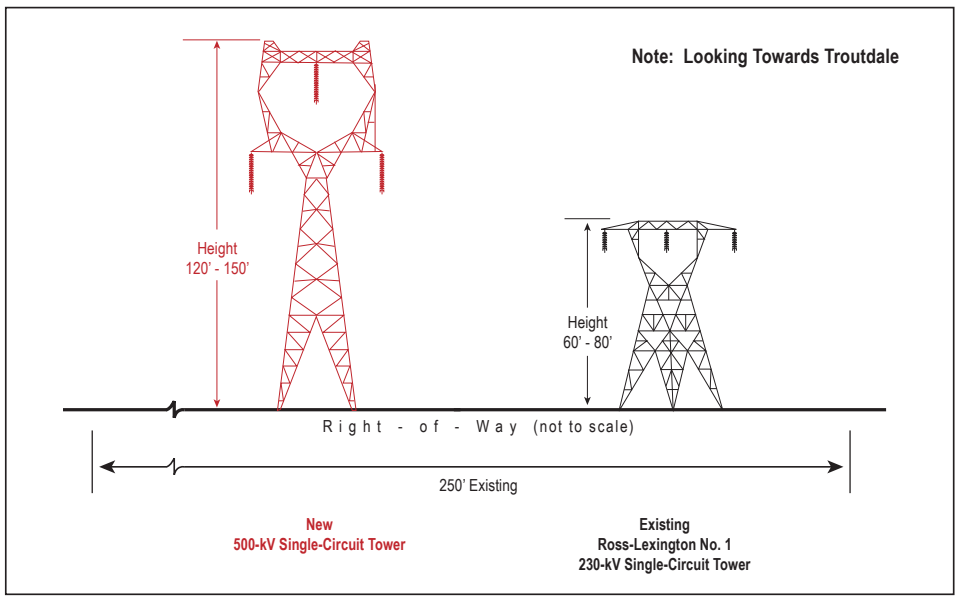
Figure B-4 Route Segment 9

Towers 9/1-9/11

Existing. Single-Circuit Structure Cowlitz PUD Line Parallel to the Ross-Lexington No. 1 Line

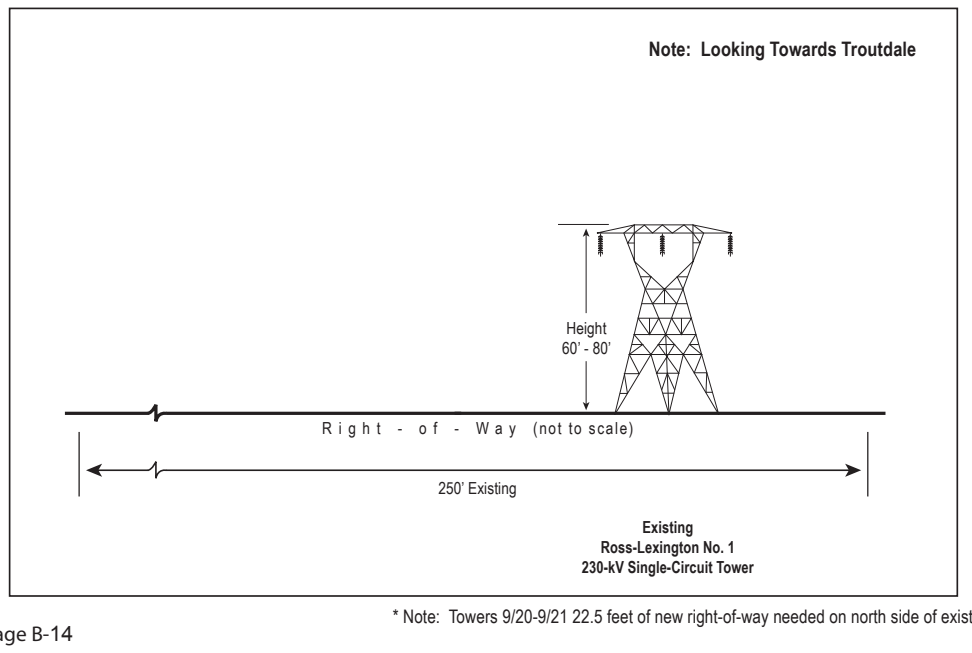


Proposed. New Single-Circuit Tower Replacing Cowlitz PUD Line Parallel to the Ross-Lexington No. 1 Line

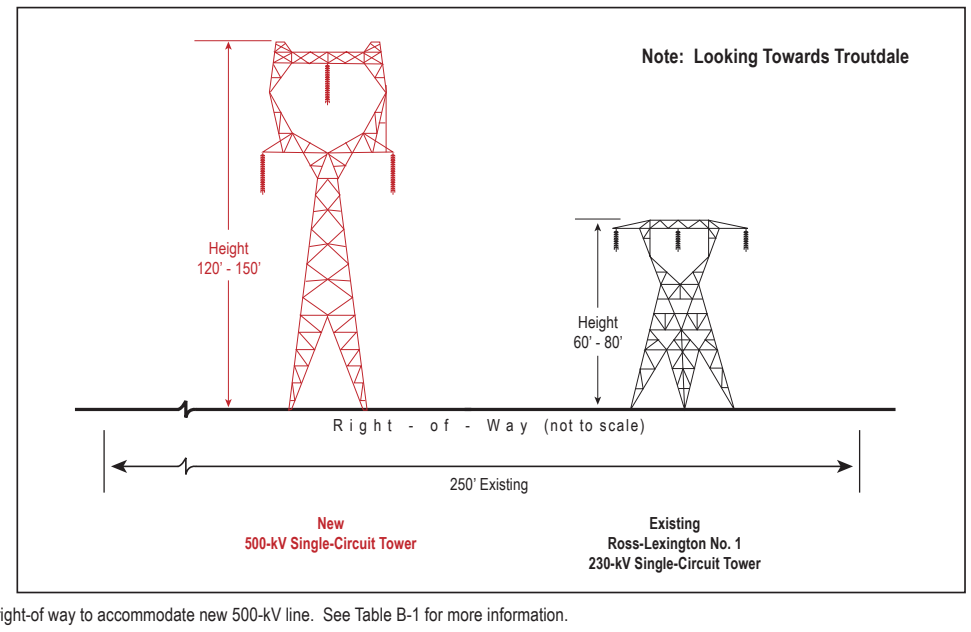


Towers 9/11-9/82*

Existing. Single-Circuit Tower Ross-Lexington No. 1 Line



Proposed. New Single-Circuit Tower Parallel to the Ross-Lexington No. 1 Line

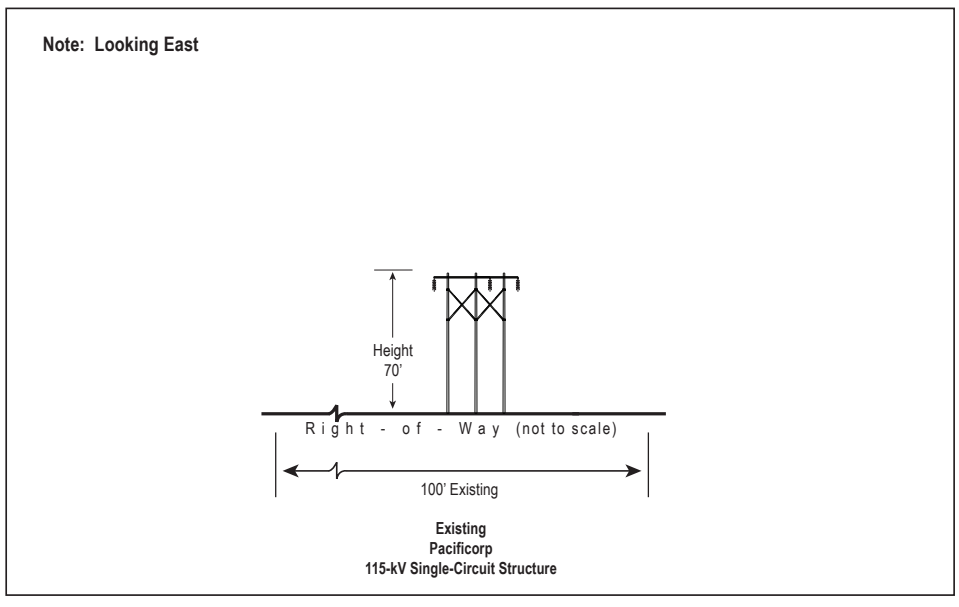


* Note: Towers 9/20-9/21 22.5 feet of new right-of-way needed on north side of existing right-of way to accommodate new 500-kV line. See Table B-1 for more information.

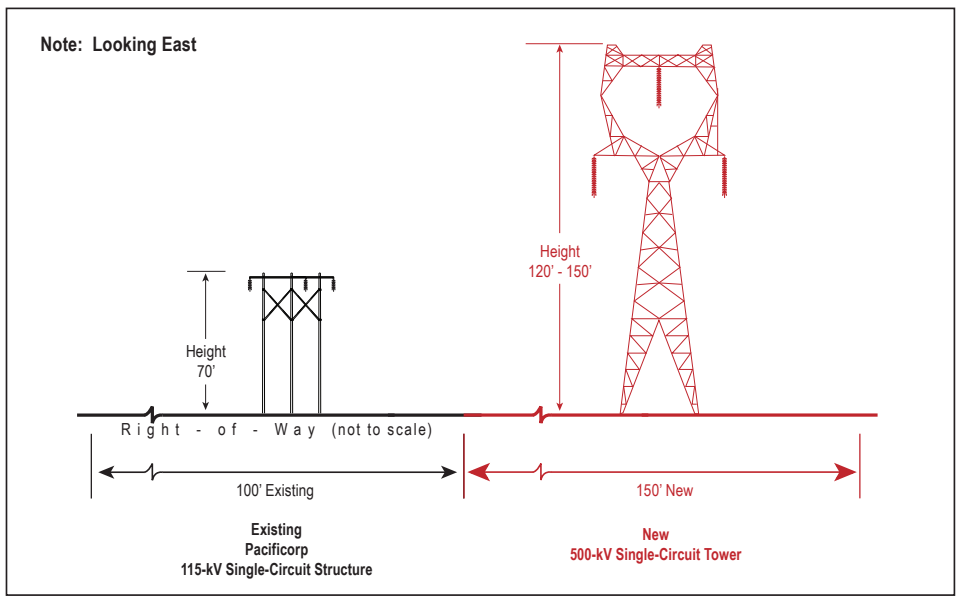
Figure B-5 Route Segment 18

Towers 18/1-18/22*

Existing. Single-Circuit Structure Pacificorp 115-kV Line



Proposed. New Single-Circuit Tower Parallel to the Pacificorp 115-kV Line

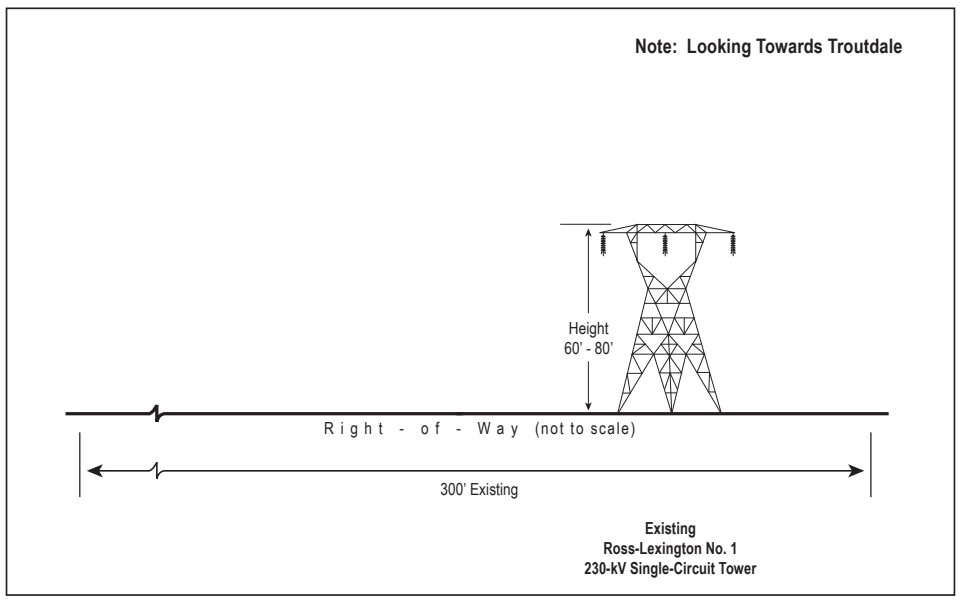


* Note: Towers 18/22-18/32 will require 150 feet of new right-of-way. See Figure B-1 for more information.

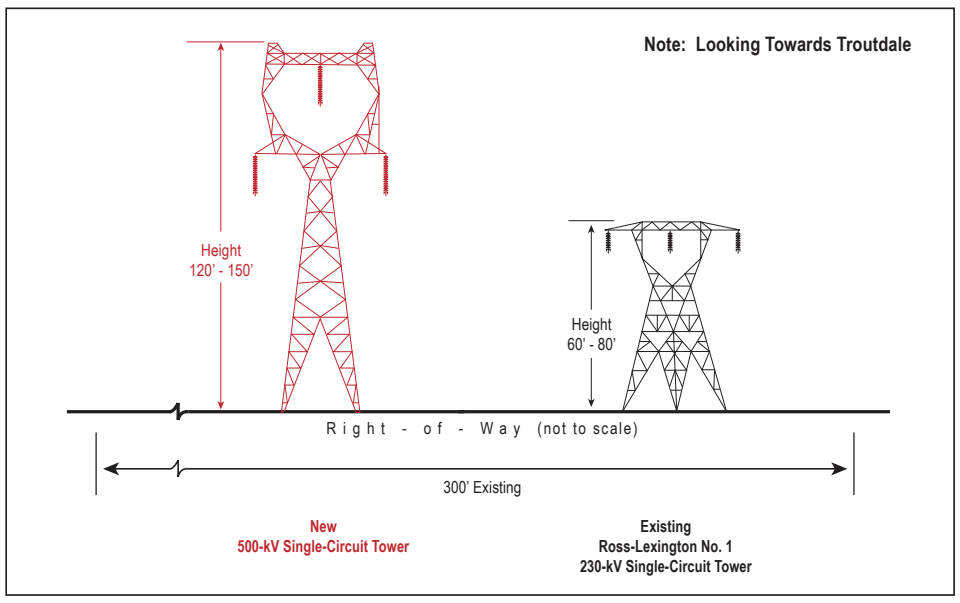
Figure B-6 Route Segment 25

Towers 25/1-25/106*

Existing. Single-Circuit Tower Ross-Lexington No. 1 Line



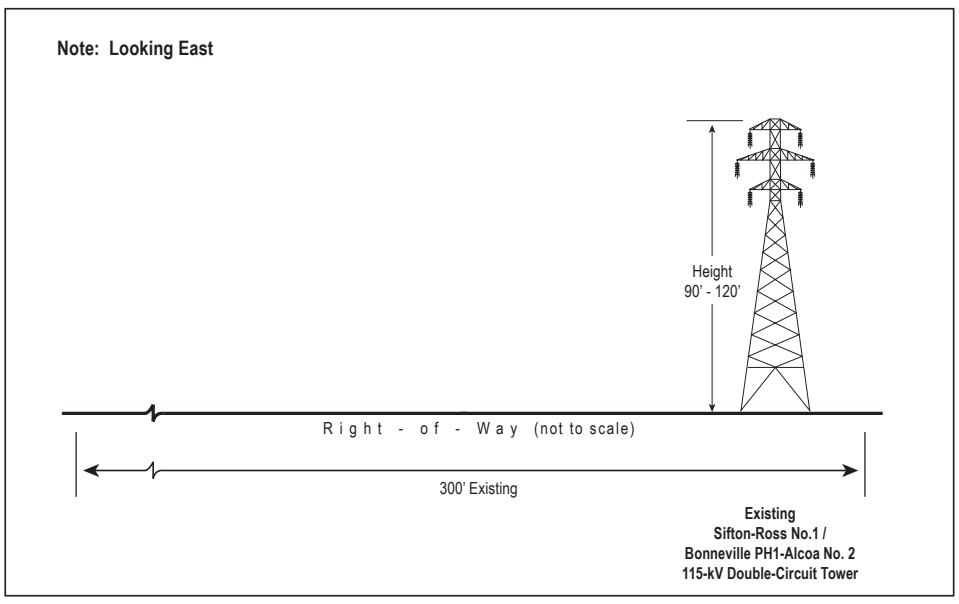
Proposed. New Single-Circuit Tower Parallel to the Ross-Lexington No. 1 Line



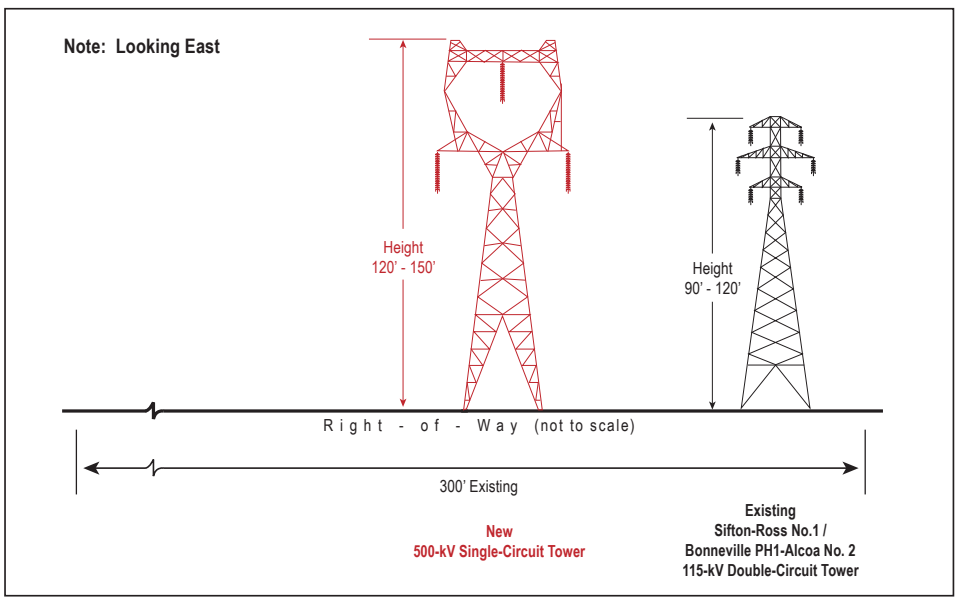
* Note: Towers 25/18-25/19 12.5 feet of new right-of-way needed on east side of existing right-of way to accommodate new 500-kV line. See Table B-1 for more information.

Towers 25/106-25/110

Existing. Double-Circuit Tower Sifton-Ross No. 1 Line / Bonneville PH1-Alcoa No. 2 Line

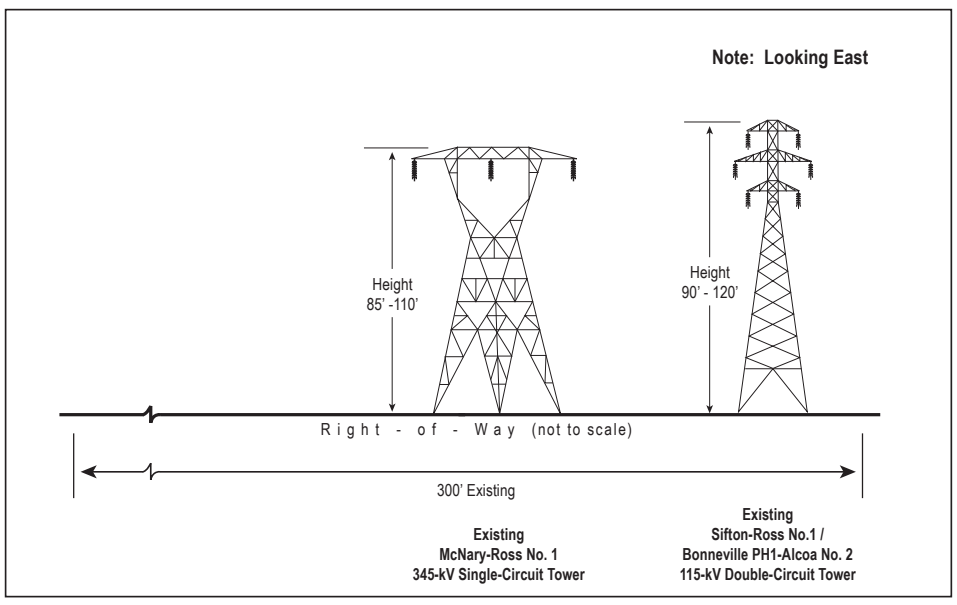


Proposed. New Single-Circuit Tower Parallel to the Sifton-Ross No. 1 Line / Bonneville PH1-Alcoa No. 2 Line

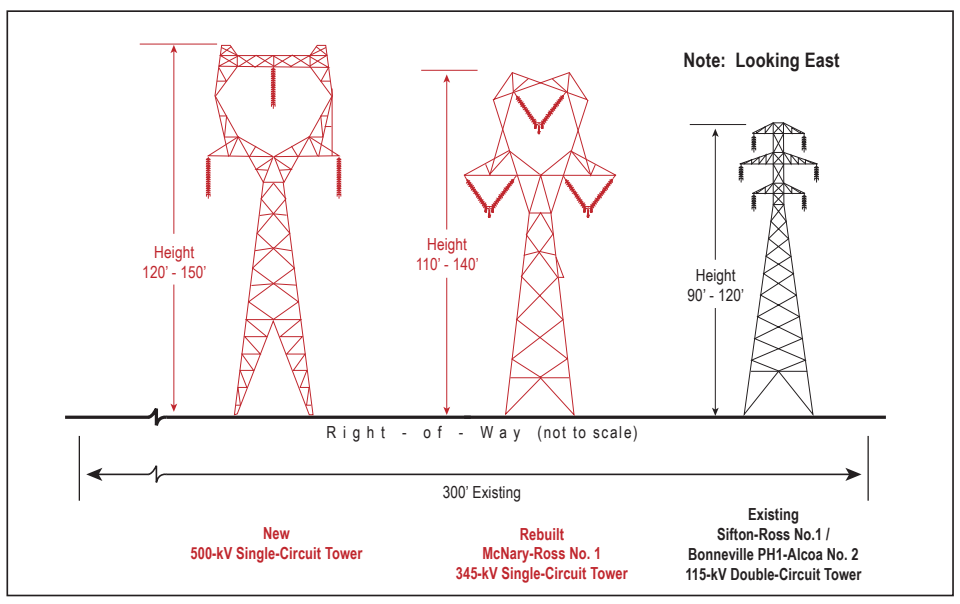


Towers 25/110-25/151*

Existing. Single-Circuit McNary-Ross No. 1 Line Parallel to the Sifton-Ross No. 1 Line / Bonneville PH1-Alcoa No. 2 Line



Proposed. New Single-Circuit Tower Parallel to Rebuilt McNary-Ross No. 1 Line

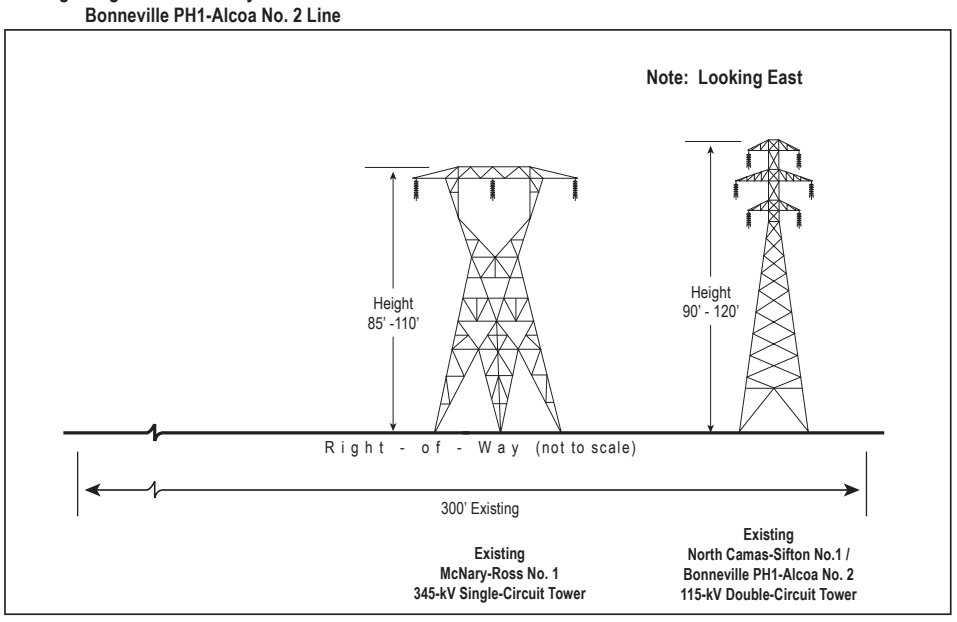


* Note: Towers 25/141-25/151 the existing McNary-Ross No. 1 345-kV Line will remain as-is; 30 feet of new right-of-way needed on north side of existing right-of-way to accommodate new 500-kV line. See Table B-1 for more information.

Figure B-6 Route Segment 25 (cont.)

Towers 25/151-25/152

Existing. Single-Circuit McNary-Ross No. 1 Line Parallel to the North Camas-Sifton No. 1 Line / Bonneville PH1-Alcoa No. 2 Line



Proposed. New Single-Circuit Tower Parallel to the McNary-Ross No. 1 Line

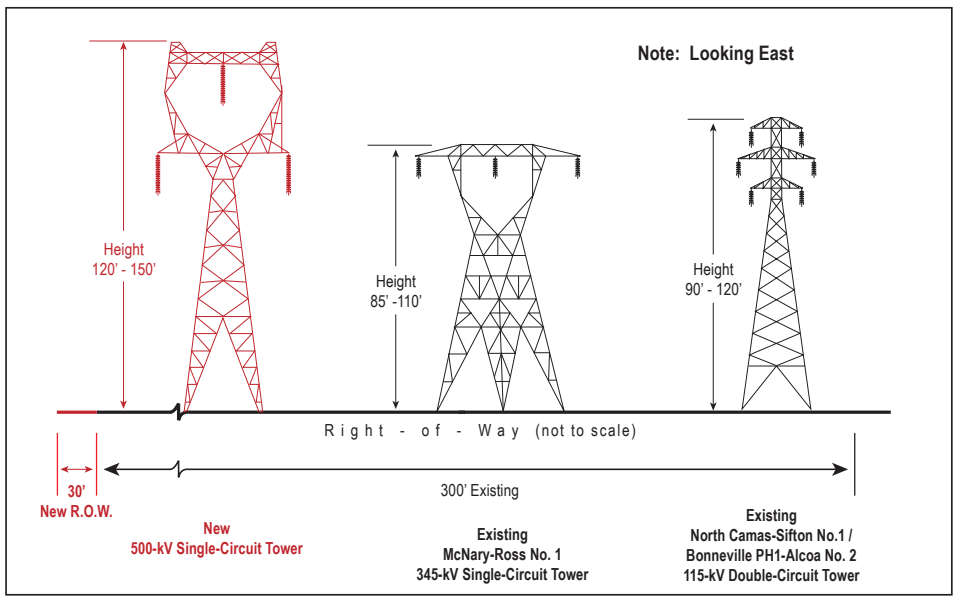
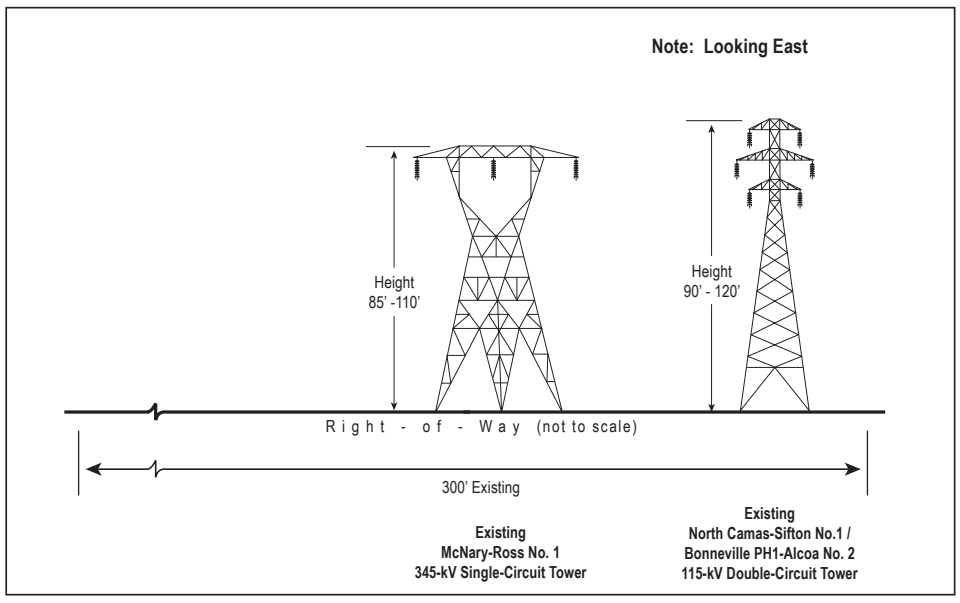


Figure B-7 Route Segment 36

Towers 36/1-36/2

Existing. Single-Circuit McNary-Ross No. 1 Line Parallel to the North Camas-Sifton No. 1 Line / Bonneville PH1-Alcoa No. 2 Line



Proposed. New Single-Circuit Tower Parallel to the McNary-Ross No. 1 Line

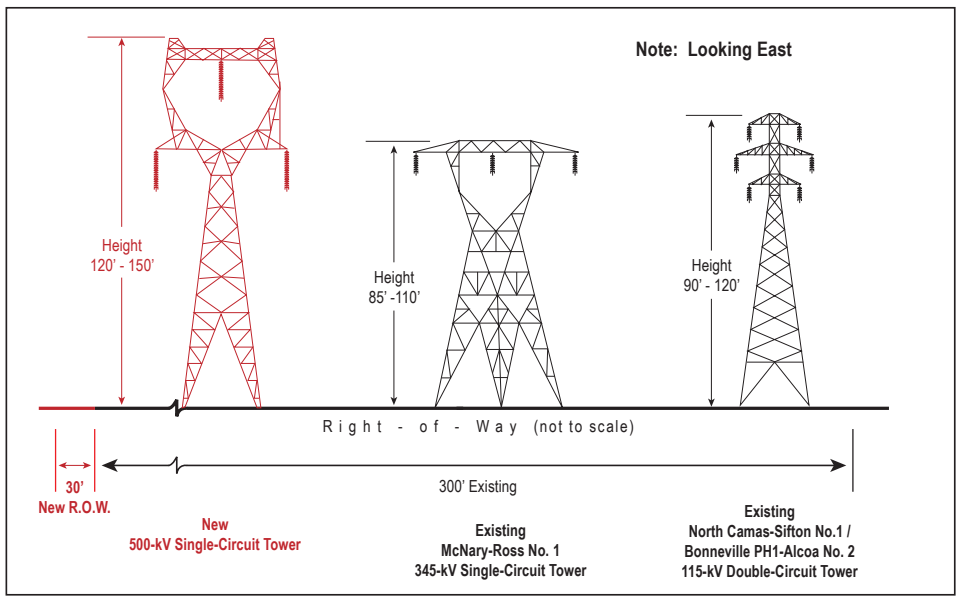
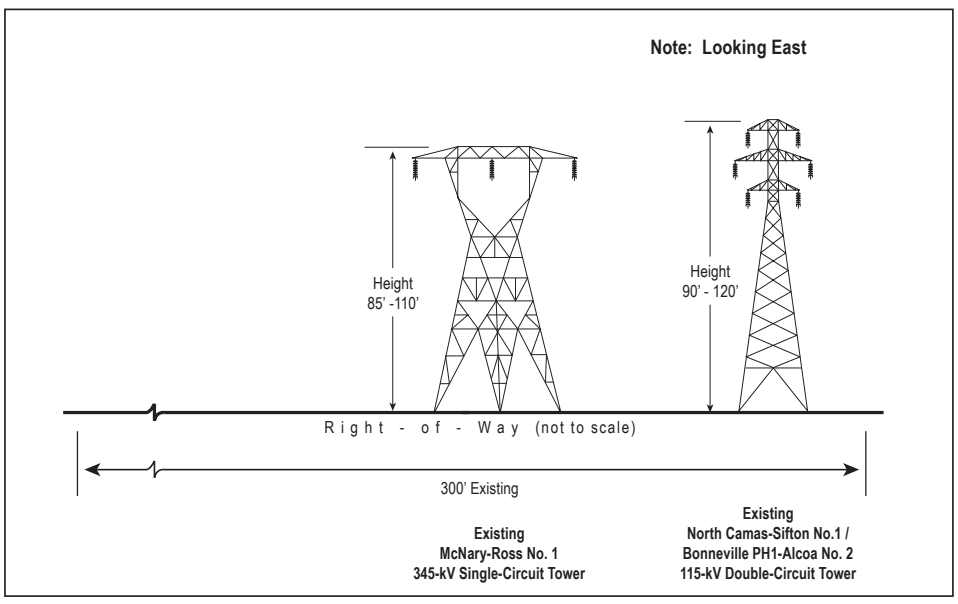


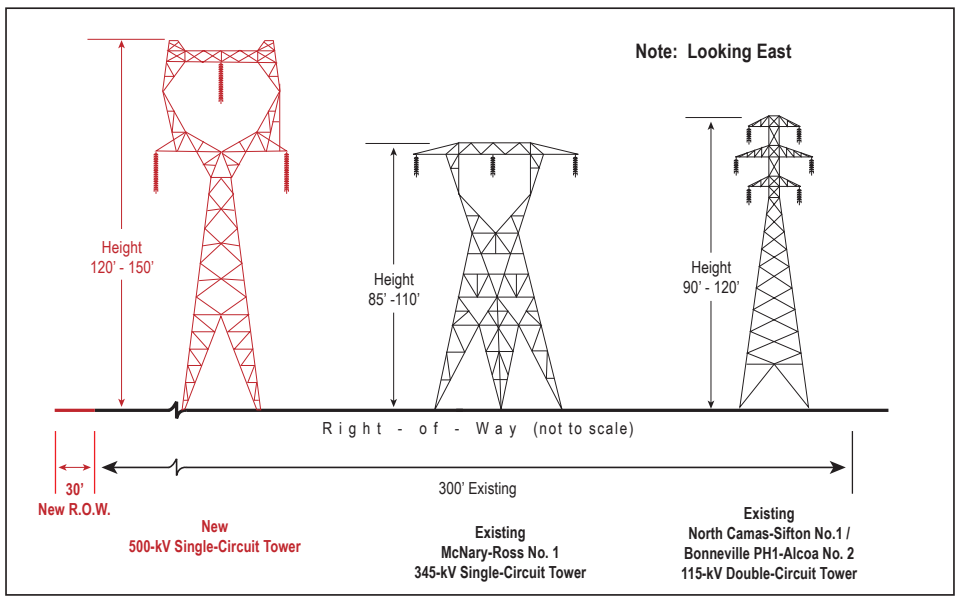
Figure B-8 Route Segment 36A

Towers 36A/1-36A/6*

Existing. Single-Circuit McNary-Ross No. 1 Line Parallel to the North Camas-Sifton No. 1 Line / Bonneville PH1-Alcoa No. 2 Line



Proposed. New Single-Circuit Tower Parallel to the McNary-Ross No. 1 Line

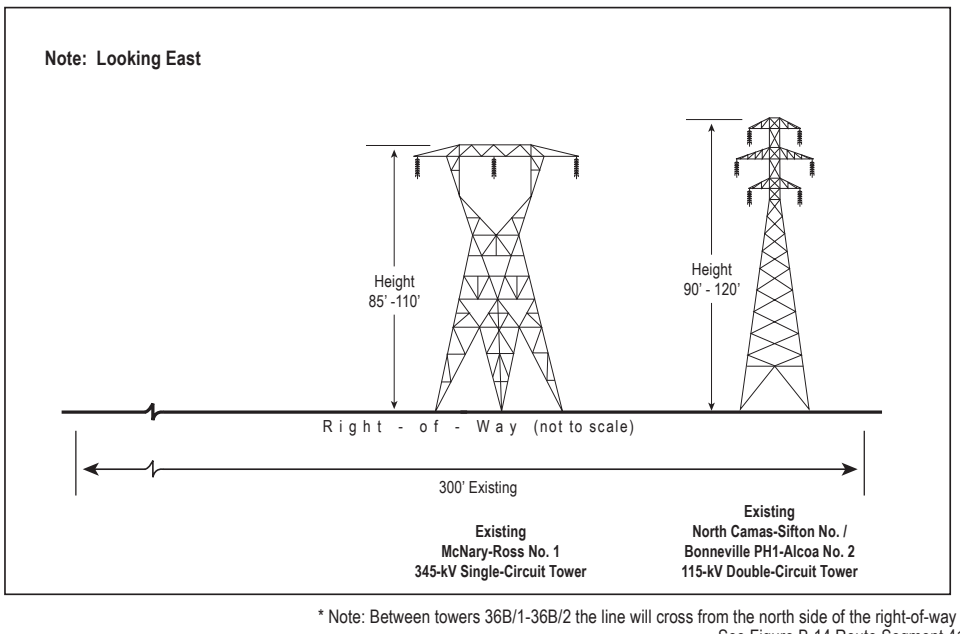


* Note: No new right-of-way needed between towers 36A/5-36A/6. Between towers 36A/4-36A/6 rebuild about 3 towers of McNary-Ross No. 1 345-kV line to narrow 345-kV line configuration to accommodate new 500-kV line.
See Figure B-6 Route Segment 25, Towers 25/110-25/151 for more information.

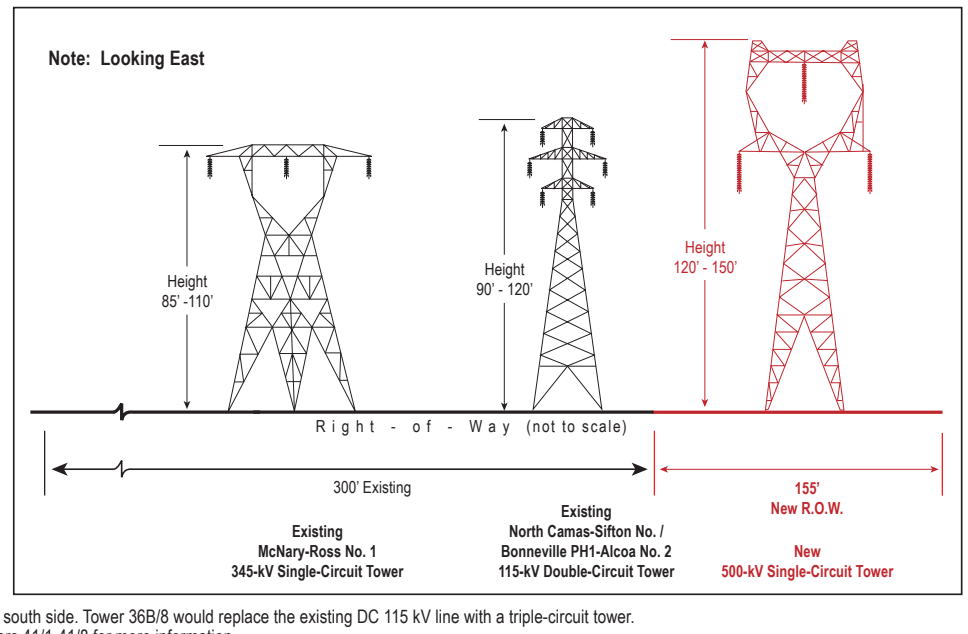
Figure B-9 Route Segment 36B

Towers 36B/1-36B/8*

Existing. Single-Circuit McNary-Ross No. 1 Line Parallel to the North Camas-Sifton No. 1 Line / Bonneville PH1-Alcoa No. 2 Line



Proposed. New Single-Circuit Tower Parallel to North Camas-Sifton No. 1 Line / Bonneville PH1-Alcoa No. 2 Line

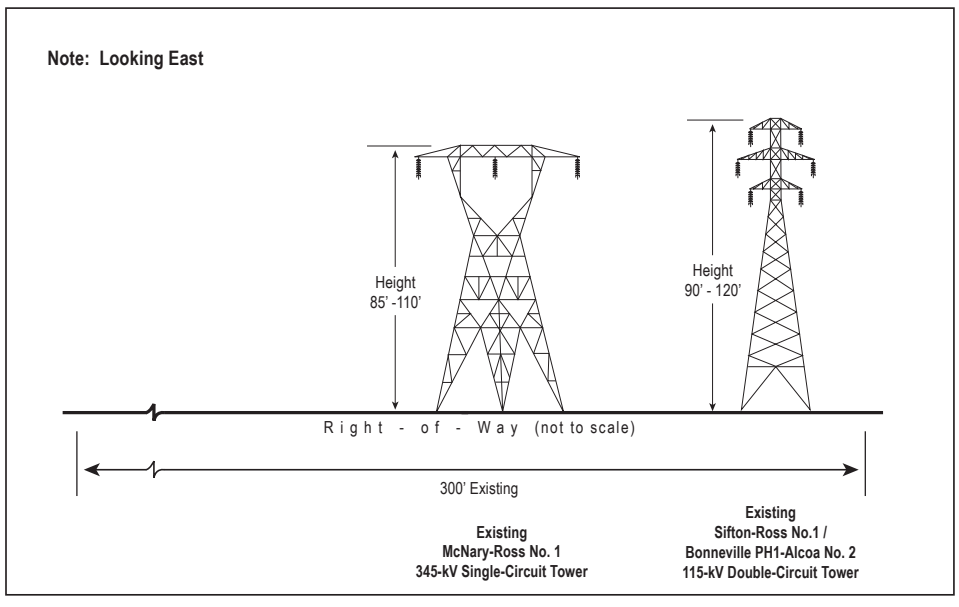


* Note: Between towers 36B/1-36B/2 the line will cross from the north side of the right-of-way to the south side. Tower 36B/8 would replace the existing DC 115 kV line with a triple-circuit tower.
See Figure B-14 Route Segment 41, towers 41/1-41/8 for more information.

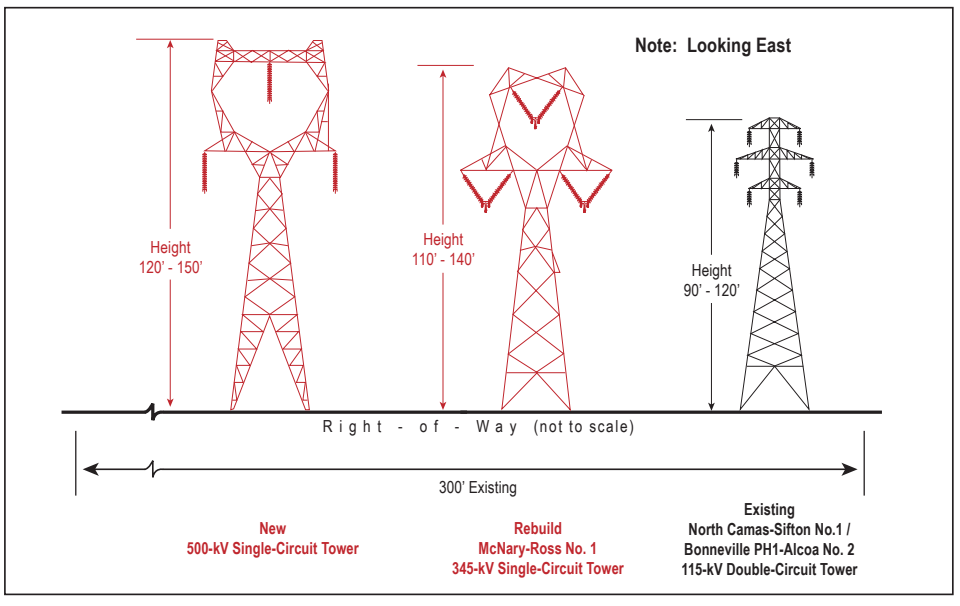
Figure B-10 Route Segment 37

Towers 37/1-37/2

Existing. Single-Circuit McNary-Ross No. 1 Line Parallel to the North Camas-Sifton No. 1 Line / Bonneville PH1-Alcoa No. 2 Line

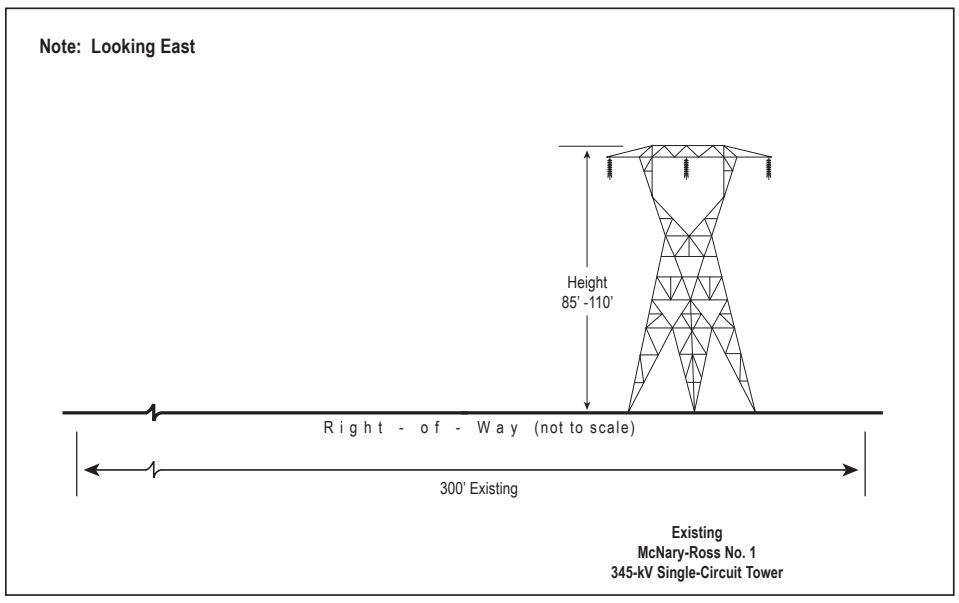


Proposed. New Single-Circuit Tower Parallel to Rebuilt McNary-Ross No. 1 Line



Towers 37/2-37/4

Existing. Single-Circuit McNary-Ross No. 1 Line



Proposed. New Single-Circuit Tower Parallel to McNary-Ross No. 1 Line

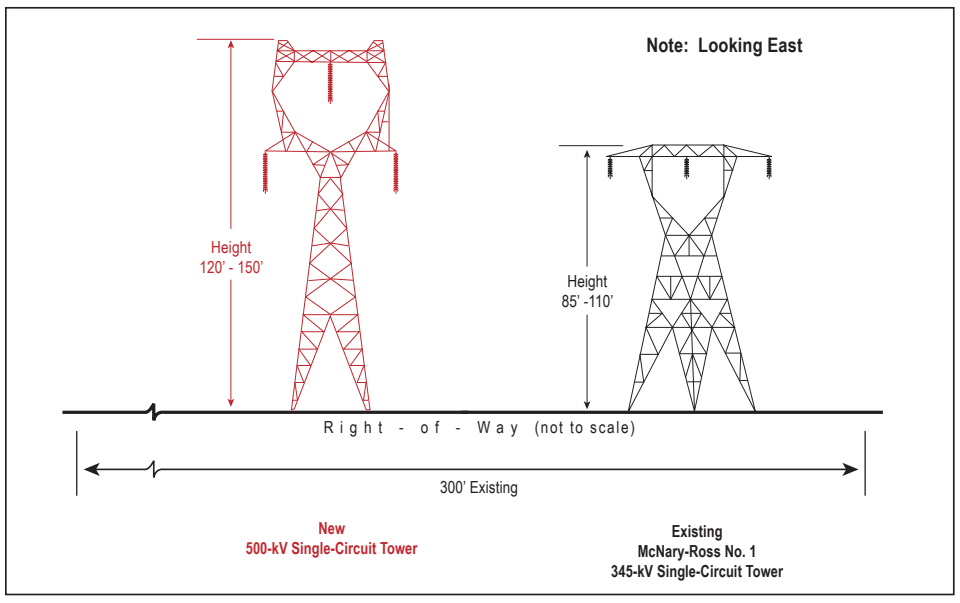
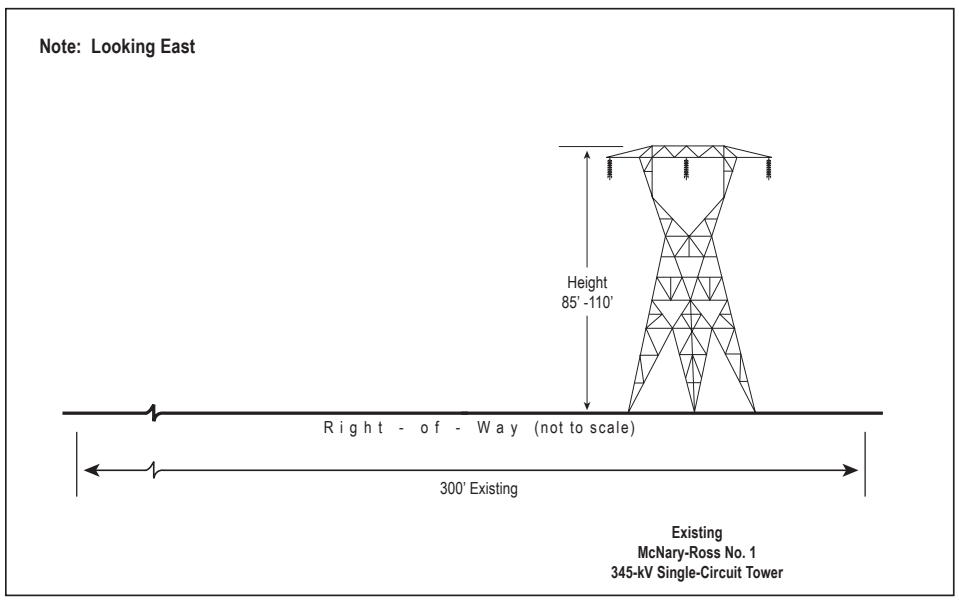


Figure B-11 Route Segment 38

Towers 38/1-38/5

Existing. Single-Circuit McNary-Ross No. 1 Line



Proposed. New Single-Circuit Tower Parallel to McNary-Ross No. 1 Line

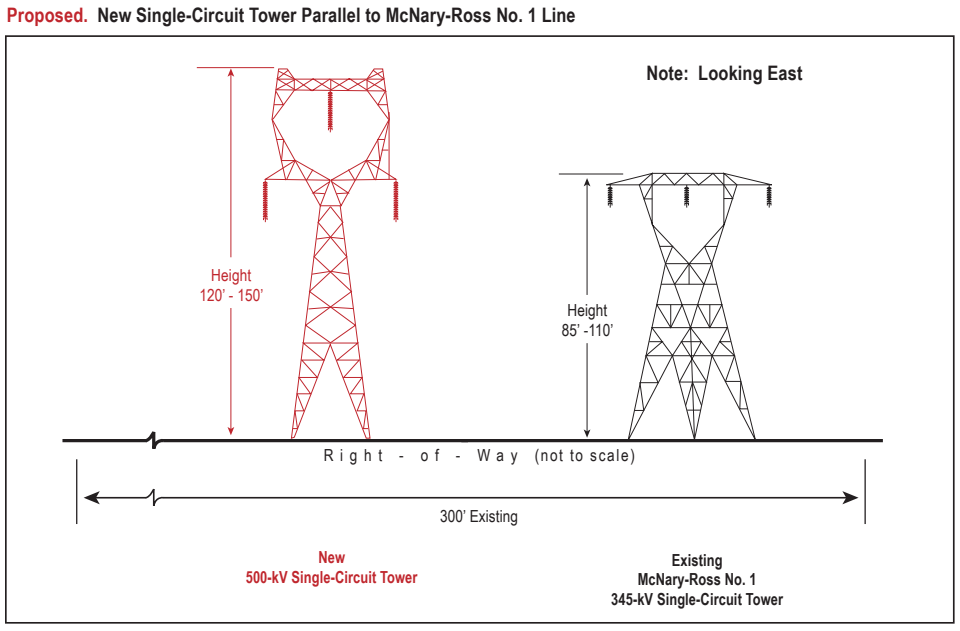
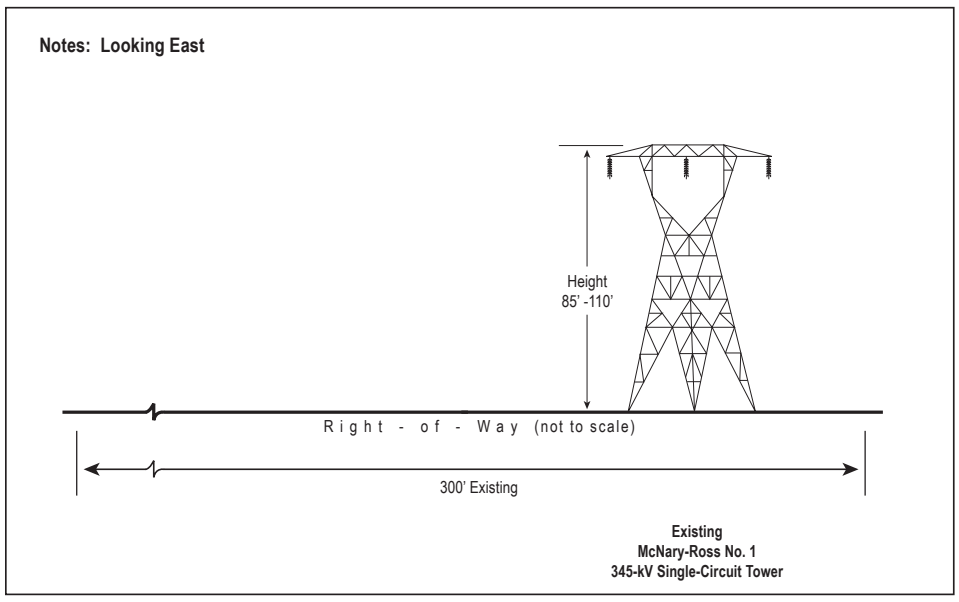


Figure B-12 Route Segment 39

Towers 39/1-39/20

Existing. Single-Circuit McNary-Ross No. 1 Line



Proposed. New Single-Circuit Tower Parallel to McNary-Ross No. 1 Line

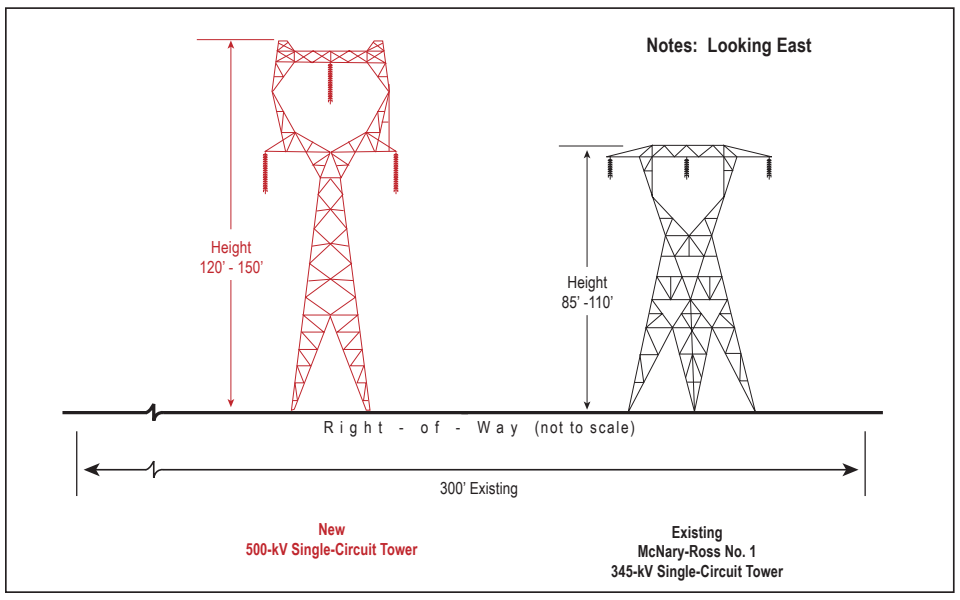
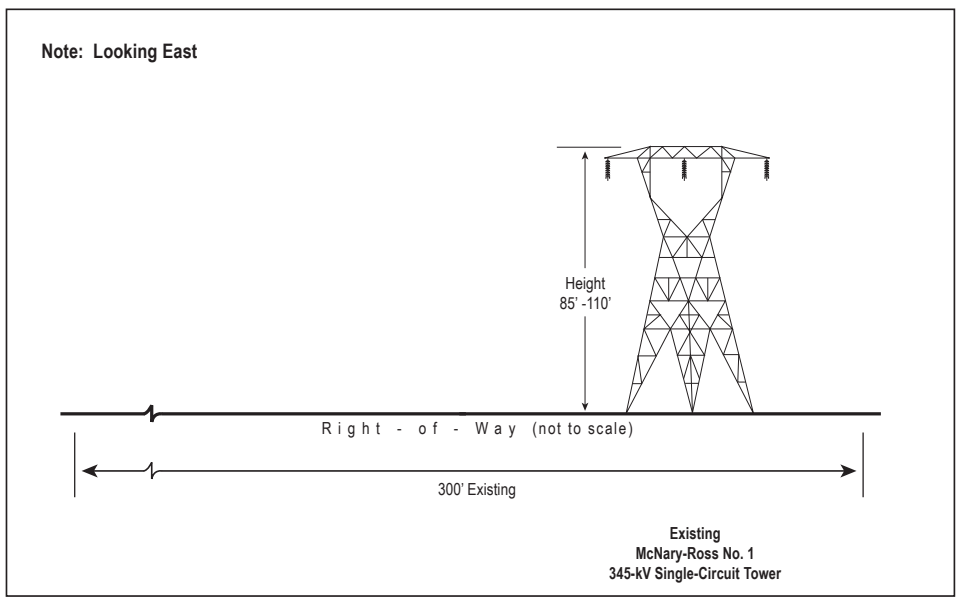


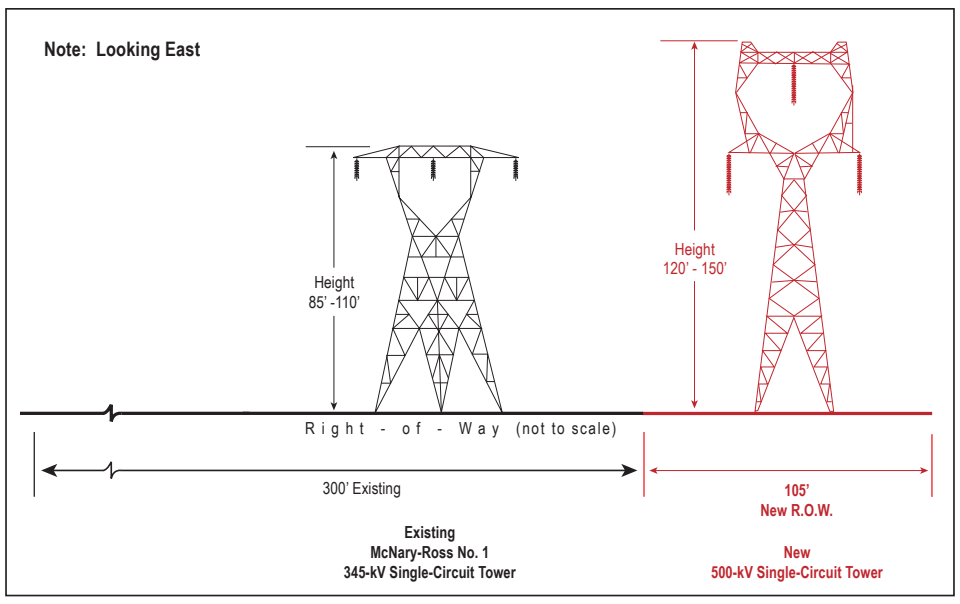
Figure B-12 Route Segment 39 (cont.)

Towers 39/20-39/23

Existing. Single-Circuit McNary-Ross No. 1 Line

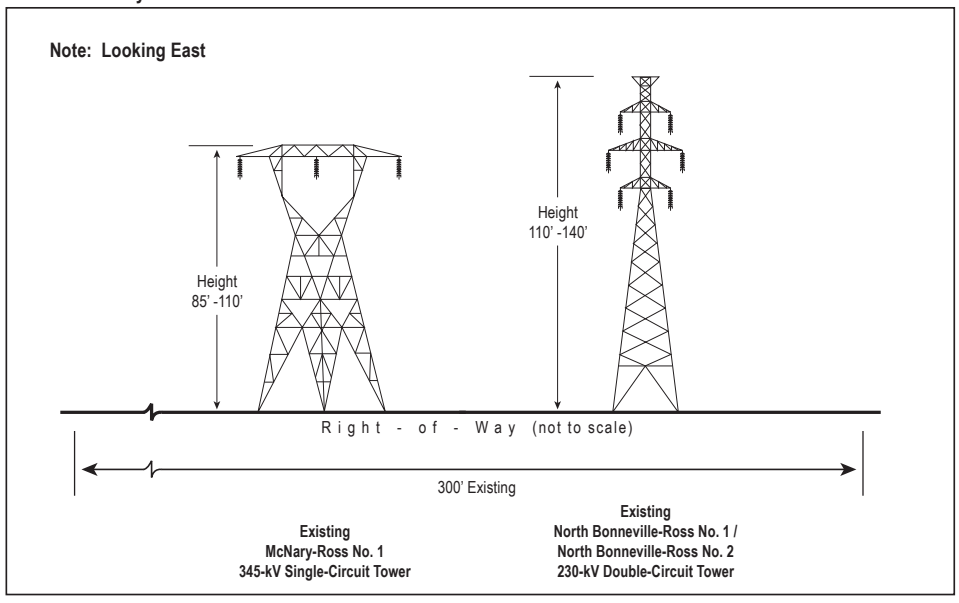


Proposed. New Single-Circuit Tower Parallel to McNary-Ross No. 1 Line



Towers 39/23-39/27

Existing. Double-Circuit North Bonneville-Ross No. 1 Line / North Bonneville-Ross No. 2 Line Parallel to the McNary-Ross No. 1 Line



Proposed. New Single-Circuit Tower Parallel to the North Bonneville-Ross No. 1 Line / North Bonneville-Ross No. 2 Line

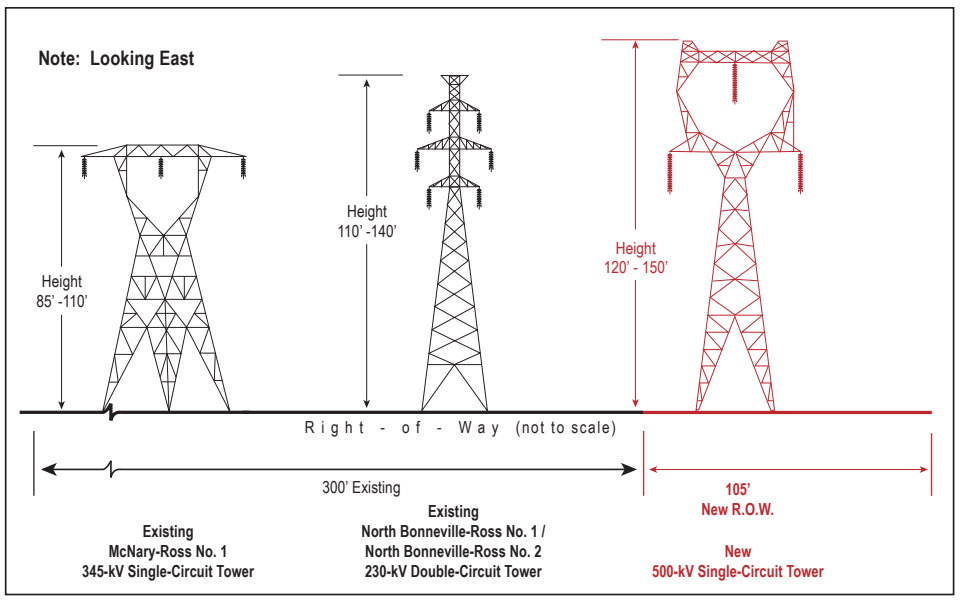
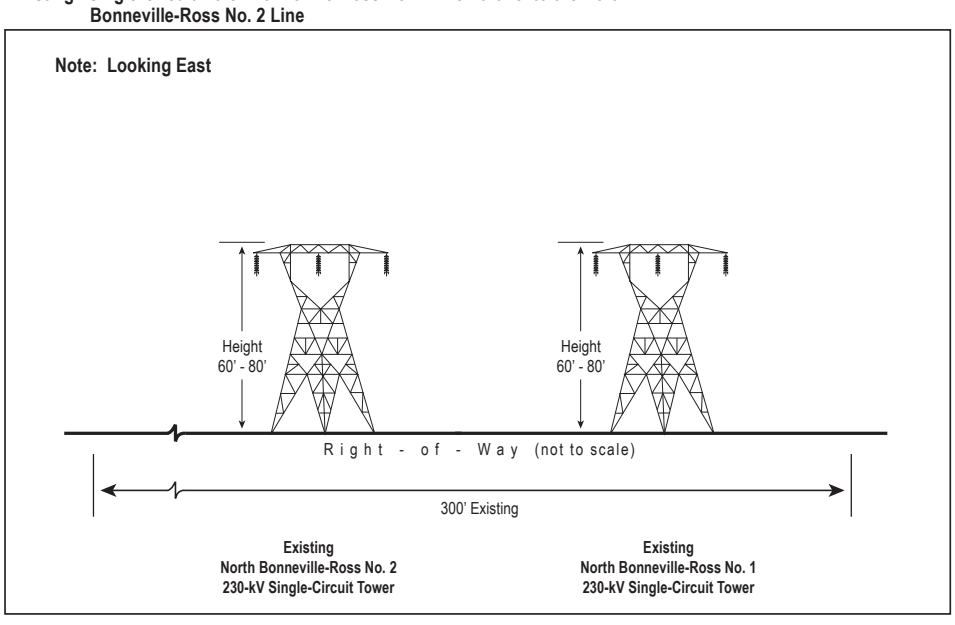


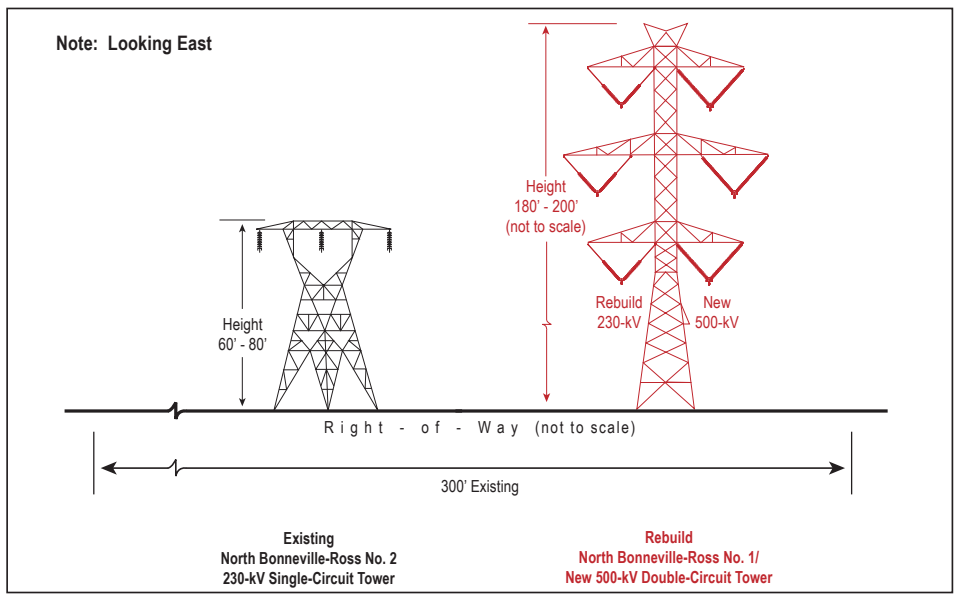
Figure B-13 Route Segment 40

Towers 40/11-40/14*

Existing. Single-Circuit North Bonneville-Ross No. 1 Line Parallel to the North Bonneville-Ross No. 2 Line



Proposed. Rebuild New Double-Circuit Tower Parallel to the North Bonneville-Ross No. 2 Line

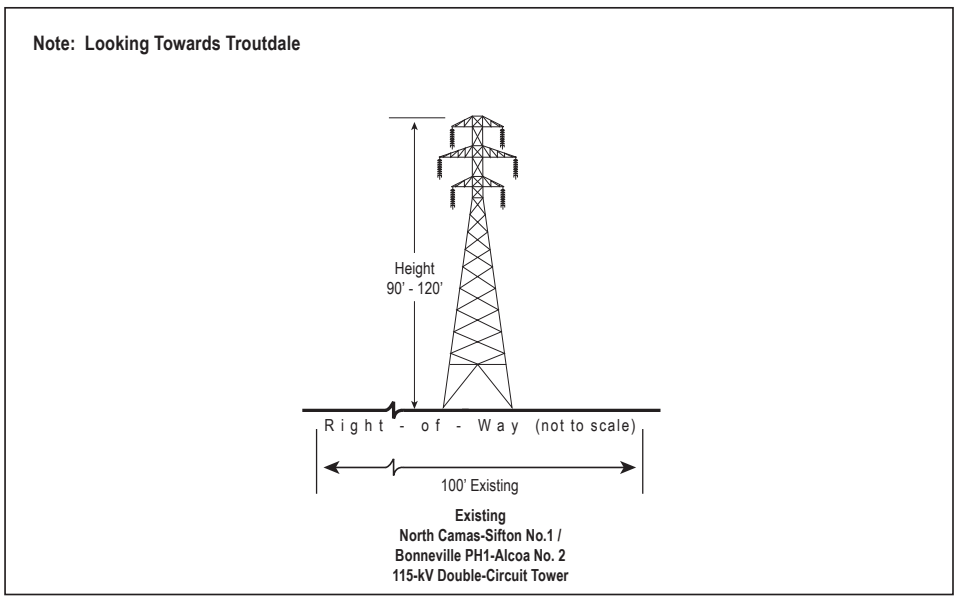


* Note: Towers 40/1-40/11 will require 150 feet of new right-of-way. See Figure B-1 for more information.

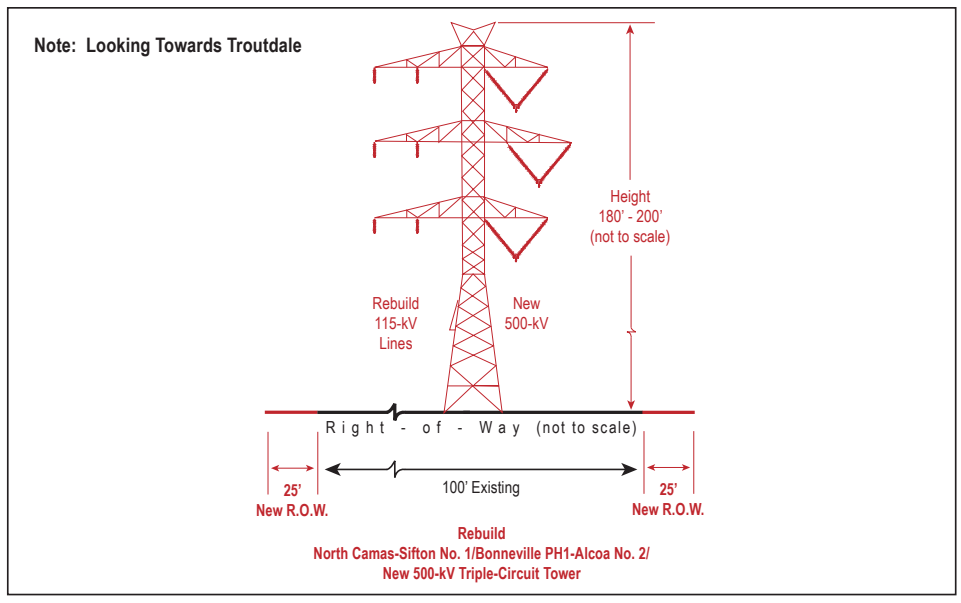
Figure B-14 Route Segment 41

Towers 41/1-41/8*

Existing. Double-Circuit North Camas-Sifton No.1 Line / Bonneville PH1-Alcoa No. 2 Line



Proposed. New Triple-Circuit Tower Replacing Double-Circuit 115-kV Tower

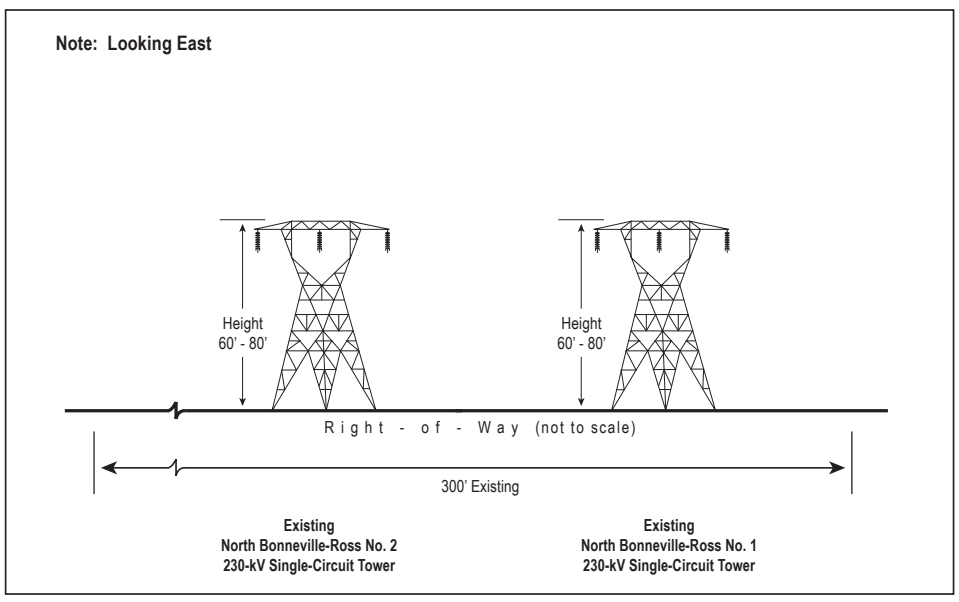


* Note: New 500-kV line replaces double-circuit 115-kV line at 41/1 (36B/8) with triple-circuit 500-kV line. See Table B-1 for more information.

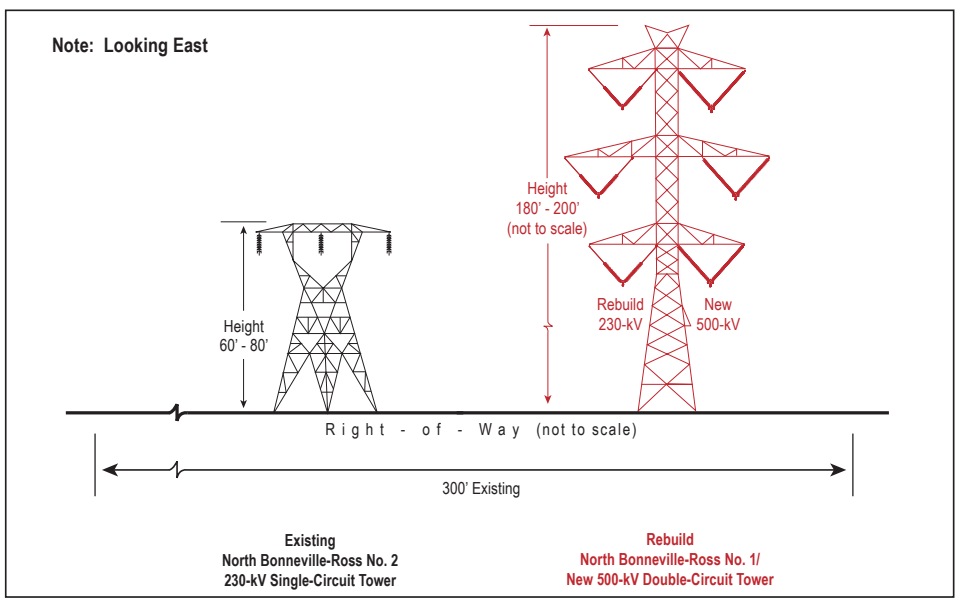
Figure B-15 Route Segment 43

Towers 43/9-43/10*

Existing. Single-Circuit North Bonneville-Ross No. 1 Line Parallel to the North Bonneville-Ross No. 2 Line



Proposed. Rebuild New Double-Circuit Tower Parallel to the North Bonneville-Ross No. 2 Line

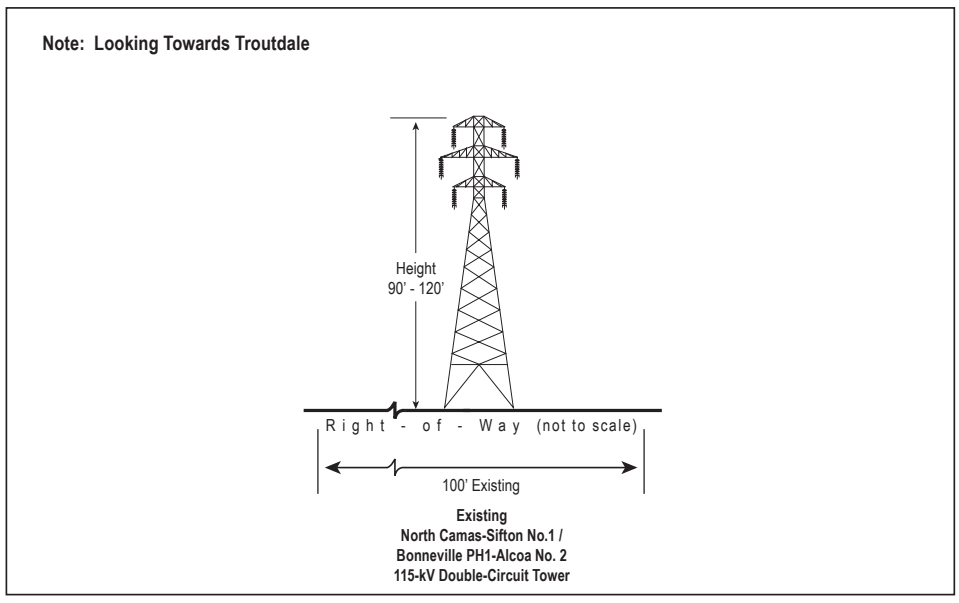


* Note: Towers 43/1-43/9 will require 150 feet of new right-of-way. See Figure B-1 for more information.

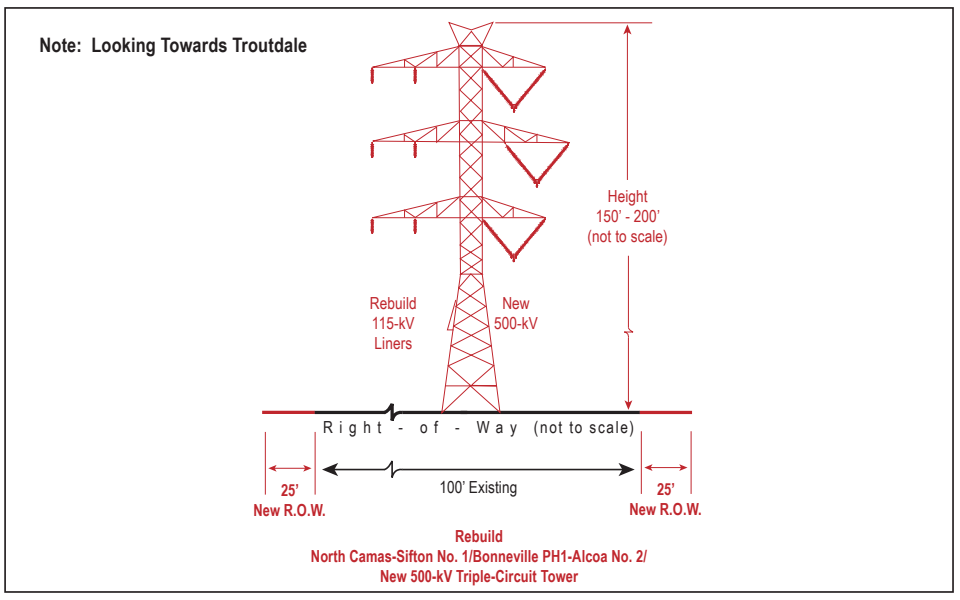
Figure B-16 Route Segment 45

Towers 45/1-45/3*

Existing. Double-Circuit North Camas-Sifton No.1 Line / Bonneville PH1-Alcoa No. 2 Line



Proposed. New Triple-Circuit Tower Replacing Double-Circuit 115-kV Tower

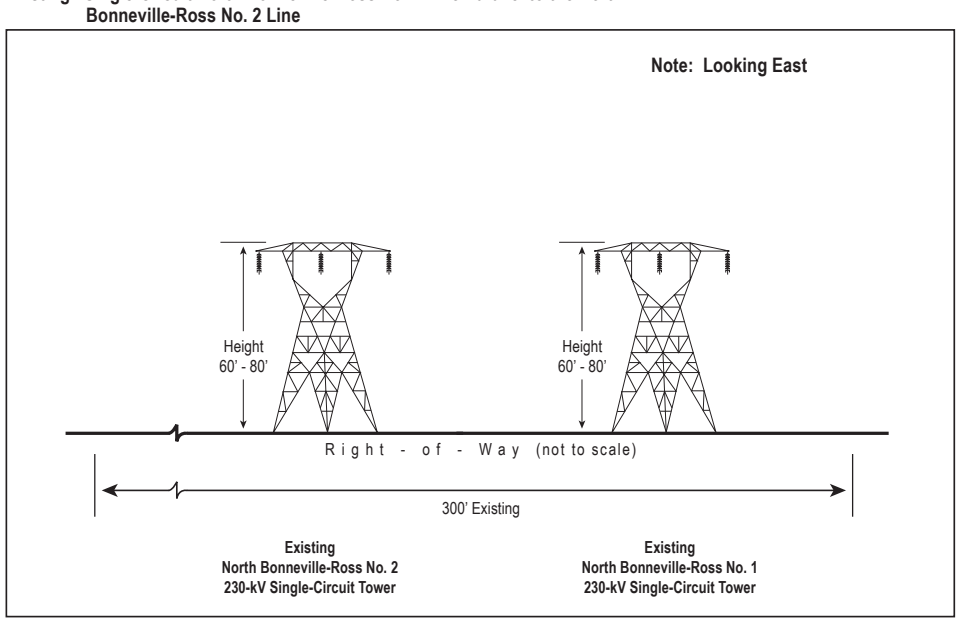


* Note: Towers 45/3-45/6 will require 150 feet of new right-of-way. See Figure B-1 for more information.

Figure B-17 Route Segment 46

Towers 46/1-46/3

Existing. Single-Circuit North Bonneville-Ross No. 1 Line Parallel to the North Bonneville-Ross No. 2 Line



Proposed. Rebuild New Double-Circuit Tower Parallel to the North Bonneville-Ross No. 2 Line

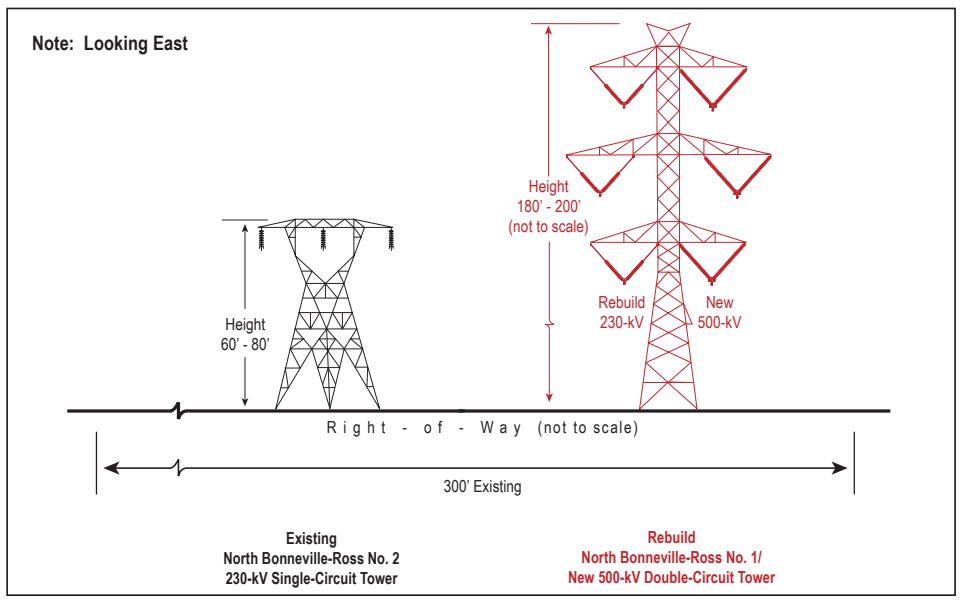
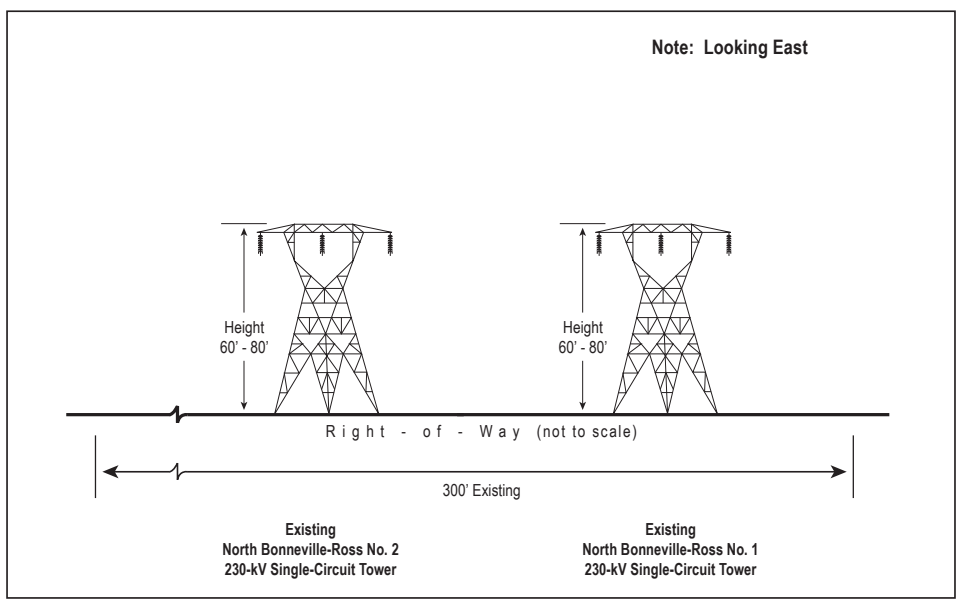


Figure B-18 Route Segment 47

Towers 47/1-47/4

Existing. Single-Circuit North Bonneville-Ross No. 1 Line Parallel to the North Bonneville-Ross No. 2 Line



Proposed. Rebuild New Double-Circuit Tower Parallel to the North Bonneville-Ross No. 2 Line

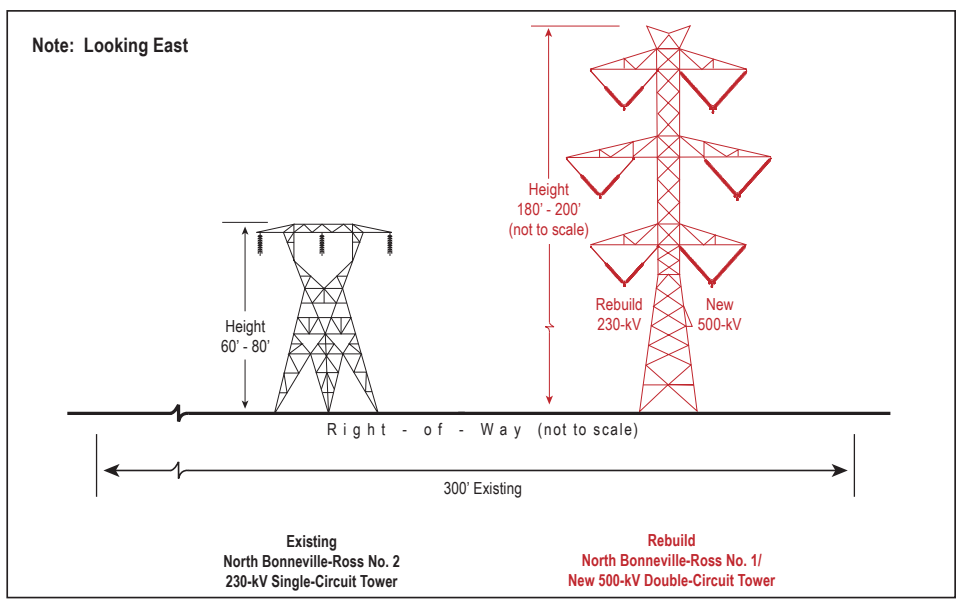
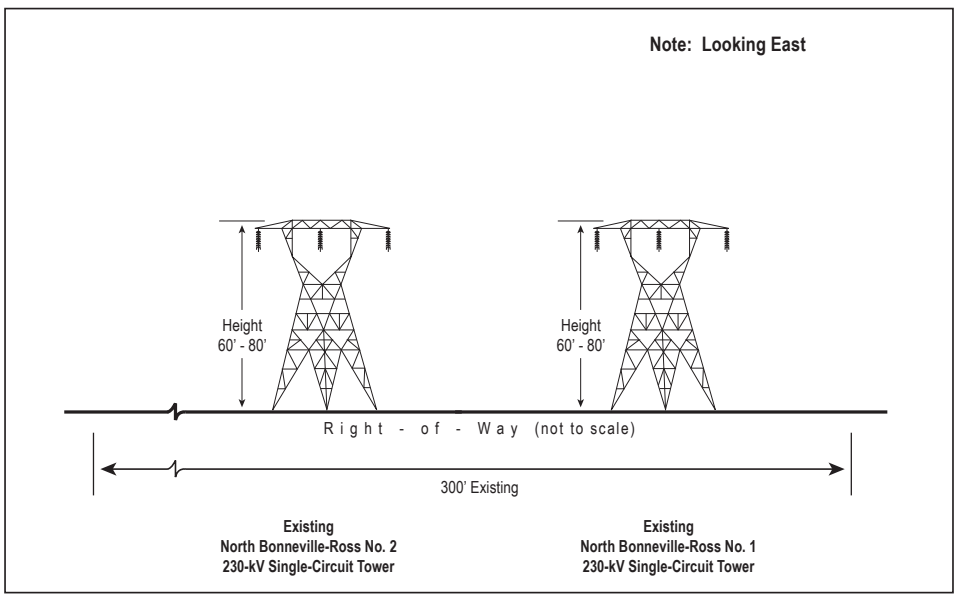


Figure B-19 Route Segment 48

Towers 48/1-48/14

Existing. Single-Circuit North Bonneville-Ross No. 1 Line Parallel to the North Bonneville-Ross No. 2 Line



Proposed. Rebuild New Double-Circuit Tower Parallel to the North Bonneville-Ross No. 2 Line

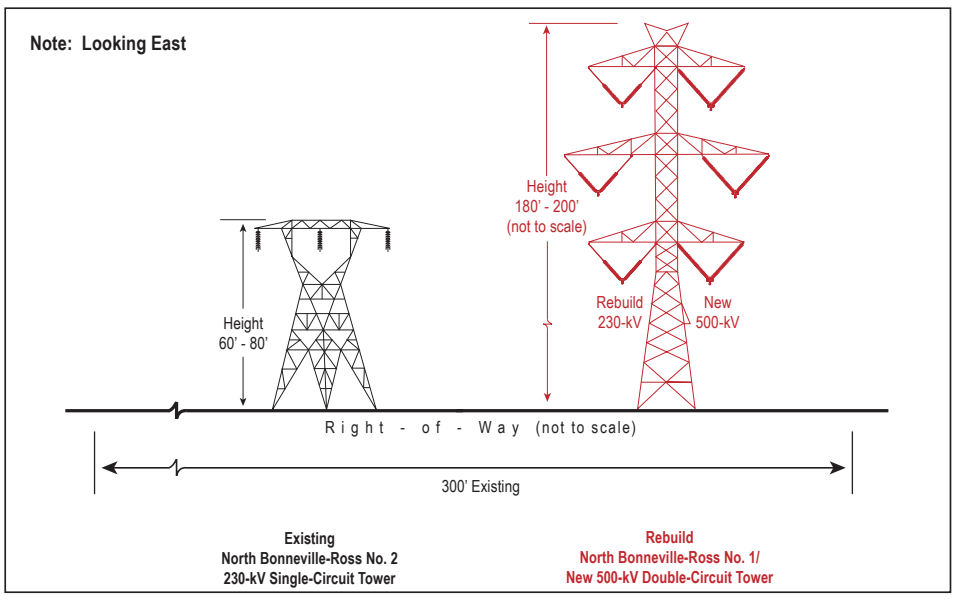
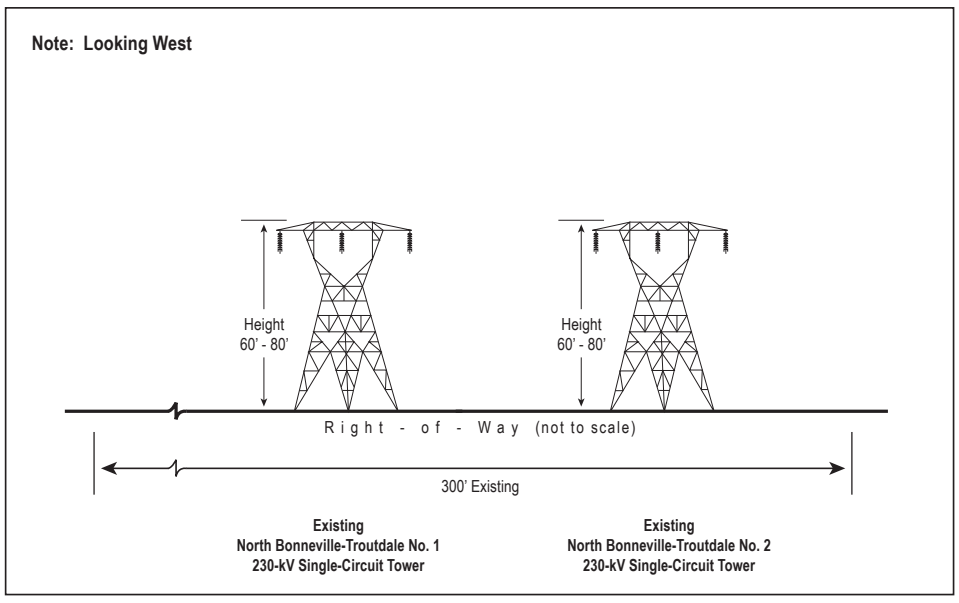


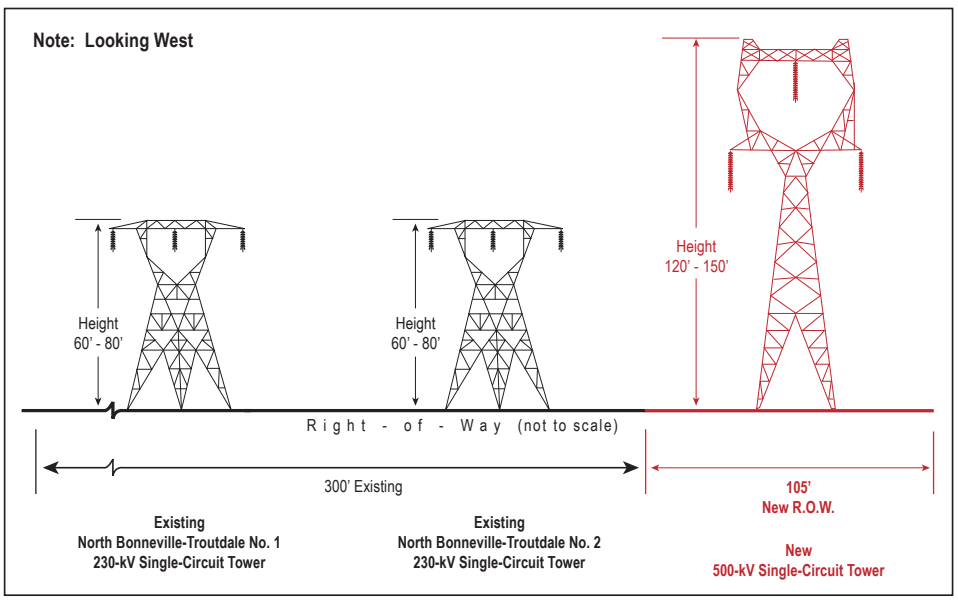
Figure B-20 Route Segment 49

Towers 49/7-49/10*

Existing. Single-Circuit North Bonneville-Troutdale No. 1 Line Parallel to the North Bonneville-Troutdale No. 2 Line



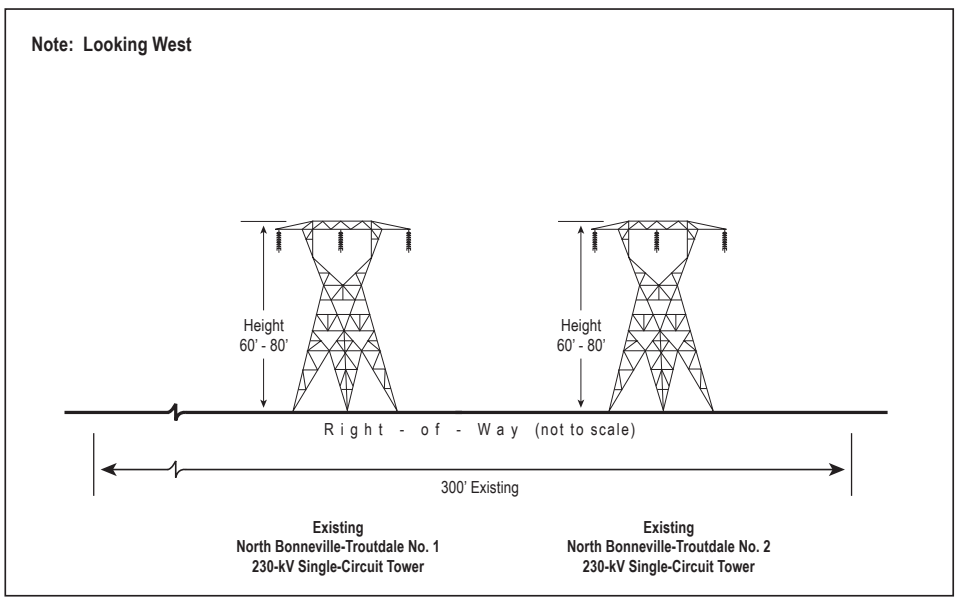
Proposed. New Single-Circuit Tower Parallel to the North Bonneville-Troutdale No. 2 Line



* Note: Towers 49/1-49/7 will require 150 feet of new right-of-way. See Figure B-1 for more information.

Towers 49/10-49/15

Existing. Single-Circuit North Bonneville-Troutdale No. 1 Line Parallel to the North Bonneville-Troutdale No. 2 Line



Proposed. Rebuild New Double-Circuit Tower Parallel to the North Bonneville-Troutdale No. 1 Line

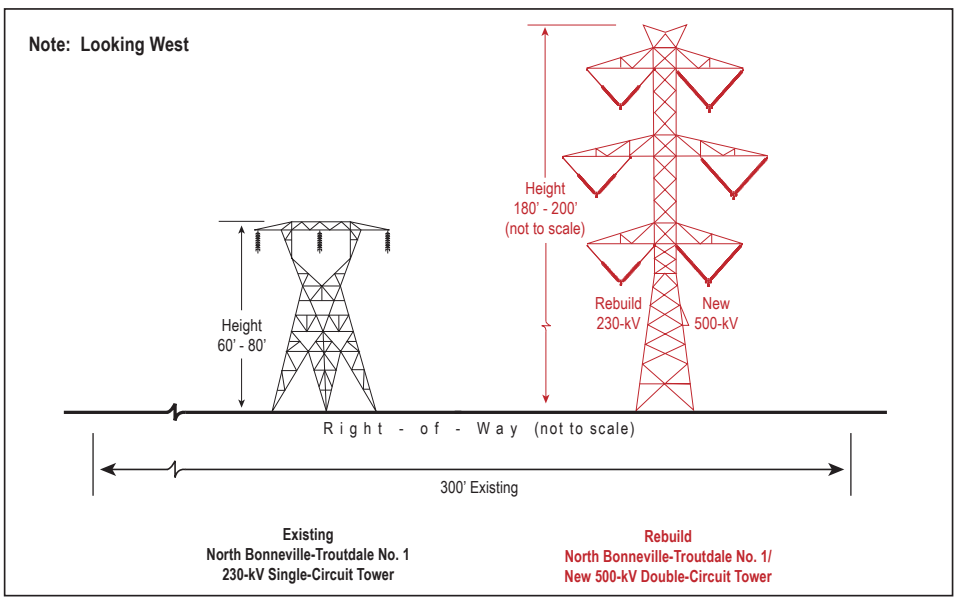
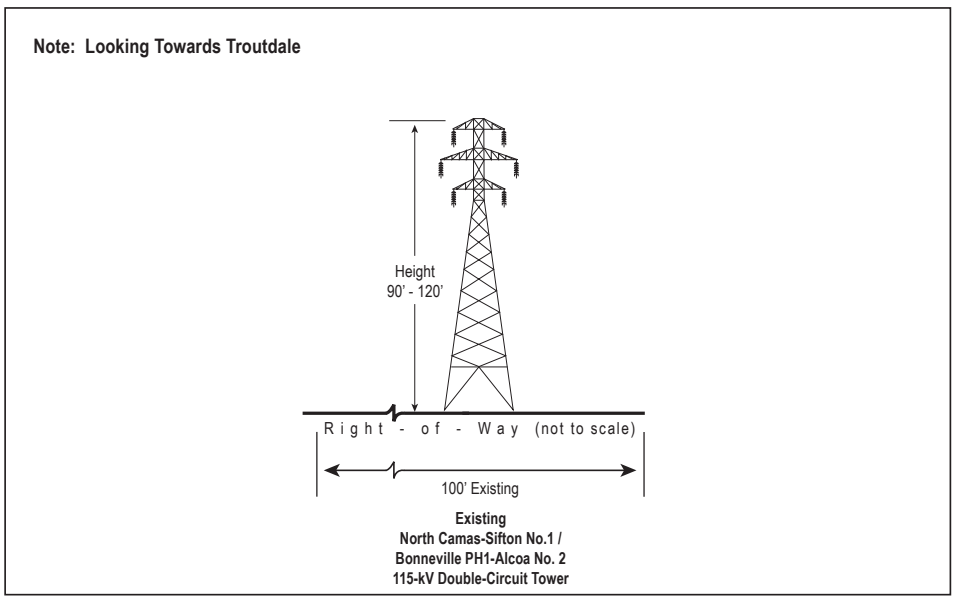


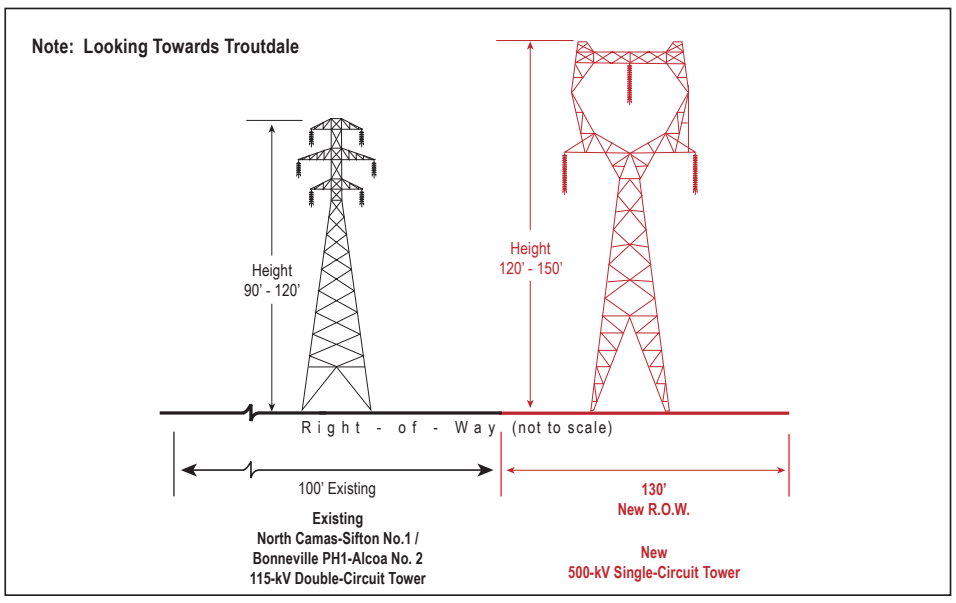
Figure B-21 Route Segment 50

Towers 50/5-50/13*, Towers 50/21-50/26

Existing. Double-Circuit North Camas-Sifton No.1 Line / Bonneville PH1-Alcoa No. 2 Line



Proposed. New Single-Circuit Tower Parallel to the North Camas-Sifton No.1 Line / Bonneville PH1-Alcoa No. 2 Line



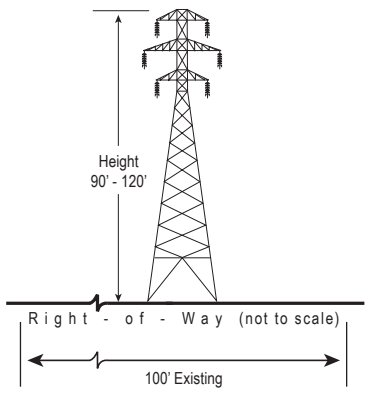
* Note: Towers 50/1-50/5 will require 150 feet of new right-of-way. See Figure B-1 for more information.

Figure B-21 Route Segment 50 (cont.)

Towers 50/13-50/21

Existing. Double-Circuit North Camas-Sifton No.1 Line / Bonneville PH1-Alcoa No. 2 Line

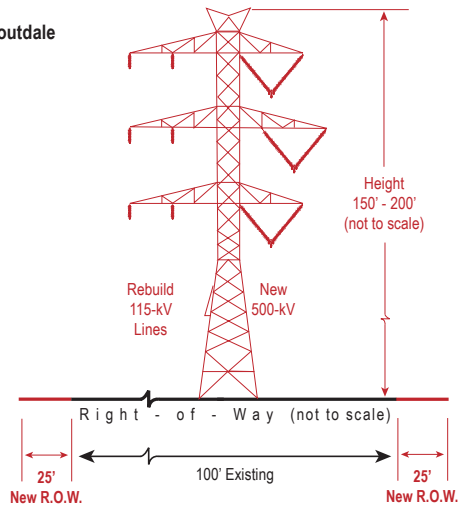
Note: Looking Towards Troutdale



Existing
North Camas-Sifton No.1 /
Bonneville PH1-Alcoa No. 2
115-kV Double-Circuit Tower

Proposed. New Triple-Circuit Tower Replacing Double-Circuit 115-kV Tower

Note: Looking Towards Troutdale



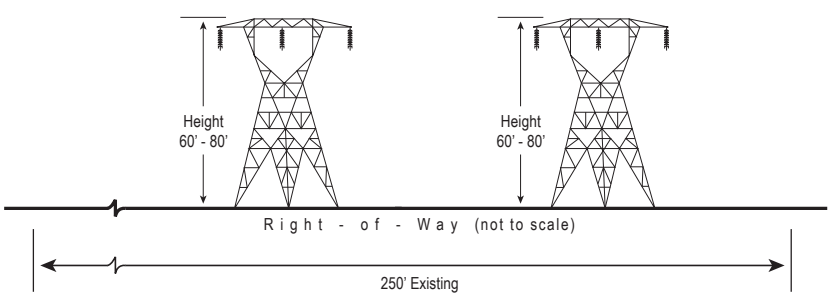
Rebuild
North Camas-Sifton No. 1/Bonneville PH1-Alcoa No. 2/
New 500-kV Triple-Circuit Tower

Figure B-22 Route Segment 51

Towers 51/1-51/11

Existing. Single-Circuit North Bonneville-Troutdale No. 1 Line Parallel to the North Bonneville-Troutdale No. 2 Line

Note: Looking Towards Troutdale

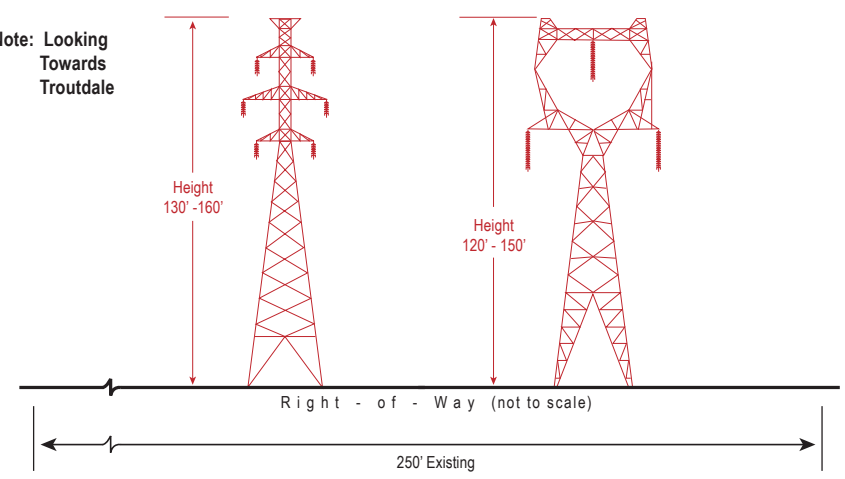


Existing
North Bonneville-Troutdale No. 1
230-kV Single-Circuit Tower

Existing
North Bonneville-Troutdale No. 2
230-kV Single-Circuit Tower

Proposed. New Single-Circuit Tower Parallel to the Rebuilt North Bonneville-Troutdale No. 1 Line / North Bonneville-Troutdale No. 2 Line

Note: Looking Towards Troutdale



Rebuild
North Bonneville-Troutdale No. 1 /
North Bonneville-Troutdale No. 2
230-kV Double-Circuit Tower

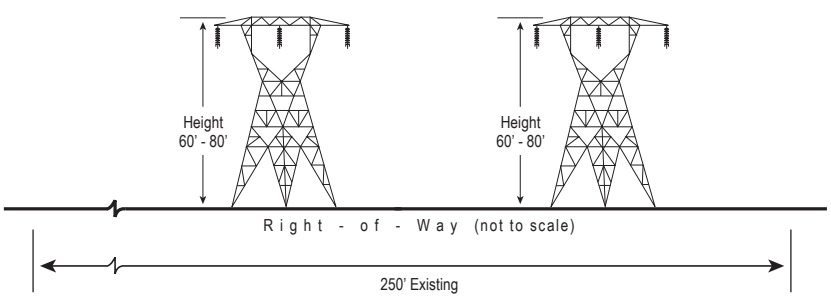
New
500-kV Single-Circuit Tower

Figure B-23 Route Segment 52

Towers 52/1-52/2, Towers 52/9-52/17*

Existing. Single-Circuit North Bonneville-Troutdale No. 1 Line Parallel to the North Bonneville-Troutdale No. 2 Line

Note: Looking Towards Troutdale

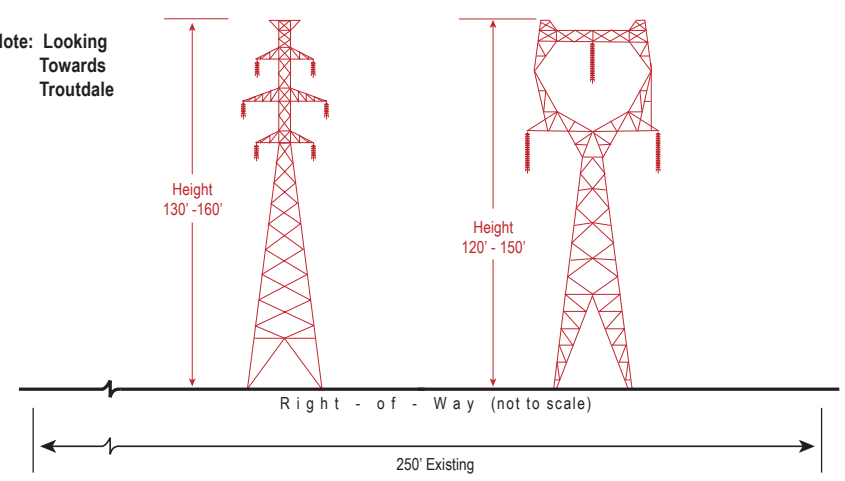


Existing
North Bonneville-Troutdale No. 1
230-kV Single-Circuit Tower

Existing
North Bonneville-Troutdale No. 2
230-kV Single-Circuit Tower

Proposed. New Single-Circuit Tower Parallel to the Rebuilt North Bonneville-Troutdale No. 1 Line / North Bonneville-Troutdale No. 2 Line

Note: Looking Towards Troutdale



Rebuild
North Bonneville-Troutdale No. 1 /
North Bonneville-Troutdale No. 2
230-kV Double-Circuit Tower

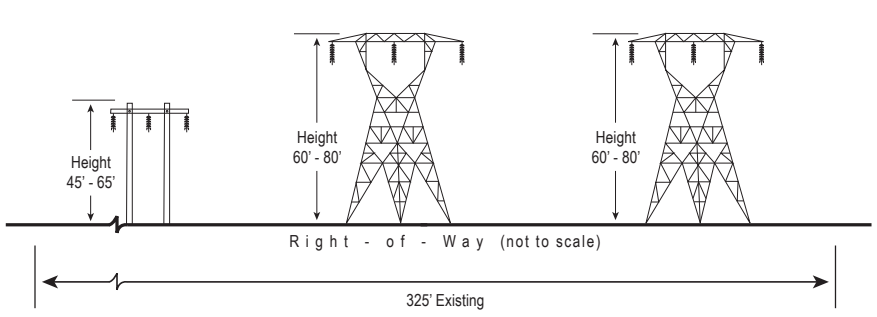
New
500-kV Single-Circuit Tower

* Note: Towers 52/17-52/20 and 52/22-52/24 will require 150 feet of new right-of-way. See figure B-1 for more information.

Towers 52/2-52/9

Existing. Single-Circuit North Bonneville-Troutdale No. 1 Line Parallel to the North Bonneville-Troutdale No. 2 Line

Note: Looking Towards Troutdale



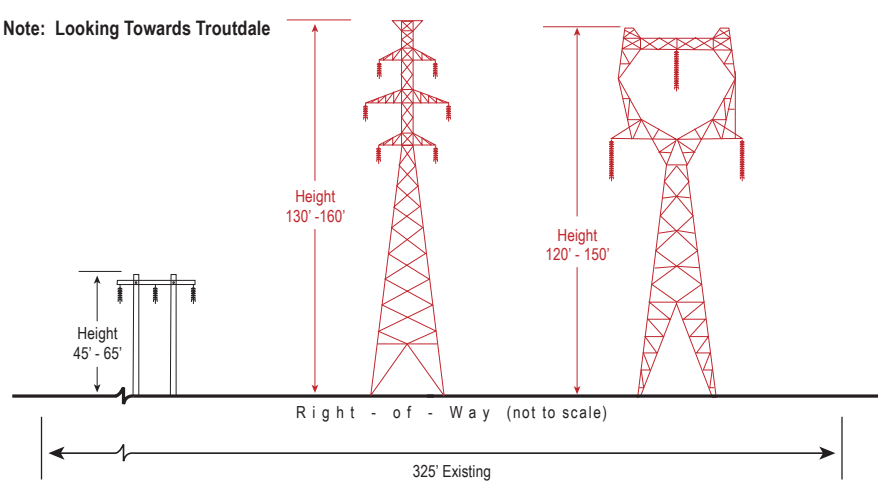
Existing
North Camas-Oak Park
115-kV Single-Circuit Structure

Existing
North Bonneville-Troutdale No. 1
230-kV Single-Circuit Tower

Existing
North Bonneville-Troutdale No. 2
230-kV Single-Circuit Tower

Proposed. New Single-Circuit Tower Parallel to the Rebuilt North Bonneville-Troutdale Nos. 1 and 2 Line

Note: Looking Towards Troutdale



Existing
North Camas-Oak Park
115-kV Single-Circuit Structure

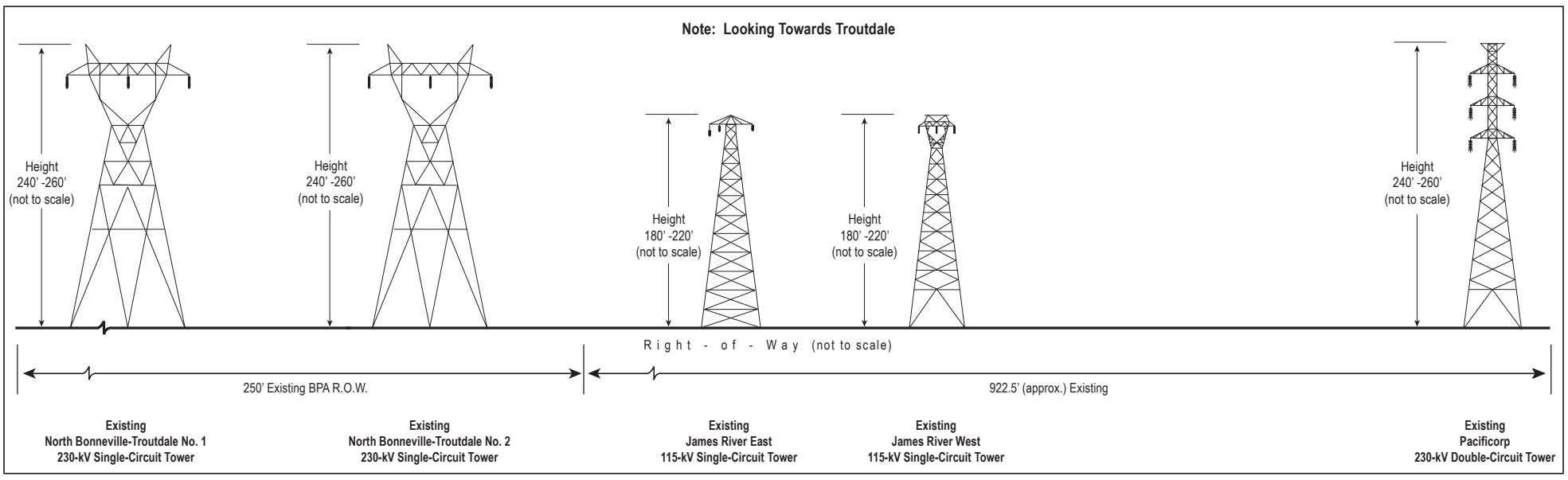
Rebuild
North Bonneville-Troutdale No. 1 /
North Bonneville-Troutdale No. 2
230-kV Double-Circuit Tower

New
500-kV Single-Circuit Tower

Figure B-23 Route Segment 52 (cont.)

Towers 52/20-52/22

Existing. Single-Circuit North Bonneville-Troutdale No. 1 Line Parallel to the North Bonneville-Troutdale No. 2 Line



Proposed. New Single-Circuit Tower Parallel Between Two Non-BPA Lines Across the Columbia River

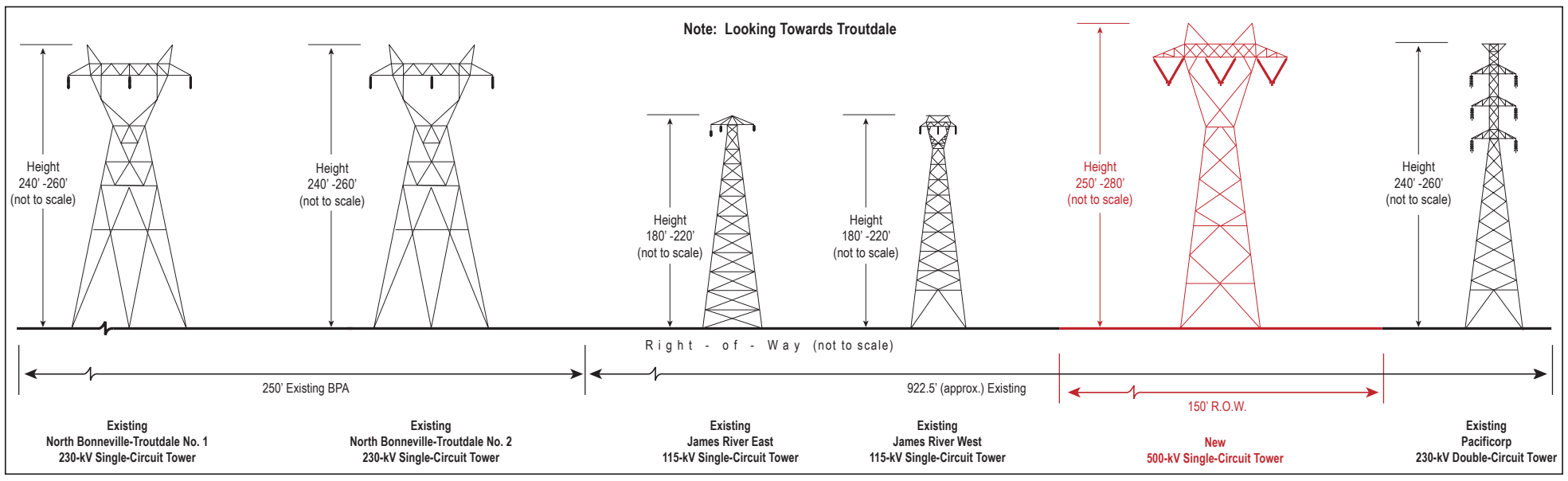
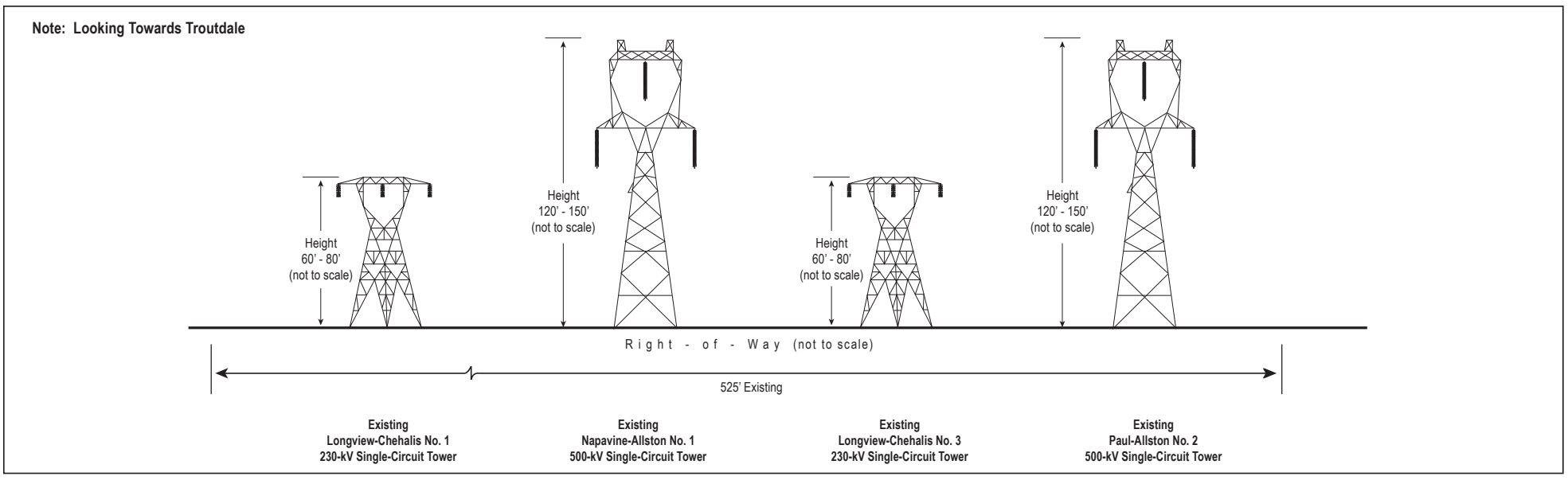


Figure B-24 Route Segment A

Towers A/1-A/9

Existing. Single-Circuit Longview-Chehalis No. 1 Line Parallel to the Napavine-Allston No. 1 Line



Proposed. New Single-Circuit Tower Parallel to the Longview-Chehalis No. 1 Line

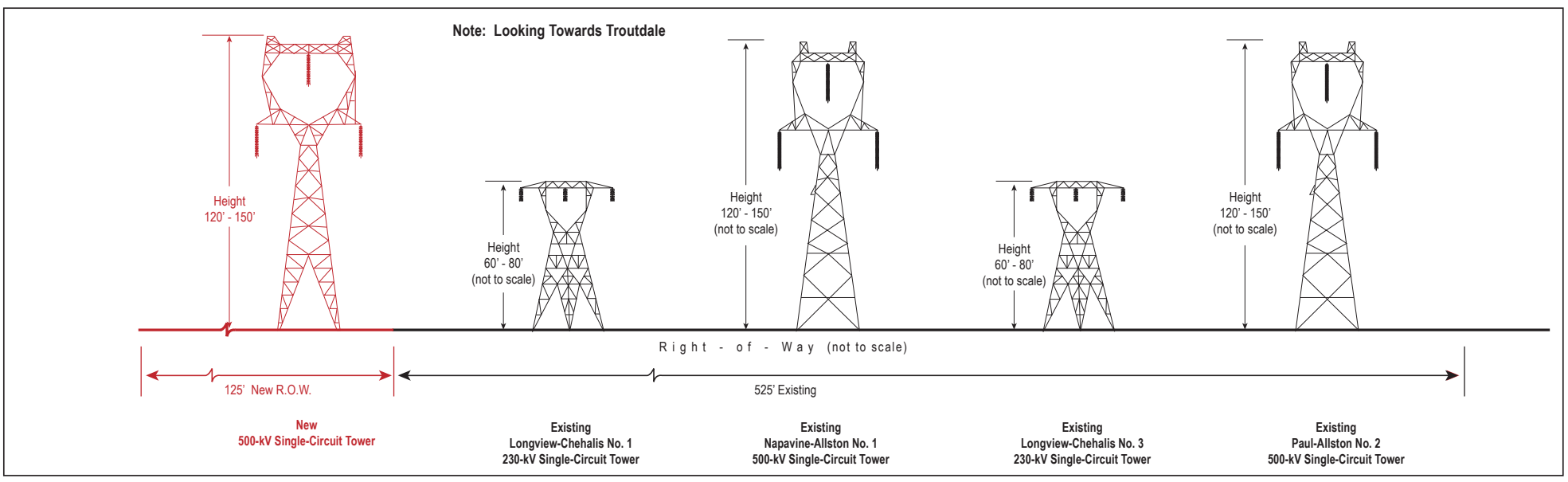
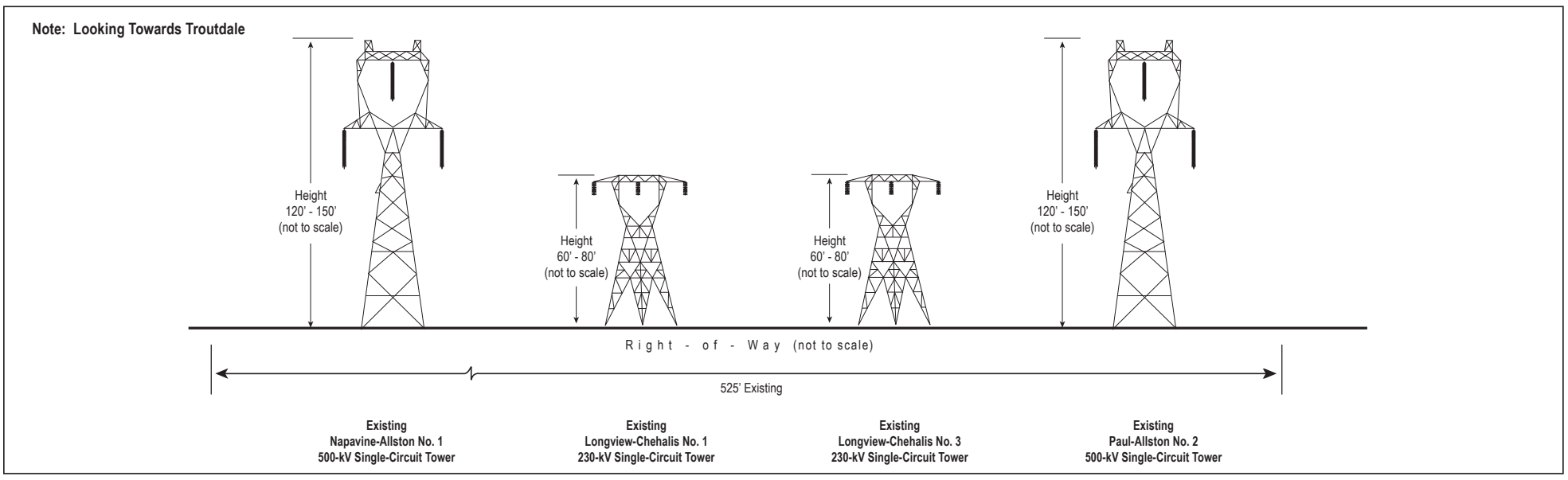


Figure B-24 Route Segment A (cont.)

Towers A/9-A/12

Existing. Single-Circuit Napavine-Allston No. 1 Line Parallel to the Longview-Chehalis No. 1 Line



Proposed. New Single-Circuit Tower Parallel to the Napavine-Allston No. 1 Line

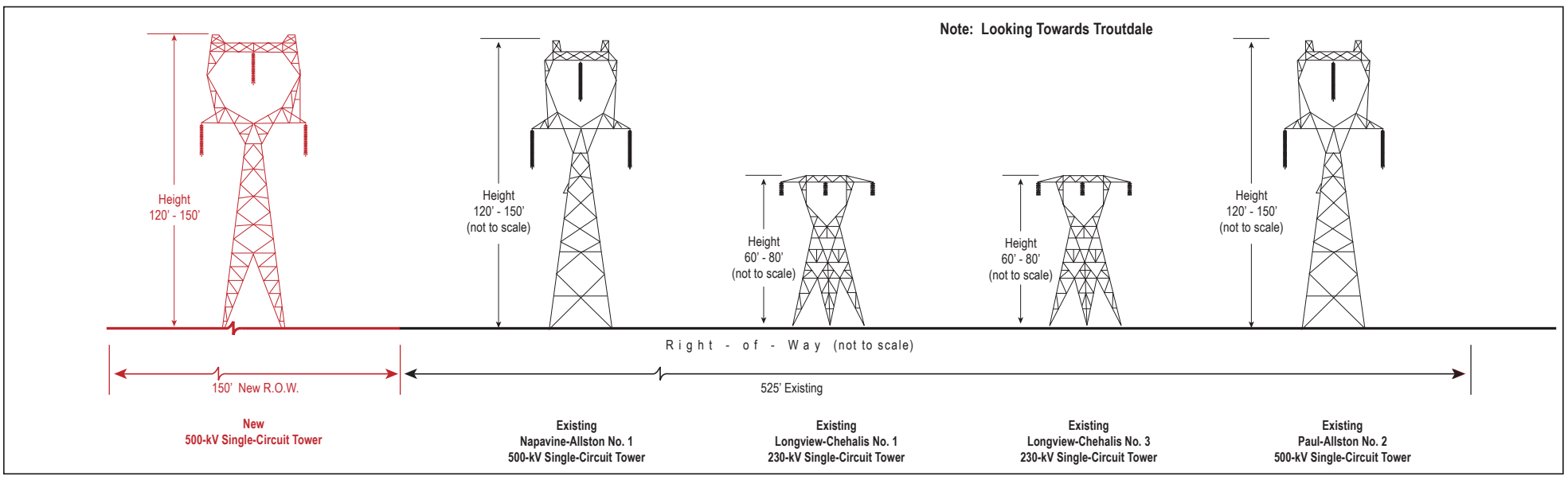
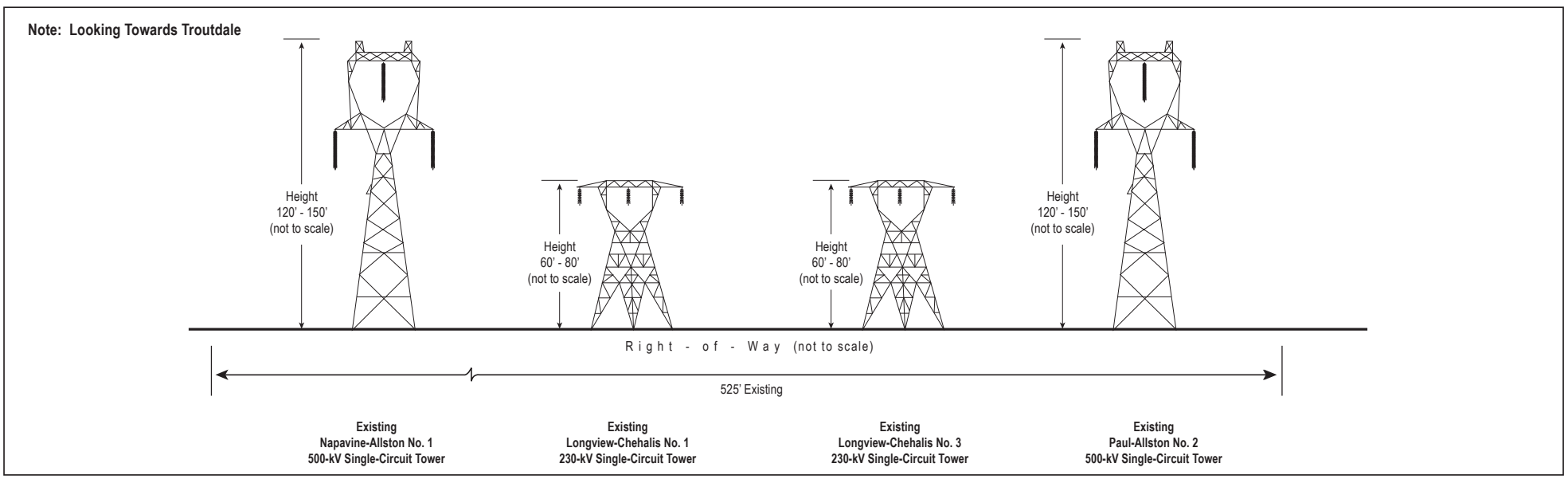


Figure B-25 Route Segment C

Towers C/1-C/17

Existing. Single-Circuit Napavine-Allston No. 1 Line Parallel to the Longview-Chehalis No. 1 Line



Proposed. New Single-Circuit Tower Parallel to the Rebuilt Longview-Chehalis Nos. 1 and 3 Lines

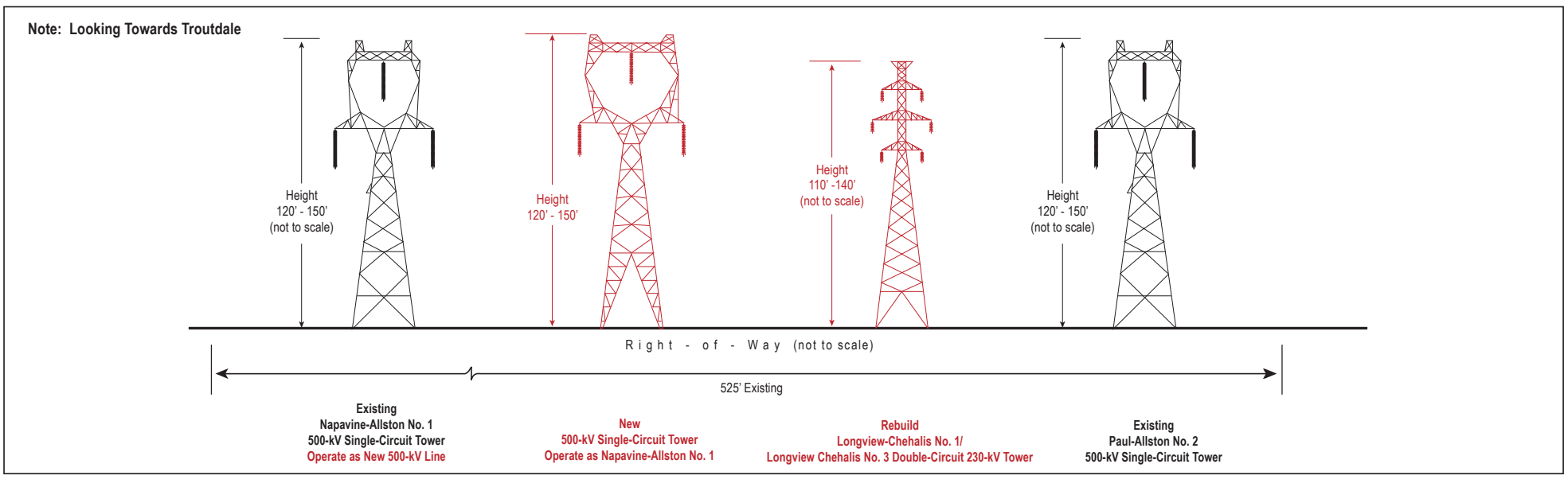
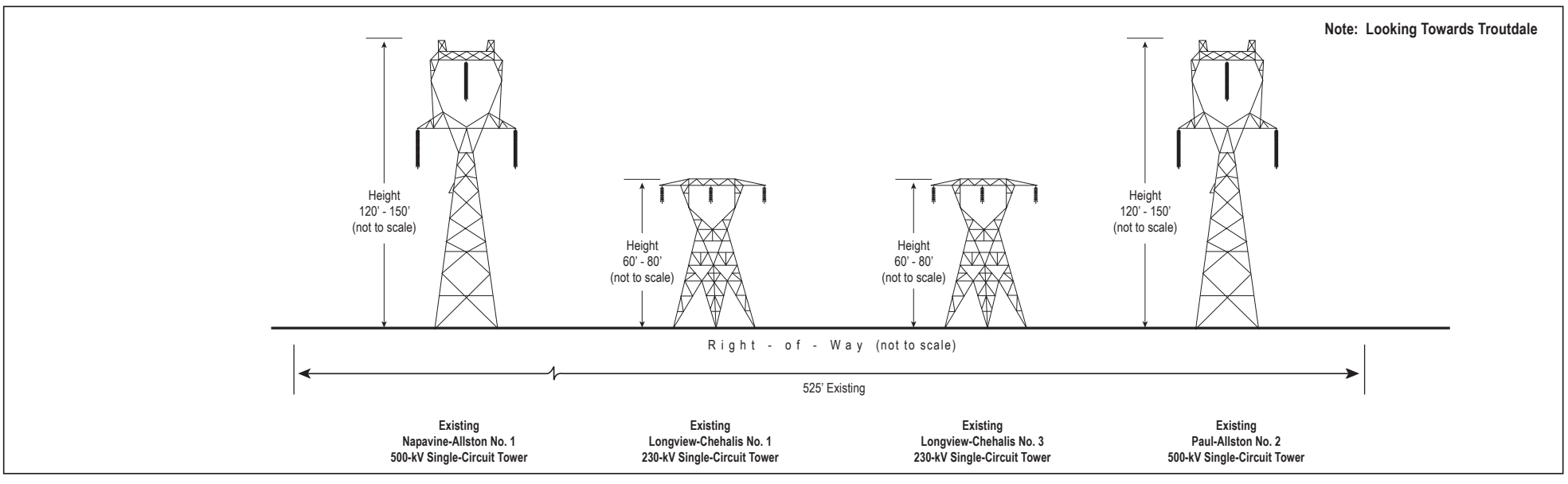


Figure B-26 Route Segment D

Towers D/1-D/17

Existing. Single-Circuit Napavine-Allston No. 1 Line Parallel to the Longview-Chehalis No. 1 Line



Proposed. New Single-Circuit Tower Parallel to the Napavine-Allston No. 1 Line

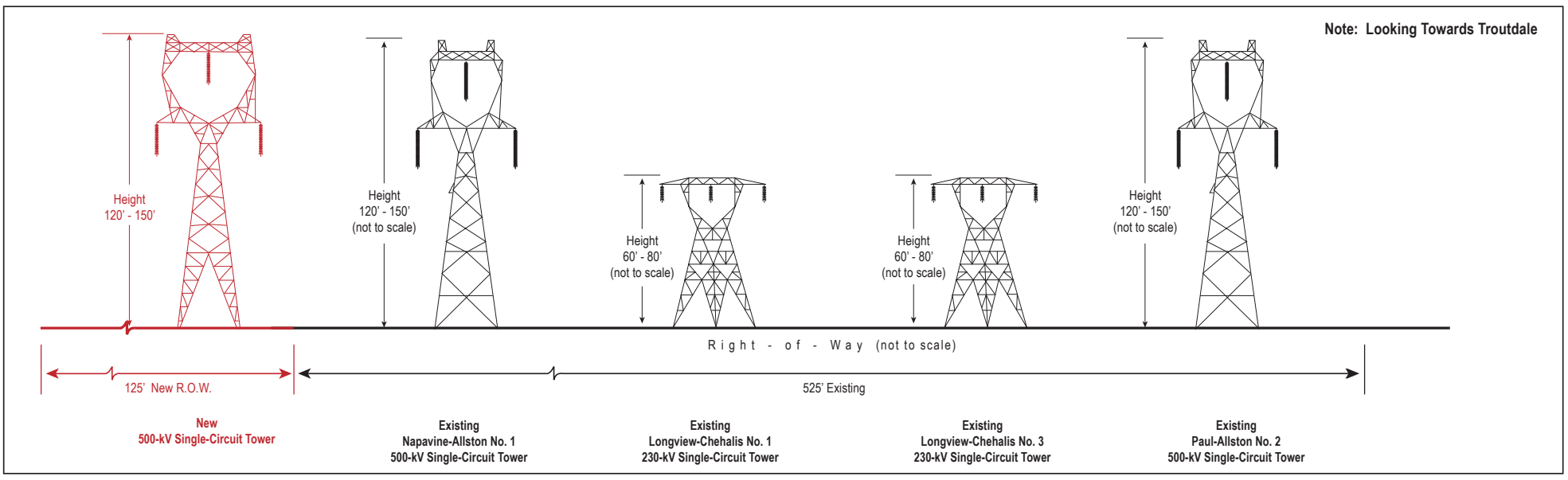
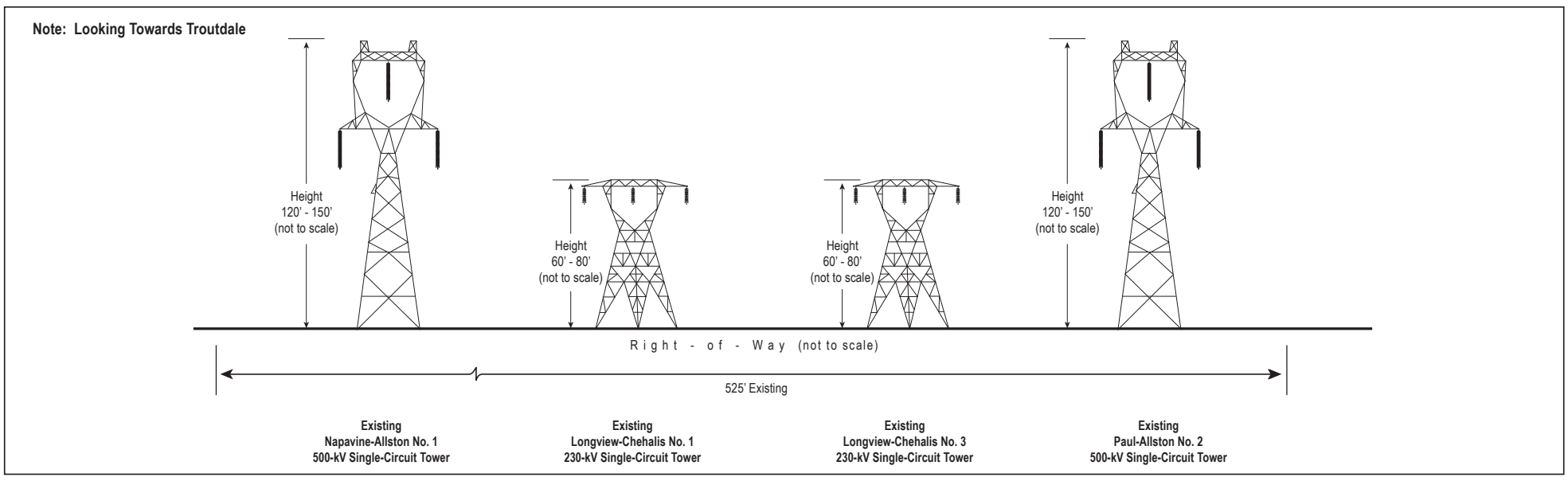


Figure B-27 Route Segment E

Towers E/1-E/6

Existing. Single-Circuit Napavine-Allston No. 1 Line Parallel to the Longview-Chehalis No. 1 Line



Proposed. New Single-Circuit Tower Parallel to the Rebuilt Longview-Chehalis Nos. 1 and 3 Lines

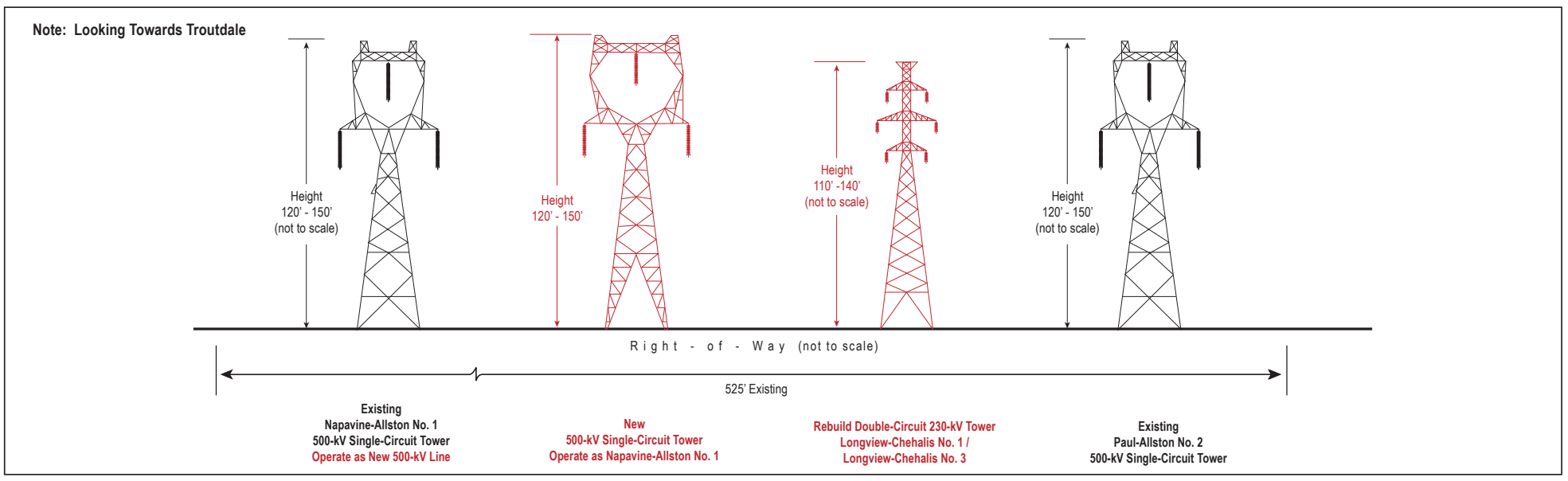
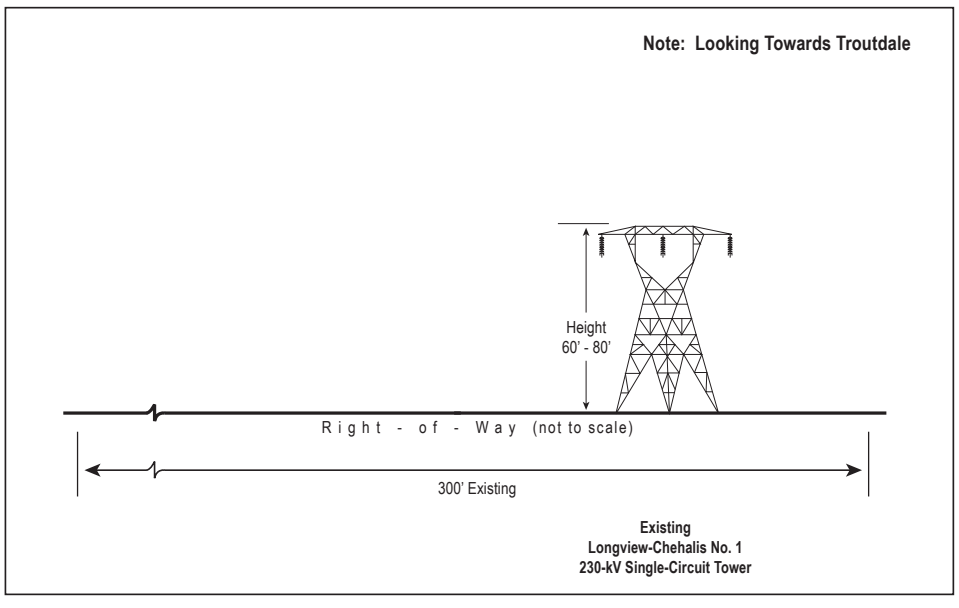


Figure B-27 Route Segment E (cont.)

Towers E/6-E/7

Existing. Single-Circuit Structure Lexington-Delameter No. 1 Line Parallel to the Longview-Chehalis No. 1 Line



Proposed. New Single-Circuit Tower Replacing Lexington-Delameter No. 1 Line Parallel to the Longview-Chehalis No. 1 Line

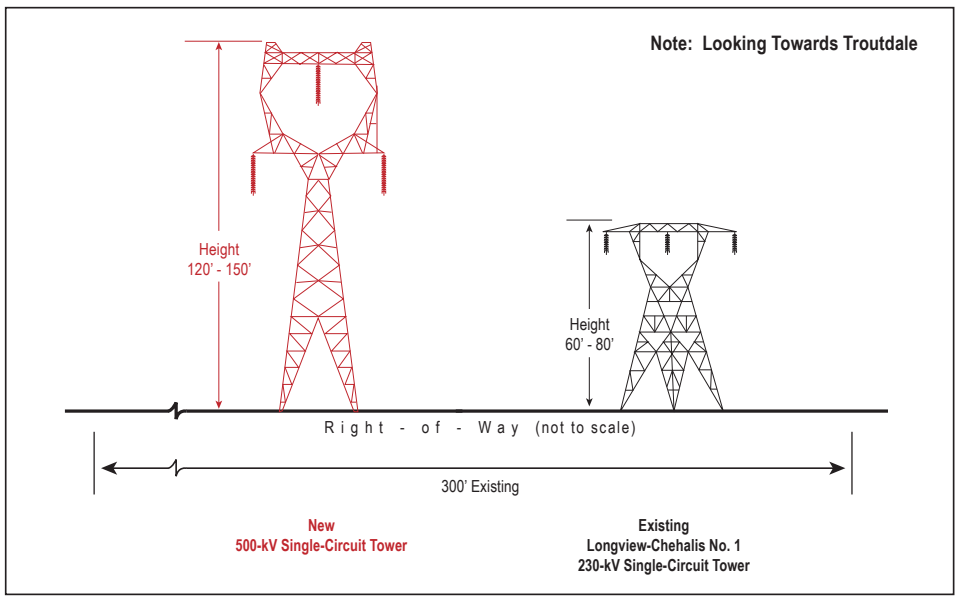
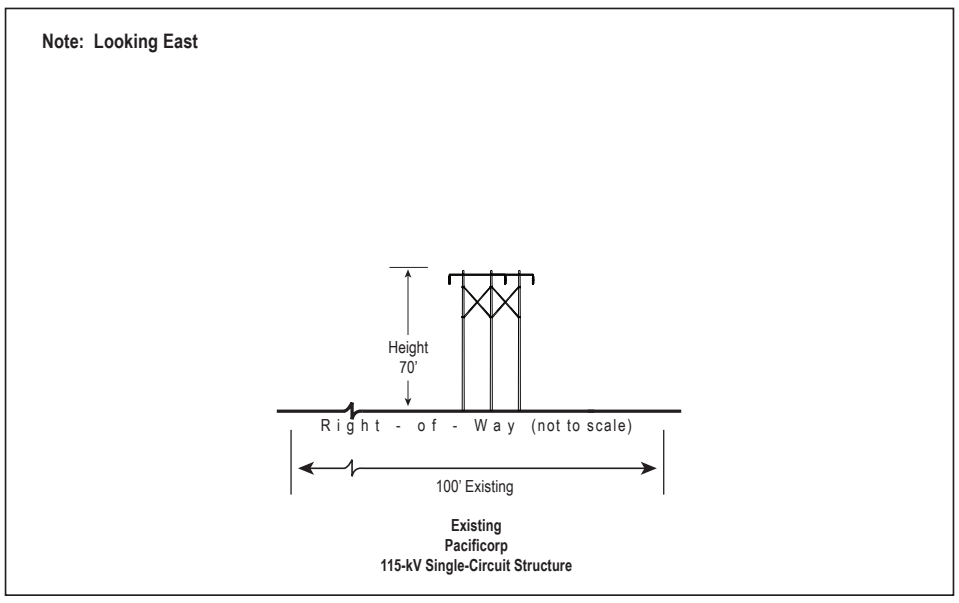


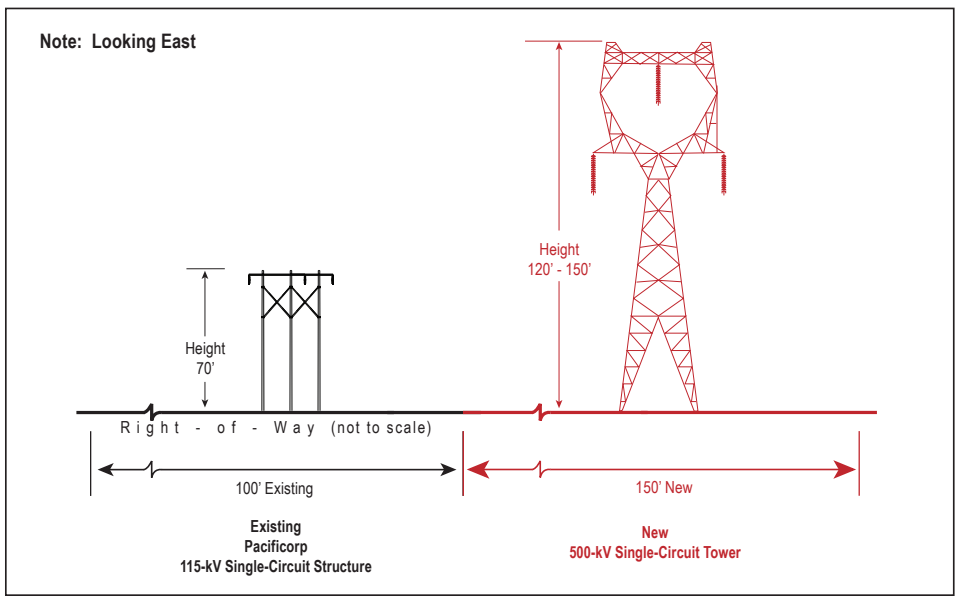
Figure B-28 Route Segment L

Towers L/5-L/9*

Existing. Single-Circuit Structure Pacificorp 115-kV Line



Proposed. New Single-Circuit Tower Parallel to the Pacificorp 115-kV Line

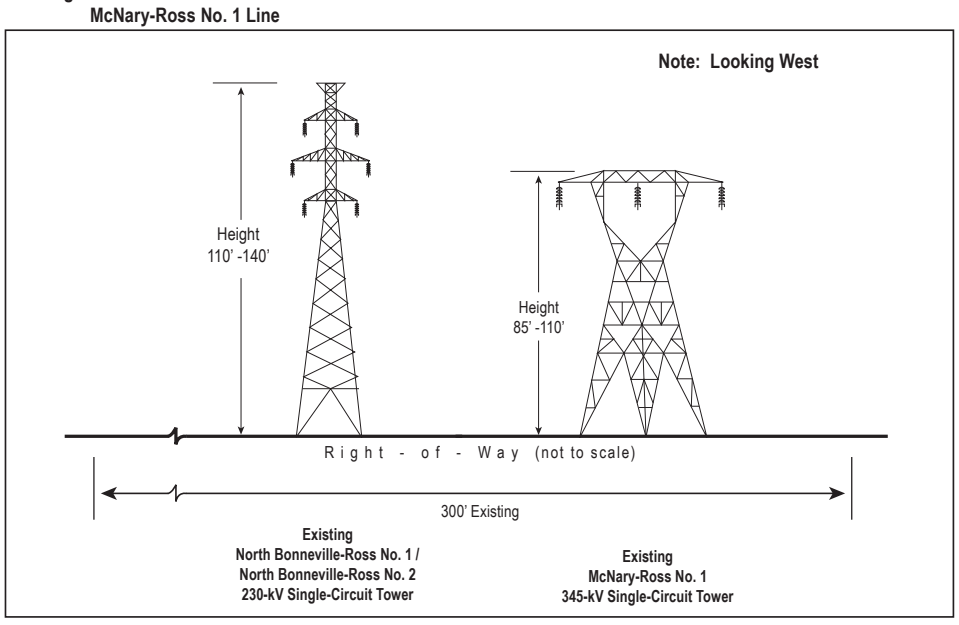


* Note: Towers L/1-L/5 will require 150 feet of new right-of-way. See Figure B-1 for more information.

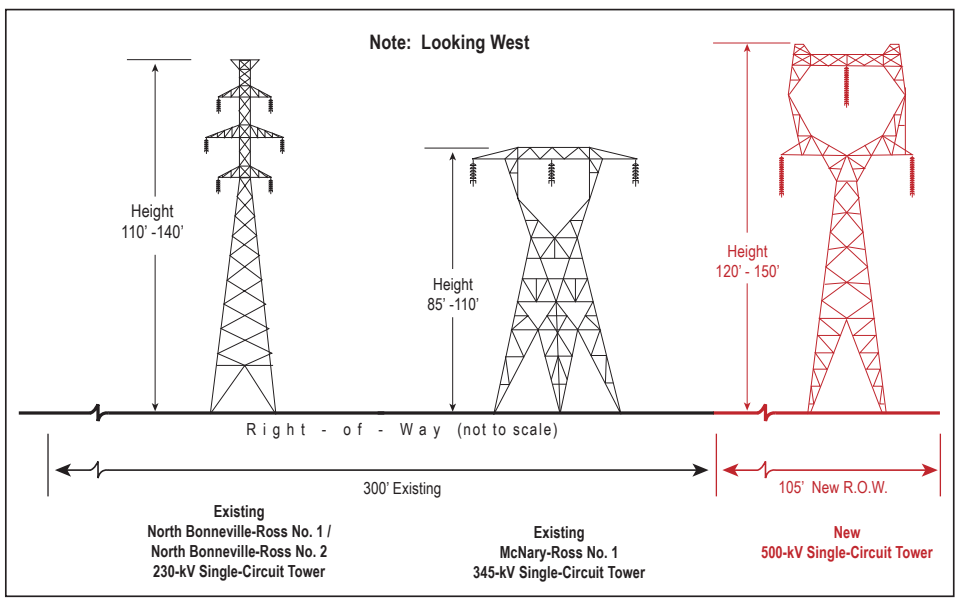
Figure B-29 Route Segment R

Towers R/10-R/19*

Existing. Double-Circuit North Bonneville-Ross No. 1 / North Bonneville-Ross No. 2 Line Parallel to the McNary-Ross No. 1 Line



Proposed. New Single-Circuit Tower Parallel to the McNary-Ross No. 1 Line



* Note: Towers R/1-R/10 will require 150 feet of new right-of-way. See Figure B-1 for more information.

Appendix D

Underground Route Study

January 21, 2011

BONNEVILLE POWER ADMINISTRATION

I-5 Transmission Corridor Project

Underground Route Study

Issued Final

PROJECT NUMBER:
119864

PROJECT CONTACT:
DENNIS JOHNSON
EMAIL:
DEJOHNSON@POWERENG.COM
PHONE:
(913) 338-0599

POWER ENGINEERS

UNDERGROUND ROUTE STUDY

PREPARED FOR: BONNEVILLE POWER ADMINISTRATION

PREPARED BY: DENNIS JOHNSON
(913) 338-0599
DEJOHNSON@POWERENG.COM

REVISION HISTORY		
DATE	REVISED BY	REVISION
07/06/10	Dennis Johnson	A
11/05/10	Dennis Johnson	B
01/21/11	Dennis Johnson	0

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY 1

1.1 SCOPE OF WORK 1
1.2 OVERVIEW OF PROJECT DESIGN 1
1.3 COST ESTIMATES 2
1.4 SUMMARY 2

2.0 PROJECT DESCRIPTION 3

3.0 UNDERGROUND CABLE SYSTEMS 5

3.1 EXPERIENCE 5
3.2 CABLE SYSTEM RATING 7
3.3 CONSTRUCTION METHODS 7
3.3.1 Open Trench 8
3.3.2 Trenchless Installation 8
3.3.3 Manholes 11
3.3.4 Cable Installation and Testing 12
3.4 LAND USE 13
3.5 ELECTRICAL CONSIDERATIONS 15
3.5.1 Reactive Compensation 15
3.5.2 Electric and Magnetic Fields 17
3.6 TRANSITION STATIONS/SUBSTATIONS 17
3.7 MAINTENANCE 18
3.7.1 System Maintenance 21
3.8 CABLE SYSTEM RELIABILITY 22
3.9 CABLE FAILURE LOCATING AND REPAIR 22
3.9.1 Fault Locating 22
3.9.2 Cable Repair 23

4.0 OVERHEAD TRANSMISSION SYSTEM 24

4.1 OVERHEAD EXPERIENCE 24
4.2 SYSTEM DESIGN 24
4.2.1 Conductor Size 24
4.2.2 Tower Type 24
4.2.3 Foundation Type 25
4.3 CONSTRUCTION METHODS 25
4.3.1 Conventional 25
4.3.2 Aerial Construction 26
4.3.3 Line Crossings 26
4.4 LAND USE 26
4.5 ELECTRICAL CONSIDERATIONS 27
4.6 MAINTENANCE 28
4.7 FAULT LOCATING 28

5.0 UNDERGROUND CONCEPTUAL DESIGN 29

5.1 CABLE SYSTEM DESIGN 30
5.1.1 Open Cut Trench Design 30
5.1.2 Trenchless Design 31
5.2 ELECTRICAL CHARACTERISTICS 34
5.3 MAGNETIC FIELD CALCULATIONS 35
5.4 SYSTEM OPERATION 36

6.0 OVERHEAD CONCEPTUAL DESIGN 38

6.1 FACILITIES DESIGN 38
6.2 CONSTRUCTABILITY 38
6.3 SPECIAL CONSTRUCTION AREAS 39

7.0 COST ESTIMATES 40

7.1 COST ESTIMATE ASSUMPTIONS 40
7.2 UNDERGROUND COST ESTIMATES 41
7.3 OVERHEAD COST ESTIMATES 42
7.4 COST ESTIMATES COMPARISON 42

APPENDIX A – ENVIRONMENTAL REPORT

APPENDIX B – DISCUSSION OF AVAILABLE UNDERGROUND CABLE SYSTEMS

1.0 EXECUTIVE SUMMARY

1.0 EXECUTIVE SUMMARY

1.1 Scope of Work

Bonneville Power Administration (BPA) is proposing to install a new single circuit 500 kilovolt (kV) alternating current (AC) transmission line from a proposed substation near Castle Rock, Washington extending approximately 70 miles south to a proposed substation near Troutdale, Oregon. The line is being developed to proactively counter the growing demand within BPA's existing electrical transmission system in southwest Washington and northwest Oregon. To ease congestion and keep pace with these growing demands, an in depth analysis at implementing a new transmission line through the proposed project area has been undertaken to comply with the provisions of the National Environmental Policy Act (NEPA). The NEPA process is intended to promote better agency decisions by ensuring that high quality environmental information is available to agency officials and the public before the agency decides whether and how to undertake a federal action. As part of the NEPA scoping process, BPA has enlisted POWER Engineers, Inc. (POWER) to investigate the feasibility and prepare estimated costs to place the proposed transmission line underground as well as a comparative overhead line cost assessment. This report provides an overview of available underground transmission technologies, applications, and capabilities; as well as construction, operation, maintenance, repair, and estimated costs for a 500kV underground and comparable overhead line.

Narrowing the Project area to two possible routes, BPA provided both the study area as well as a number of route segments for POWER to base the feasibility study and estimates on. Additionally, BPA made available their typical estimating practices, overhead structure families, and intended operation of the line to assist POWER in its work.

To minimize the overall scope of design work, the underground portion of the study focuses solely on high voltage extruded dielectric cable (HVED); namely cross-linked polyethylene (XLPE). While other cable technologies do exist, the current US trend is to utilize XLPE cable because of its favorable traits in reliability, constructability, and long term operation and maintenance.

1.2 Overview of Project Design

The basis of the underground design and installation is developed from the target power transfer requirement, from which a cable size and the total number of cables can be determined using predetermined environmental and system operating characteristics. For the anticipated underground project, it is assumed that four cables per phase will be required which will be installed in four independent concrete encased duct banks. The duct banks would be installed via open-cut trench and backfilled with thermally corrective fill to improve cable operating performance. A number of major waterways, railroad tracks and roadways would be encountered along each evaluated route. It has been assumed that major waterways and wetlands would be crossed using horizontal directional drilling (HDD) and major roadways would be crossed by means of a jack and bore (J&B). Reactor stations would be installed at two intermediate points, approximately every 25 miles and at each end.

The assumption for the overhead estimate is standard 500kV lattice tower construction according to BPA standards.

1.3 Cost Estimates

Using the predefined route segments, estimated costs for each route were developed taking into account the environmental conditions, geology, and anticipated construction method. Detailed assumptions have been included in Section 7 of this report. The estimated installed costs for the proposed transmission line for each route can be seen in Table 1-1.

TABLE 1-1 COMPARISON COST ESTIMATES

Route/Installation	Length (mi)	Overhead Cost	Underground Cost
Eastern Route	76	$151,215,000	$2,369,721,000
Western Route	68.5	$147,080,000	$2,051,490,000

1.4 Summary

While installing an underground 500kV transmission line of the proposed length appears to be technically feasible, there is a significant cost increase compared to the overhead alternative of nearly 15 times. In addition to the cost, there are significant operational, system loss, performance and reliability concerns.

- Operational Concerns – With the addition of the capacitance and reactors, BPA will need to do an extensive system analysis to determine the operational impact to their system. It may require replacement of downstream equipment as well.

- System Losses – No analysis was performed to determine the additional system losses associated with the underground cable system compared with an overhead line. However, it is well understood that the systems losses for the underground system will be significantly higher than the overhead.

- Performance and Reliability – With only a few land installations throughout the world, totaling less than 30 circuit miles, the cable and accessories have not proven themselves to maintain the high reliability demands of today's electric grids.

While a direct current (DC) cable system was not evaluated for this report, recent studies have shown that for lengths greater than 40 miles, the cost of the DC converters and DC cable system would be equivalent and may be less expensive compared to the proposed AC cable system.

2.0 PROJECT DESCRIPTION

2.0 PROJECT DESCRIPTION

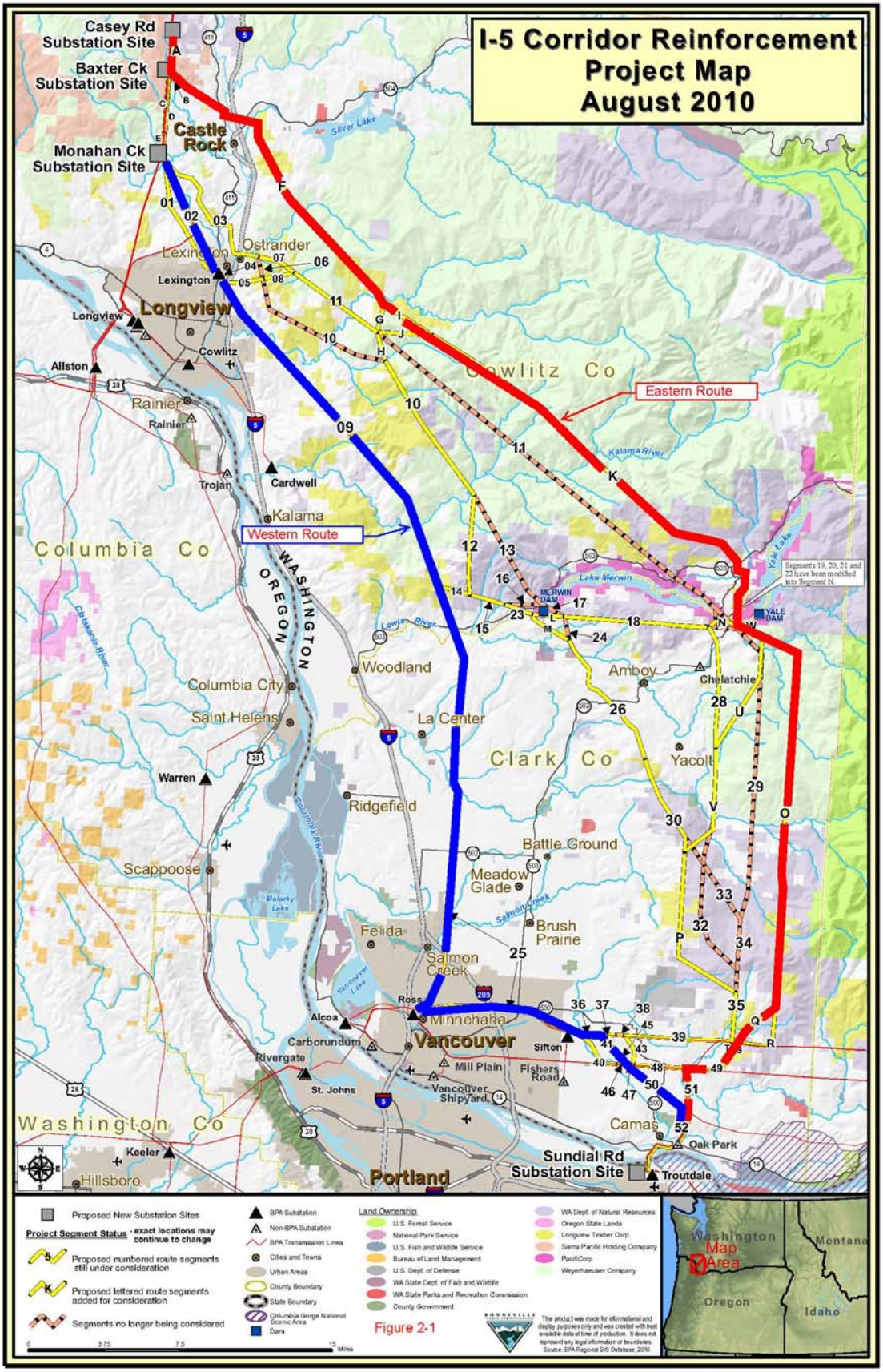
Bonneville Power Administration (BPA) is proposing to install a new single circuit 500 kilovolt (kV) alternating current (AC) transmission line from a proposed substation near Castle Rock, Washington extending approximately 70 miles south to a proposed substation near Troutdale, Oregon. The line is being developed to proactively counter the growing demand within BPA's existing electrical transmission system in southwest Washington and northwest Oregon. To ease congestion and keep pace with these growing demands, an in depth analysis at implementing a new transmission line through the proposed project area has been under taken to comply with the provisions of the National Environmental Policy Act (NEPA). The NEPA process is intended to promote better agency decisions by ensuring that high quality environmental information is available to agency officials and the public before the agency decides whether and how to undertake a federal action. As part of the NEPA scoping process, BPA has enlisted POWER Engineers, Inc. (POWER) to investigate the feasibility and prepare estimated costs to place the proposed transmission line underground as well as a comparative overhead line cost assessment. This report provides an overview of available underground transmission technologies, applications, and capabilities; as well as construction, operation, maintenance, repair, and estimated costs for a 500kV underground and comparable overhead line.

Appendix A provides a discussion of the potential environmental impacts from construction, operation, and maintenance of an overhead and underground 500kV transmission line. A description of the types of environmental resources which may be impacted by a new transmission line is provided, followed by a discussion of potential environmental impacts which may occur to these resources. The environmental impacts which are presented are general impacts and they do not relate to a specific project, location, or project proponent. Therefore, the environmental impacts and associated mitigation measures in the report may or may not apply to any particular project, including this proposed 500kV project.

Narrowing the Project area to two possible routes, BPA provided both the study area as well as a number of route segments for POWER to base the feasibility study and estimates on. These routes are comprised of a number of different route segments. The studied routes and associated route segments are:

- Eastern Route – This route length would be approximately 76 miles. This route would be made up of the following segments: A, F, I, K, W, O, Q, S, 49, 51, 52

- Western Route – This route length would be approximately 68.5 miles. This route would be made up of the following segments: 2, 4, 9, 25, 36, 41, 45, 50, 52


I-5 Corridor Reinforcement
Project Map
August 2010
Casey Rd Substation Site
Baxter Ck Substation Site
Monahan Ck Substation Site
Castle Rock
Longview
Lexington
Ostrander
Cowlitz Co
Eastern Route
Western Route
Columbia Co
Clark Co
Washington Co
Portland
Vancouver
Sundial Rd Substation Site
Proposed New Substation Sites
Project Segment Status - exact locations may continue to change
Proposed numbered route segments still under consideration
Proposed lettered route segments added for consideration
Segments no longer being considered
BPA Substation
Non-BPA Substation
BPA Transmission Lines
Cities and Towns
Urban Areas
County Boundary
State Boundary
Columbia Gorge National Scenic Area
Dams
Land Ownership
U.S. Forest Service
National Park Service
U.S. Fish and Wildlife Service
Bureau of Land Management
U.S. Dept. of Defense
WA State Dept. of Fish and Wildlife
WA State Parks and Recreation Commission
County Government
WA Dept. of Natural Resources
Oregon State Lands
Longview Timber Corp.
Sierra Pacific Holding Company
PacifiCorp
Weyerhaeuser Company
Figure 2-1
Washington
Montana
Oregon
Idaho
Map Area

3.0 UNDERGROUND CABLE SYSTEMS

3.0 UNDERGROUND CABLE SYSTEMS

Today, primarily two types of underground cable systems are being installed at the 500kV AC voltage level worldwide. They are:

- High Voltage Extruded Dielectric (HVED) cable system
- Self Contained Fluid-Filled (SCFF) cable system.

While a majority of the extra high voltage (EHV) underground cable installations worldwide are SCFF, a significant amount of HVED cable has recently been installed. As the cable manufacturing process has evolved and utilizing cross-linked polyethylene (XLPE) as the primary insulation material, HVED cable systems have largely become the preferred underground cable system for underground cable installations in the US. With the emergence of the XLPE cable technology at higher voltages, installations of SCFF cable systems have began to decrease, as XLPE cable systems eliminate the need for continuous monitoring of fluid systems, reduced environmental tensions, and increased long-term system reliability.

While other EHV technologies, Gas Insulated Transmission Line (GITL) and High Temperature Superconducting (HTS), exists, GITL is not recommended for long distance applications and HTS cable has not been developed for use at 500kV and long length applications. Additional information on both of these systems has been included in Appendix B.

Another underground technology that could be utilized is to convert the power system to a direct current (DC) system and install a DC cable system. There are considerably more AC underground systems installed in the world compared to DC systems, simply because the later are relatively expensive in comparison. This is mainly due to the high cost of AC/DC converters to transform AC to DC and back again. However, when the length of the circuit is relatively long and the system voltage is above 230kV, a underground DC system may become economical viable compared to the equivalent AC underground system.

At the request of BPA, this report only addresses AC systems and the use of an XLPE cable system. Brief discussions of XLPE and SCFF cable systems are included in Appendix B.

3.1 Experience

There are a limited number of underground XLPE cable systems installed in the world at 500kV. However, there have been an increasing number of 400kV installations around the world. The highest voltage of XLPE cable installed in the US is 345kV.

The following is a list of AC underground cable installations for voltages 345kV and above.

Country	Date	Voltage (kV)	Circuit Length (miles)	Installation Type
Taiwan	2000	345	12.8	Tunnel
Korea	2003	345	12.2	Tunnel
USA	2006	345	8.6	Duct/manhole
USA	2007	345	2.4	Duct/manhole
USA	2008	345	8.1	Duct/manhole

Country	Date	Voltage (kV)	Circuit Length (miles)	Installation Type
Denmark	1997	380-400	13.2	Direct Buried
Germany	1998	380-400	7.8	Tunnel
Denmark	1999	380-400	7.5	Direct Buried
Germany	2000	380-400	6.5	Tunnel
Saudi Arabia	2000	380-400	7.0	Direct Buried
Iraq	2001	380-400	2.5	
Spain	2002	380-400	3.7	Tunnel
Abu Dhabi	2003	380-400	7.8	Direct Buried
Denmark	2004	380-400	16.8	Direct Buried/ducts
Italy	2006	380-400	10.4	Direct Buried
Spain	2004	380-400	15.9	Tunnel
UK	2005	380-400	12.8	Tunnel
UK	2005	380-400	3.4	Tunnel
Austria	2005	380-400	6.5	Direct Buried/Tunnel
Netherlands	2005	380-400	2.8	Direct Buried/ducts
Italy	2005	380-400	0.8	Direct Buried
UAE	2006	380-400	1.7	
Italy	2006	380-400	5.1	Direct Buried
UK	2007	380-400	8.3	Tunnel
Italy	2007	380-400	2.2	Direct Buried
Turkey	2007	380-400	8.2	Direct Buried
Netherlands	2007	380-400	0.9	Direct Buried/pipes
Netherlands	2008	380-400	4.9	Direct Buried
Qatar	2009	380-400	0.8	
Abu-Dhabi	2009	380-400	3.7	Direct Buried
Qatar	2009	380-400	10.2	Direct Buried
France	2009	380-400	3.1	Duct
Qatar	2010	380-400	13.7	Direct Buried
Qatar	2010	380-400	7.0	Direct Buried
Netherlands	2010	380-400	8.0	Direct Buried/pipes
Netherlands	2010	380-400	2.7	Duct
UK	2010	380-400	4.5	Direct Buried
UK	2010	380-400	6.8	Tunnel
UK	2010	380-400	1.1	Trough
Japan		500	25	Tunnel/Bridge
Russia		500	0.9	Tunnel
China		500	21.3	Tunnel

As can be seen in the above table, there has only been three installations of 500kV XLPE cable in the world and these were all installed in tunnels. There is no experience anywhere in the world with installing 500kV XLPE cable in a duct bank system. It is important to point out that the longest 500kV cable system in service is only 25 miles in length.

3.2 Cable System Rating

The ampacity, or current rating, of a cable is one of the most important concepts to understand when designing an underground cable system, since its calculation encompasses many aspects of the cable construction and installation. There are many factors that come into play when trying to design the optimal and most economical underground cable systems. One of the main factors is the thermal performance of the underground cable system.

There are many design parameters that must be determined to achieve optimal thermal performance, thus achieving the load transfer requirements. These considerations are as follows:

- Cable Size – increasing the cable size generally allows for an increased load transfer. However, there is a limit to the maximum conductor size that can be manufactured by the majority of the cable manufacturers. This conductor size is typically accepted to be up to 5000 kcmil for XLPE. The larger conductor sizes are typically manufactured at a significant increase in cost.

- Soil Thermal Resistivity – the ability of the heat to dissipate away from the cable is based on the thermal properties of the soil/backfill installed around the cable.

- Cable Depth – the deeper the cable is from the surface the harder it is for the surrounding soil to dissipate the heat, thus resulting in a lower ampacity. Typically, horizontal directional drill (HDD) construction requires a larger cable size.

- Cable Separation – other cables in close proximity also generate heat, thus resulting in mutual heating. Mutual heating can be reduced further by increasing the separation of the cables. However, the further the cables are separated the larger the excavation would need to be and an increase in cost would result.

3.3 Construction Methods

Regardless of the voltage rating, the same construction methods are used to install XLPE cable systems. As can be seen in the experience table above, the most common method of installation of EHV XLPE cable systems is by direct buried with a few being installed in tunnels or ducts. While direct buried is the most economical method for installing a XLPE cable system, the most common method used in the US is to install the cable in concrete encased ducts, commonly called a duct bank system. The reason a duct bank is the most common US installation method is the following:

- Provides mechanical protection
- Eliminates any re-excavation in the event of a cable failure.
- Easier to repair
- Short length of trench can be opened for construction activities. A direct buried system requires that the entire trench be left open in order to be able to install the cable.

In general, the most economical construction method for constructing an underground duct bank is by open cut trenching. Trenchless methods such as horizontal directional drilling (HDD) and jack and bore (J&B) are also common when open trenching is not allowed or feasible.

The following sections provide a general discussion on the construction and installation of a XLPE cable system.

3.3.1 Open Trench

This consists of using excavation equipment to remove any concrete, asphalt road surface, topsoil and sub-grade material to the desired depth. The material removed is taken to an appropriate off-site location for disposal or used for fill as appropriate. Once a portion of the trench is dug, polyvinyl chloride (PVC) conduit is assembled and lowered into the trench. The area around the conduit is filled with a high strength thermally corrective concrete (3000 psi). After the concrete is installed the trench is backfilled and the site restored. Backfill materials can be clean excavated material, thermal sand and/or a thermally corrective concrete mix. Figure 3-1 shows a typical trench excavation.

Figure 3-1: Typical Trench Excavation

3.3.2 Trenchless Installation

There are two types of trenchless methods that are commonly utilized when open trenching may not be allowed. They are: jack and bore (J&B) and horizontal directional drilling (HDD). Common areas where open trenching may not be allowed are: crossing roadways, street intersections, railroad crossings, bodies of water, wetlands and other environmentally sensitive areas.

Jack and Bore (J&B)

The jack and boring method is commonly used for short crossings, under 400 feet, and where no bends are required. But J&B have been used for longer lengths depending on the soil conditions. A J&B installation consists of installing a casing under the obstruction and then installing the conduit inside the casing. Selection of the casing material is very important. Historically, most bores have been installed with steel casings, but there has been a trend to non-metallic casings such as high density polyethylene (HDPE), fiberglass or reinforced concrete pipe (RCP) due to the affect on ampacity.

To initiate a J&B installation, a bore pit having a minimum size of 40 feet long by 10 feet wide would be excavated to install a single casing. This bore pit is required by the boring equipment and for placing and welding 20-foot sections of casing pipe. If multiple casings are planned the bore pit may be enlarged or individual bore pits used. Also, prior to starting the boring process, a receiving pit approximately 10 feet in length is excavated for each casing on the opposite side of the crossing. Since a bore is basically at a greater depth than an open trench, the entrance and exit pits require shoring (and possibly tight sheeting) in accordance with OSHA regulations. Secondly, if the boring encounters poorly consolidated soil (soil that begins to slough or flow if unsupported after a few minutes), solid sheeting would be required to enclose the entire entrance pit, allowing only an opening for inserting and installing the casing and auger. Once the boring machine is in place, the bore begins and continues until the casing reaches the other side. Figure 3-2 shows a typical J&B set-up.

Casing sizes can vary for cable systems from 14 to 84 inches, depending upon the type of cable system, number of circuits being installed, and length of the bore. The longer the bore, the more difficult it is to control the direction of the bore and to fill the casing after the pipe/duct installation.

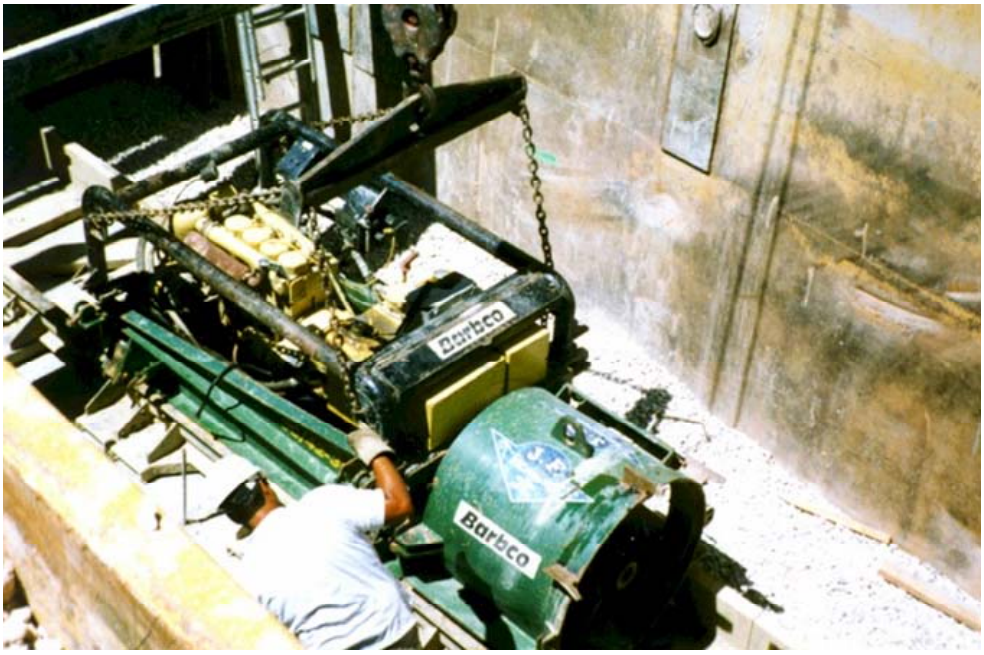


Figure 3-2: Typical Jack and Bore Set-up

Horizontal Directional Drilling (HDD)

The HDD method is commonly used for longer crossing and where bends may be needed. A HDD installation for a HVED cable system consists of installing a casing with conduits inside or just installing the conduits in a bundle by themselves.

The HDD method consists of a process, where a small diameter pilot hole is drilled from entry to exit, followed by a reamer that is pulled back to enlarge the pilot hole. Finally, the product pipe is pulled into the enlarged hole. HDD operations have become quite popular with utilities since it eliminates the need to excavate large bore pits and the work can be performed from the surface. While this method does not require any significant pit excavation, it does require a significant area at the entry point and exit points of the drill. A typical entry point site requires an area of about 100 feet by 150 feet and an exit area of 100 feet by 100 feet. Figure 3-3 shows a typical HDD set up.

Figure 3-3: Typical HDD Set-up

If a casing is installed, the duct would be installed using specially designed spacers. The pipe would then be filled with a thermally approved grout. Without a casing, the conduits would be bundled together using specially designed spacers and then pulled back into the hole as a complete package.

When crossing any body of water a number of concerns arise, and generally these concerns are area specific. The main issues involve the type of body of water to be crossed, whether or not the area is environmentally sensitive, the location of any access points, environmental control, and permitting. When performing any work around bodies of water special permitting is usually required, as is an environmental impact study. In addition, extensive measures must be taken in preserving the natural water flow. This can range anywhere from erosion control to complete removal of all excavated soils. Because horizontal directional drilling uses bentonite, a clay type drilling fluid to stabilize the bore and reduce mechanical wear, concerns of frac-out into the water body arise. Frac-out, or inadvertent return of drilling lubricant, is caused when excessive drilling pressure results in drilling mud propagating toward the surface and can be a potential concern when an HDD is used under sensitive habitats, waterways, and areas of concern for cultural resources. While bentonite is non-toxic and commonly used in farming practices, benthic

invertebrates, aquatic plants, and fish and their eggs can be smothered by the fine particles if bentonite were discharged to waterways. To minimize the possibility of a frac-out requires a thorough geotechnical investigation. Prior to construction, a frac-out response plan is often required.

3.3.3 Manholes

Manholes are needed periodically along an underground route to facilitate cable installation, for maintenance requirements and access for future repairs. Manholes are typically spaced every 1,500 to 2,500 feet along the route. The manhole size and layout is based on the type of cable system installed. The manhole size is determined on the space required for cable pulling, splicing and supporting the cable in the manhole. For a 500 kV XLPE cable, the typical outside dimensions for each manhole would be about 10 feet wide by 35 feet long and the spacing between manholes would be about 1,300 to 1,800 depending on the cable size. Many utilities require a separate manhole for each set of cables for safety reasons. These utilities do not allow entrance to the manhole with any cables being energized. So for the purpose of this report, POWER assumed a manhole would be installed for each set of three phase cables at each splice location. During detail design specially designed manholes could be investigated that would allow multiple circuits to be installed in a single manhole and reduce the overall footprint of the manholes at each splice location.

The factors contributing to the final placement of the manholes are: allowable pulling tensions, sidewall pressure on the cable as it goes around a bend and the maximum length of cable that can be transported on a reel, based on the reels width, height and weight.

Typically the manholes are pre-cast and delivered to the site on a tractor trailer. A crane is then used to set the manhole. Figure 3-4 shows the setting of a pre-cast manhole.

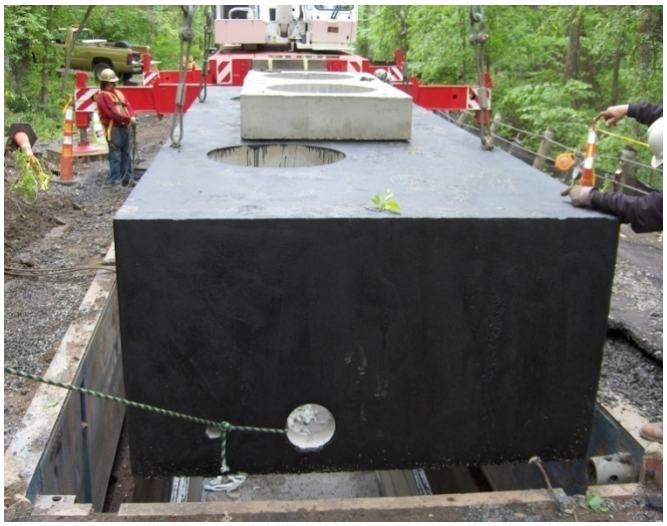


Figure 3-4: Typical Manhole Placement

3.3.4 Cable Installation and Testing

Following the installation of the duct bank and manholes, the cable would be installed. Prior to installation of the cable, the conduit would be tested and cleaned by pulling a mandrel and swab through each of the ducts. A mandrel is a torpedo shaped pulling device used to ensure the conduits were installed properly and are free from any debris that may have entered the duct bank. Made of either wood or aluminum, a mandrel is pulled through each individual conduit. The mandrel is approximately ½" smaller than the inner diameter (ID) of the conduit being tested. If the mandrel passes through the conduit without getting stuck or showing significant scaring, the conduit passes inspection and cable can be installed. The swab, or often times referred to as a rag bundle, is commonly pulled through the conduit in conjunction with the mandrel. The swab, pulled in front of the mandrel, acts as a "pipe cleaner" to remove any loose material within the conduit.

Cable installation procedures and equipment would be based on environmental conditions, equipment and material placement and pulling requirements. The typical cable pulling setup would be to set the reel of cable at the transition structure or at one of the manholes and place the winch truck at the opposite end. The cable should always be pulled from the transition structure to the nearest manhole. Direction of pull between manholes should be determined based on the direction that results in the lowest pulling or sidewall tensions. Once all the cable is pulled into a manhole from each direction, splicing of the cable could commence. This process would be followed until all the cable has been pulled, terminated or spliced. Once this has occurred the cable would be tested. Figure 3-5 shows a typical cable reel set up.

Figure 3-5: Typical Cable Pulling Set up

Upon installation and termination of each cable, the cable must be tested before being placed in service. Typical testing includes a jacket integrity test using a specified DC voltage to ensure the jacket is continuous from end to end. Historically, an AC soak test would also be preformed where the cable would be connected at rated voltage without load and left to "soak" for 24 hours. This enables the insulation to be stressed prior to current flow.

Recently, testing equipment has become available in the US to perform AC hi-pot and partial discharge (PD) commissioning testing similar to the tests that are performed in the factory. While this testing is becoming more common at lower transmission voltages (below 230kV), there is a limit to the voltage that can be generated and the length of the cable that can be tested. The higher the voltage requirement and the longer the length, the more costly the tests are to perform.

3.4 Land Use

When routing an underground line, it is important to know the type of area and terrain that the line will be crossing.

Urban

Urban areas are becoming more and more congested with traffic and underground utilities. This makes the installation of a new underground transmission lines difficult. When choosing routes in urban areas for new circuits, extreme care is required to locate the existing underground facilities. The typical location for a new underground circuit in an urban area is within the road right-of-way. There is usually very little undeveloped land available that could be used for installing an underground line. Major thoroughfares should be avoided because of the large amount of traffic that would have to be controlled. The designer should be aware that a significant cost of installing circuits in urban locations is traffic control.

Suburban

Suburban areas, like urban areas, are becoming congested with traffic and construction activities. Schools, churches, and homes will likely be included in the route selected through suburban areas, requiring additional safety considerations during construction. These areas should be avoided, if possible. During construction, the entire road may have to be closed to provide sufficient working space for the installation of the underground cable system.

Rural

Rural areas are generally easier locations in which to construct underground lines because they usually have fewer existing underground utilities; however, they also lend themselves to overhead transmission lines more easily than suburban and urban areas. Since rural areas are generally undeveloped, the type of terrain the underground line must traverse is an important design consideration. The different terrains a transmission route may encounter are: flat, rolling hills, mountains, and wetlands or other large water bodies/obstructions. A disadvantage to rural areas is the possible limited accessibility to the route corridor for construction and future maintenance.

The type of terrain and soil conditions can greatly impact the cost of installing an underground cable system.

- Flat terrain – this type of terrain is the easiest type of terrain to perform open cut trenching unless there are environmentally sensitive wetlands. If open trenching of the wetland is unacceptable, HDD is typically used to cross under the wetland. Typically, a construction road is constructed along the full length of the trenching operation in rural areas to provide the necessary construction access.

- Rolling hills – this type of a terrain is also well suited for open cut trenching as long as the slope of the hills are not extreme (<10%). Extreme slopes can make open cutting a big challenge. The main challenge is to be able get all the necessary construction equipment, concrete trucks, tractor trailers, cranes, and cable reels, up and down the slopes to the necessary locations. Suitable access roads for the construction equipment are needed to get up and down the hill. These access roads can be constructed by cutting into the hill or designing some type of switch back. The type of design is predicated on the extent of the slope. While HDD could be utilized to cross a series of hills to avoid the slope issue, the issue of gaining access to each drill location is still a primary concern and may be impossible to achieve.
- Mountains – this type of terrain can be a challenge to the construction of an underground cable system. The same issues about the grade slope discussed above, applies to the mountain terrain as well. In addition, mountainous terrain, usually indicate the existence of rock. To excavate the rock, explosives may need to be used.
- Wetlands – while open cutting can be used to cross wetlands, typically, there are significant environmental controls applied to the process, which will generally significantly increase the costs. In some cases, HDD can be used to span a large wetland area.
- Large waterbodies/obstructions – there are some situations where open trenching is not practical. This situations involve crossing of large rivers, waterways, highways or railroad tracks where open cutting is not allowed.

The type of land use often determines the amount of easement or right-of-way available for the underground line. Underground lines are frequently located in existing roadway rights-of-way. Typically, no easement is required to install the underground line in public right-of-way; however, the owner of the road usually reserves the right to have the utility relocate the underground line if a future conflict occurs. For this reason, some utilities prefer to install underground circuits within a dedicated easement adjacent and parallel to the public right-of-way, and to accept the added cost. Additionally, underground lines can be installed in existing overhead line right-of-ways or in joint use easements when long cross-country inter-ties are being installed.

While typically only a 30 foot right-of-way is required for most underground projects, this project would require a larger amount of right-of-way depending on the installation method. In an attempt to minimize conductor size, each duct bank will need at least 10 foot center-to-center separation resulting in a total right-of-way width of approximately 60 feet after access and constructability is considered. Further, temporary construction easements may be required if the underground installation could not be installed within or at the edge of road right-of-way and the road right-of-way is not suitable for the set up of the installation equipment. All trees and vegetation in the permanent and temporary easements would need to be cleared for construction. All federal, state, county, city and other applicable agencies would need to be contacted to determine permitting requirements. The final decision on the amount required for right-of-way would be determined during final route selection. Figure 3-6 shows a cross section of the proposed right-of-way.

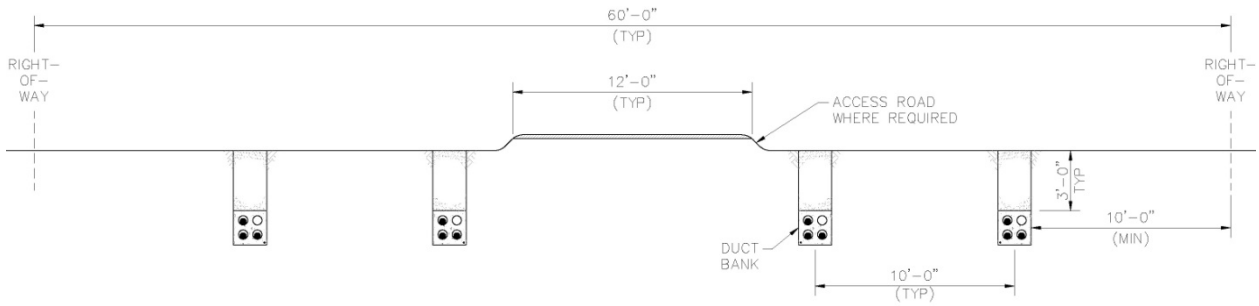


Figure 3-6: Typical Right-of-Way Usage

3.5 Electrical Considerations

The characteristics of 500 kV underground cables are significantly different from those of 500 kV overhead lines, and these differences must be taken into account when considering integrating underground cables into a transmission system composed primarily of overhead lines. The following is a list of some of the important design considerations.

- Cable reactive-compensation requirements
- Effects on power flows
- Effects on switching devices
- Effects on surge-protective devices
- Steady-state voltage effects
- Impact on system parallel harmonic resonance frequency
- Short-term overload characteristics
- Increased losses
- More complex protection scheme

An in-depth analysis of these topics requires sophisticated load-flow, transient-stability, short-circuit, and overvoltage calculation computer programs. No attempt was made to perform any system analysis. Before an underground 500 kV cable is considered further, a comprehensive system analysis should be performed to determine the impact of the underground cable system on BPA's network.

3.5.1 Reactive Compensation

One significant design consideration with a 500 kV underground cable system is the amount of capacitance which would be added to BPA's system and the resulting charging current of the underground cables. The high capacitive charging current inherent in cable circuits may cause a reduction in the amount of real power that can be transmitted through a cable circuit, and may cause appreciable energy losses. As the cable circuit length is increased, the capacitance and, therefore, the charging current increase linearly. In the worst case, the magnitude of the charging current may increase until it is equal to the cable ampacity, at which point no real power may be transmitted without overheating the cable. This length is commonly called the "critical cable length." For a 500kV cable system, this critical length is about 50 miles. To allow real power to be transmitted along a 500kv cable system longer than 50 miles, intermediate reactor stations are need to control the charging current. Figure 3-7 is a graph showing where the charging current becomes equal to the capacity of the cable for a 500kV AC system.

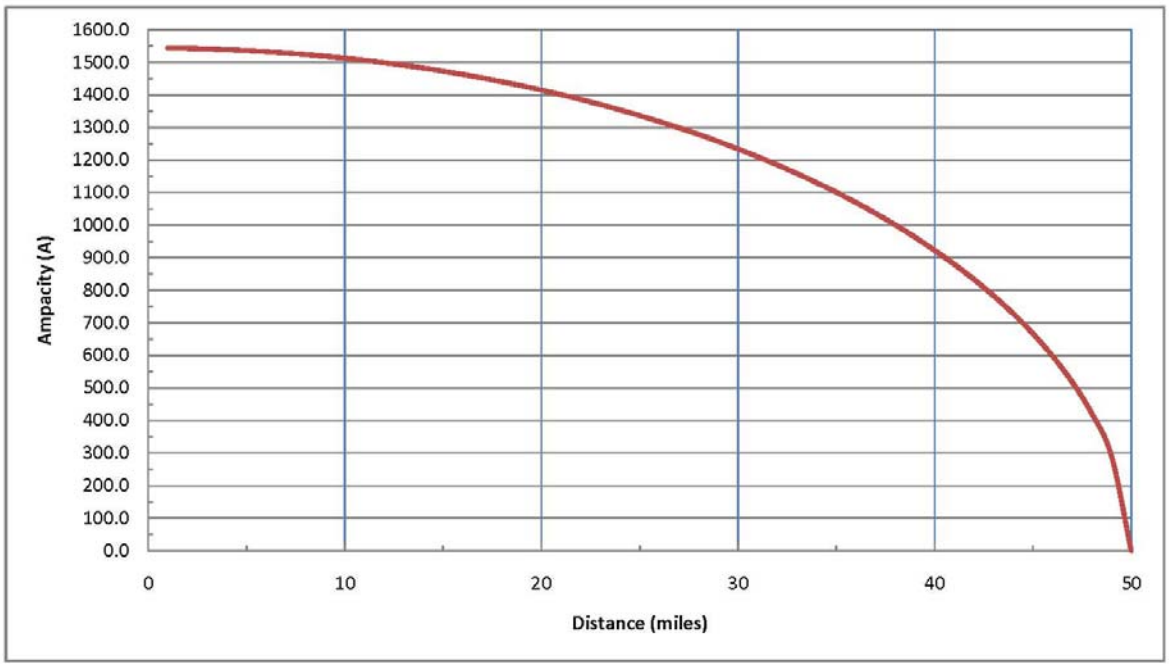


Figure 3-7: Maximum Real Current Transfer

In addition, most 500 kV transmission systems cannot accept the amount of capacitance that would be added to the system as a result of adding the underground cables. As a result, reactive compensation must be added to the system to mitigate this additional capacitance. Shunt reactors are often placed at one end, both ends or at intermediate locations along the route length to consume the charging current. The reactors limit the voltage rise during light-load conditions, especially where the local power system is relatively weak (high system impedances) at the cable location. The optimum amount and location of shunt compensation must be determined by running load-flow cases at different load levels and studying the effects of future system expansion. In systems having a significant amount of cables, system power factor can be influenced at light-load periods to the extent that the system could go leading if not corrected by reducing other capacitive sources.

Currently, the longest installed 500kV XLPE cable system is 25 miles. For cable systems longer than 25 miles, intermediate reactor stations should be installed to compensate for the cable charging current. For the purpose of this report, it was assumed that reactive compensation would be added at each substation and at two intermediate sites, separated by approximately 25 miles. The amount of compensation would be equivalent to 75% of the capacitance being added by the underground cables to the system. Calculations were performed to estimate the capacitance being added to the electric system for each design option, the amount of reactive compensation needed to offset the capacitance and the resulting charging current. The results of these calculations are included in Section 5.

3.5.2 Electric and Magnetic Fields

Electric and magnetic field (EMF) is a term used to describe electrical and magnetic fields created by electric voltage (electric fields) and electric current (magnetic fields). Electric fields are present whenever voltage exists on an object and are not dependent on current. Similarly magnetic fields are present whenever current flows in a conductor and are not dependent on the presence of a voltage. When an object has voltage and carries current, it produces both an electric and magnetic field and this is referred to as EMF. For shielded underground cables, the electric field is entirely contained within the cable. While no electric field exists external to the cable, the term EMF is still used for underground cable, but only refers to the magnetic field.

The movement of electric charges along a conductive path is called electric current and is measured in amperes (“amps”) or (“A”). Current measures the “flow” of electricity, and the moving charges in an electric current produce a magnetic field that exerts force on other moving charges. Wires running in parallel and carrying currents in the same direction attract, while wires carrying currents in opposite directions repel. This is the principle by which electric motors generate force. Magnetic fields are measured in gauss (“G”) or tesla (“T”) (1 T = 10,000 G). Smaller fields are measured in milligauss (1 mG = 0.001 G) or microtesla (1 µT = one-millionth of a tesla). In the United States, the milligauss is the unit most often used to measure the strength of power frequency magnetic fields.

Due to symmetry, the magnetic fields are typically the highest directly over the underground lines. However, the strength of the magnetic fields fall-off very rapidly with lateral distance from the cable system. Furthermore, the phase arrangement of the cables can be positioned to help reduce EMF fields through a cancelation effect.

One method to further decrease the magnetic field is to install the duct bank deeper or install multiple cables per phase; however, this may result in higher installation costs. While installing the duct bank deeper or installing multiple cables per phase may result in lower magnetic fields, it would not reduce the magnetic field at the transition structures.

3.6 Transition Stations/Substations

Because of the potential need for reactive compensation and the number of cables per circuit, special attention needs to be given to the design of the substation at each end and the intermediate reactor stations. The design of a 500 kV reactor station turns out to be similar to a large switching station. The layout and size of a reactor site would be determined by the amount of equipment that would be needed, such as disconnect switches, shunt reactors, breakers, control house, etc. Figure 3-8 shows a possible layout for an intermediate reactor station. The breaker is needed to allow the switching of the reactor during various operational scenarios.

If only a portion of the line is undergrounded, an overhead to underground transition station with reactors would be needed. For voltages under 230kV, the overhead to underground transition is commonly accommodated on a single shaft structure; however this is typically not the case for voltages above 230kV for the following reasons:

1. Typically, multiple cables per circuit are required and cannot be accommodated on a single shaft structure.

2. The charging current for underground lines of any length is usually large (>3 amps) and cannot be broken by lifting a jumper. This means a switch is needed to be installed and many disconnect switches cannot break over 2 amperes of capacitive current. This means that breakers or other special interrupting devices would be needed to allow the utility to isolate the underground cables. With the capacitive charge, special consideration in the selection of the breakers and disconnect switches need to be made.

3. The need to apply reactive compensation to the system. While reactors could be installed at nearby substations, the best location is as close to the end of the cable as possible. The other benefit of placing the reactors near the cable is that the reactor will help in bleeding off the capacitive charge of the cable.

The design of a 500 kV transition station turns out to be similar to a small switching station. The layout and size of a transition site would be determined by the amount of equipment that would be needed, such as disconnect switches, shunt reactors, breakers, control house, etc. For this application, the transition station would consist of a single overhead take-off tower typically an A-frame structure located at one end of the yard. Disconnect switches and circuit breakers are generally installed between the overhead line and underground cables. Figure 3-9 shows the minimum size layout for a transition station with four cables per phase with a shunt reactor.

An alternative to the radial design shown, a breaker and a half or ring bus scheme could be considered. By changing the breaker scheme, each set of cables can be isolated without causing a complete outage on the line. The system could operate at a reduced capacity, if one set of cables needs to be taken out of service. This will also allow for maintenance of different station equipment, breakers, reactors, etc, without de-energizing the line.

Switches would be installed for each set of cables to allow for further isolation. It is important to note that the switches would only be operable when the charging current has been discharged from the cable. If reactors are located in the transition station, the reactor will allow the cable to discharge through the reactor more quickly.

3.7 Maintenance

Routine maintenance on underground cables should be performed regularly to ensure the cables would operate with uninterrupted services.

Typical major components to be checked are as follows:

1. Terminators
2. Manholes
3. Lighting Arrestors
4. Grounds (Very Important)
5. Cables
6. Right-of-Way

The method of checking the condition and maintenance of the above items involve various methods of inspection, primarily visual and performed as follows:

Note: Some inspections should be performed only during an outage. Use extreme caution when working around energized lines. Work should be performed per standard utility practices.

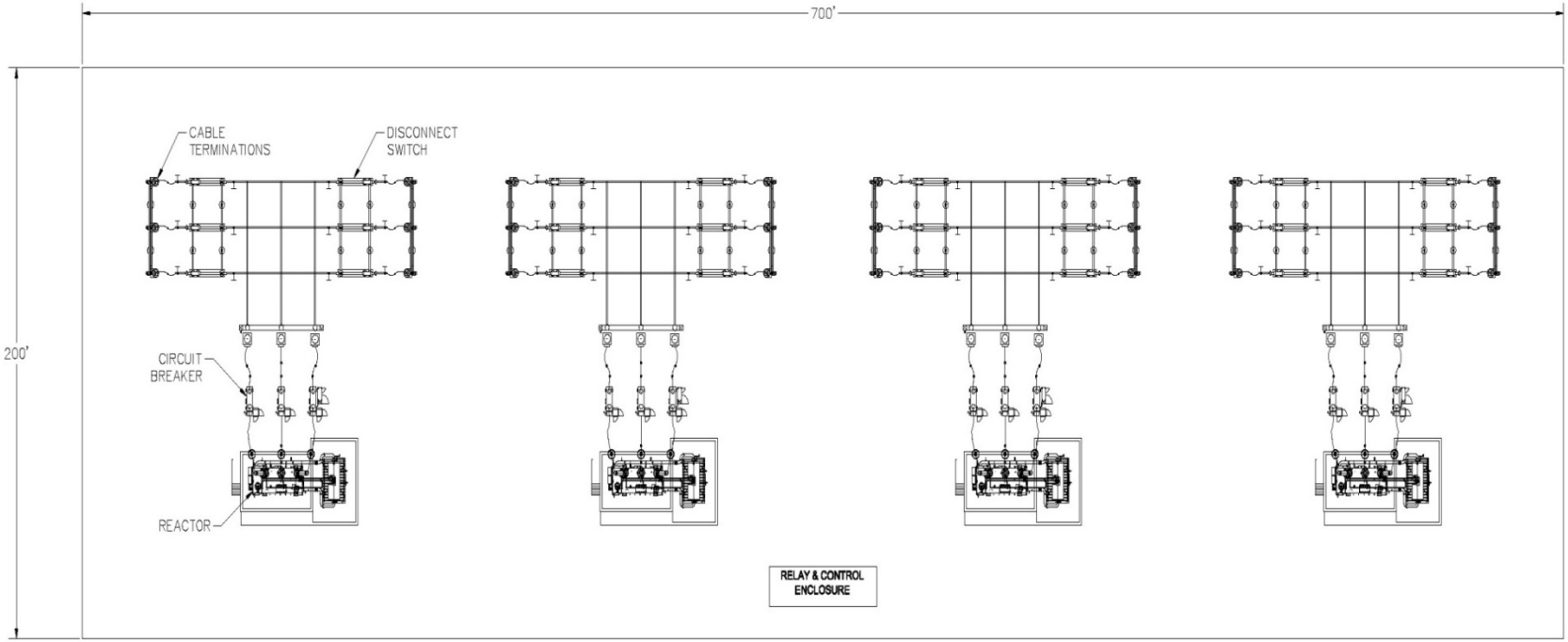


Figure 3-8: Preliminary Reactor Station Layout

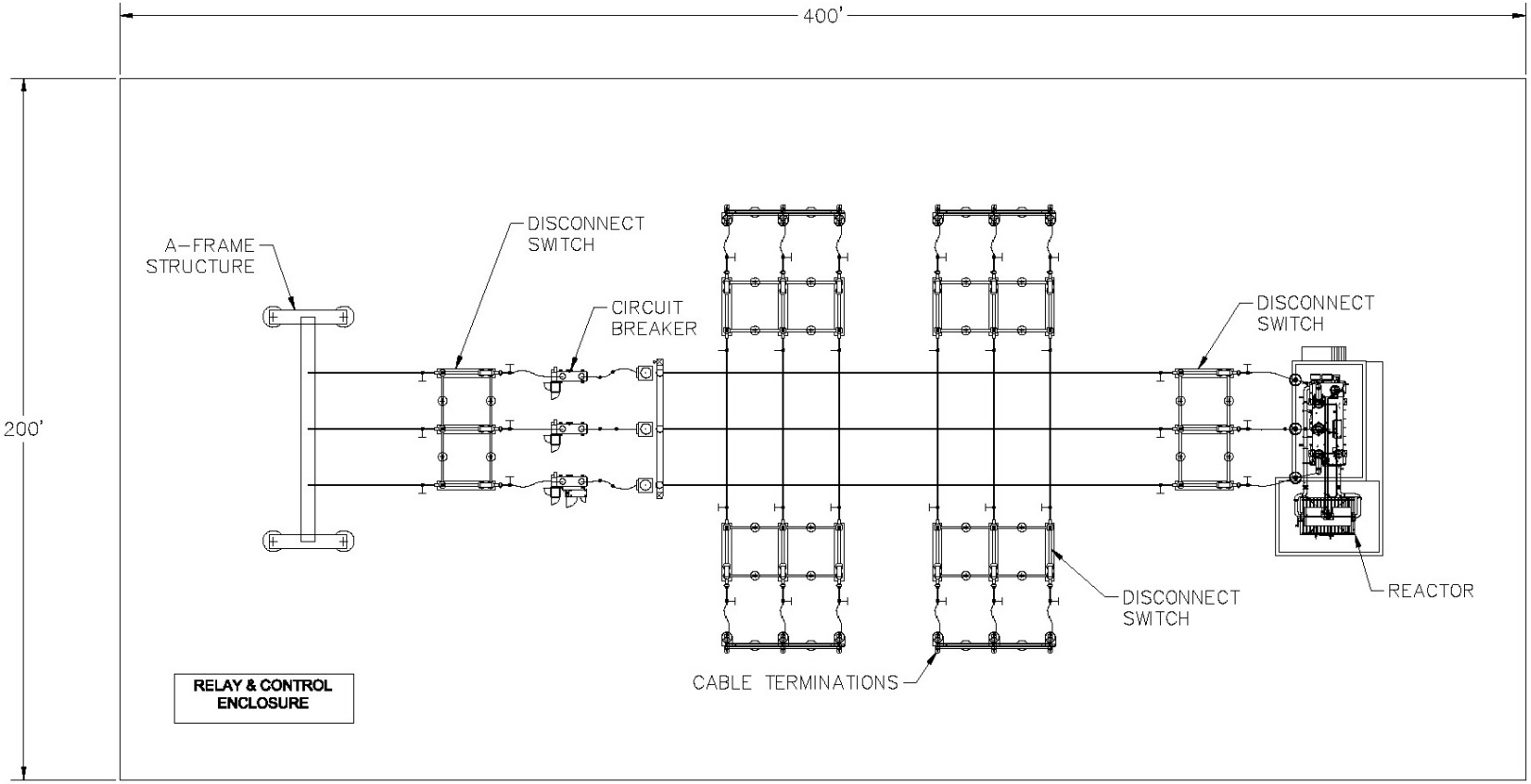


Figure 3-9: Typical Transition Station Layout

3.7.1 System Maintenance

Routine maintenance on XLPE cables should be performed regularly every six months to a year, and scheduled around an outage.

Terminators

Terminators should be inspected to determine if the insulator skirts are chipped or cracked, if so, they must be repaired or replaced. Chipped or cracked porcelain must be repaired in order to prevent ingress of moisture into the terminator.

Terminators should be checked for buildup of dirt and contaminant along the skirts, or at the ferrule. In severe cases of buildup they should be wiped clean to prevent flashovers.

Visual inspection should be made for any sign of oil leaks, cracked lead wipes, damaged grounds, sagging support brackets, overheating of connections, and damaged stand-off insulators. If any of the above is found they should be repaired.

These inspections should be performed every year and do not require an outage for visual inspection.

Manholes

Manholes should be inspected to ensure cables are securely fastened to the brackets/clamps, and that ground connections are intact, and brackets are securely attached to the walls. It is recommended that the cable system operator pump, as practical and feasible, any water inside the manholes.

These inspections should be performed every six months or as dictated by predetermined outage windows. Additionally with multiple cables per phase, the entire system would not be required to be taken out of service but the set of cables being inspected can be removed from service and grounded, while allowing the other set of cables to remain energized and operate the line at a reduced capacity.

Lightning Arrestors

Lightning arrestors should be checked for signs of tracking, and chipped or cracked skirts. Verify that ground connections are tight.

These inspections should be performed every year and do not require an outage for visual inspection.

Grounds

Grounds should be checked that all connections are tight, non-corroded, and show no signs of overheating. Grounds should be checked for proper ground resistance. A clamp-on ammeter may be used to ensure there is no excessive current flowing through the grounds. Current should be approximately 10 amps or less.

These inspections should be performed concurrently with the inspections of terminations and splices. Any physical contact with the grounds will require an outage on the set of cables being inspected and all grounds lifted at transition sites.

Cables

Cables should be checked for signs of mechanical damage such as accidental dig-in or cable movement. This would ensure the cable jackets have not cracked, or been scraped/eroded due to movement.

Cables entering terminators should be securely fastened to support grips/cable cleats minimizing cable strain to the terminators.

It is recommended that a jacket integrity test be performed to verify the integrity of the jacket, if mechanical damage is suspected or in the event the cable system undergoes a severe electrical transient condition. Lightning strikes and line-to-line or line-to-ground faults on connected above ground facilities are examples of unusual or severe transients.

These inspections should be performed every six months and the jacket integrity test every year. The entire system would not be required to be taken out of service but the set of cables being inspected would need to be isolated from the rest of the system during inspection and testing.

3.8 Cable System Reliability

Because of the limited number of world-wide installation at 500kV, the reliability of these systems has not been proven. While manufacturer type tests have shown that these systems are sustainable, actual real world data over an extended time period is not available to provide profound evidence of the tests. This lack of reliable evidence has laid the ground works for most projects to continue to be installed as overhead lines or at reduced voltages. However, as the technology progresses and the number of cable installations increases it is believed that XLPE cable systems will become more predominate at the 500kV level for short lengths.

3.9 Cable Failure Locating and Repair

In general, an underground transmission cable system is very reliable. The main reliability issue with an underground cable circuit compared to an overhead circuit is the length of the outage in the event of a circuit failure. With an overhead circuit, the line can generally be placed back into service in a relatively short amount of time, typically less than a day, thus increasing the circuit's availability for transmitting load. When there is a fault on an underground line, the line may be out of service for a significant amount of time, generally more than two weeks and up to 6 months, depending on the type of failure and how quickly it can be located and repaired. Because of these longer outage times an underground circuit has a lower circuit availability compared to an overhead circuit.

3.9.1 Fault Locating

One of the essential steps in repairing an underground cable failure is to accurately locate the cable failure. Locating a fault on an overhead line is relatively easy, but since an underground line is out of site specialized fault locating methods are needed. Faults can be located the same day technicians arrive on site, but may take up to a week or more depending on the type of fault, type of fault locating equipment and experience of the personnel operating the equipment.

The most common method of locating the fault location is to apply a capacitor discharge (thumper) signal and then detect the return signal using an acoustical/magnetic device.

The following sequence outlines the fault locating procedures:

1. The first step is to determine if the circuit fault occurred in the overhead or underground section of the line. This can be done by investigating the status of relaying after the event provided relaying equipment has been installed to monitor the underground segment independently of the overhead section of line. If this monitoring is not installed, the utility would need to drive the line to find evidence of a fault in the overhead or underground sections. The cable should be tested even if the fault is determined to be in the overhead section of the line.

2. Once it is determined the fault is in the underground section, the location of the failure needs to be determined. The primary cause of a cable fault may lead repair crews to the location as would be the case when the fault is due to a dig-in. Terminations and splices are common fault locations and should be visually inspected prior to assuming the fault is in the cable. If visual inspections fail to locate the failure, it can be assumed the fault is somewhere in the cable and special equipment is needed to locate the fault.

3. Two common methods for locating underground faults are the thumping method or VLF (very low frequency) detection. Both methods take specialized equipment. Utilities without substantial underground cable infrastructure typically contract with specialists to locate the fault.

3.9.2 Cable Repair

Once the fault is located in an XLPE cable, a special contractor would be needed to make the necessary repairs. This special contractor may be the cable manufacturer. The type of failure would determine the material needed to repair the faulted cable. This could mean having to install additional manholes, repair a damaged splice or termination, remove damaged cable and install a new cable. If multiple cables are damaged, new cable may need to be purchased.

The time required to repair a cable depends to a great extent on cable type and failure location. Failures can be repaired in only a few days but can take several months when new cable or accessories are needed.

4.0 OVERHEAD TRANSMISSION SYSTEM

4.0 OVERHEAD TRANSMISSION SYSTEM

Constructing an overhead transmission line at 500kV is very common in the US, particularly in the Northwestern United States. BPA, PacifiCorp, Northwestern Energy, and Pacific Gas and Electric all have extensive 500kV networks in the northwestern United States. The line construction presents particular challenges as the lines are generally routed long distances and in remote, non-traveled territory. Over the years techniques have been developed to efficiently construct these lines. In addition, there is significant history to effectively estimate cost and schedule for these lines.

4.1 Overhead Experience

EHV (greater than 230 kV) transmission line construction is prevalent throughout the United States and many operating and maintenance groups are in place. Because of this, the operation of these lines has a strong history and consistently strong performance. BPA is the foremost owner of 500kV facilities in the Northwest with over 4,700 miles of lines in service.

4.2 System Design

Typical power transfer ratings for 500kV lines are between 1,200 and 1,800MW. As opposed to underground lines, the limiting factor for the rating of a 500kV overhead line is generally not thermal related but is governed by electrical issues, such as impedance, corona, electrical noise, and conductor losses. This generally drives these systems to have three and sometimes four bundle conductor configurations. The thermal rating of these conductor systems are typically 2-3 times the rating of the transmission line. The resulting loadings and clearance requirements require heavy structural systems to support them – typically steel latticed towers.

4.2.1 Conductor Size

The conductor system design considers two primary electrical parameters – corona effects and fields effects. Corona is the ionization of the air that occurs at the surface of the energized conductor and suspension hardware because of high electric field strength at the surface of the metal during certain conditions. Corona may result in radio and television reception interference, audible noise, light, and production of ozone. Field effects are the voltages and currents that may be induced in nearby conducting objects. A transmission line's inherent electric and magnetic fields cause these effects. Depending on design requirements for these effects, they may have an impact on the conductor system design.

In addition, a line design study is typically performed that compares initial construction cost for various conductor systems against conductor losses for expected electrical loadings over the life of the line. An optimum conductor size is then selected based on this analysis. The conductor system is selected that considers these factors as well as utility standards.

4.2.2 Tower Type

Because of the large conductor systems – typically 3 or 4 bundle – the structural systems necessary to support them are typically steel latticed towers. Lattice towers are the most efficient structural systems to resist structural loads from the conductor systems. In some instances, public sentiment may favor the use of tubular steel poles, either in a single pole or H-framed configuration. Steel poles often have a "cleaner" look that appeals to the public. Poles have a higher installed cost than lattice towers.

Lattice towers can be broken into two categories – self-supporting and guyed types. Guyed towers utilize guy and anchor assemblies to support the loadings on the towers. Self supporting towers are four legged towers that utilize four foundations for resisting the loadings on the tower. Guyed lattice towers are typically less expensive to install. There is some concern by utilities with the history of vandalism on guyed tower lines. Self supporting towers are the most popular tower type for EHV lines.

4.2.3 Foundation Type

Foundations for self-supporting towers and center points of guyed towers utilize two typical designs. The first and most popular is a drilled pier foundation. A drilled pier is a cylindrical reinforced concrete element that is poured in-situ to a round excavated hole. The second type of foundation is a grillage type. This is a matt type foundation constructed of lattice steel material extending from the bottom of the tower to a series of horizontal members in a square or rectangular pattern in the ground to a designed depth.

Typical drilled pier sizes are diameters 3 to 5 feet and depths of 15 to 35 feet. Grillages are typically 5feet by 5 feet (tangents) up to 12 feet by 12 feet (deadends) with depths from 8 to 15 feet. The advantages of grillage foundations are that construction can occur without concrete. The access roads required for concrete trucks are generally much more extensive than for other construction equipment. Particularly in mountainous terrain, the impact of bringing concrete to site can be very expensive compared to not using concrete, or using grillage foundations. Generally, a grillage foundation is a more expensive foundation than a drilled pier, if access isn't taken into account.

4.3 Construction Methods

As previously stated, the construction industry is relatively mature for 500kV transmission lines. The primary issue that impacts construction cost and schedule is accessibility of the line. With increasing environmental restrictions, aerial construction is becoming more common.

4.3.1 Conventional

Typical overhead line construction for a transmission line generally follows the following sequence –

- Clearing and Access Development
- Foundation Installation
- Tower Haul and delivery
- Tower assembly
- Tower erection
- Conductor string, sag, and clip-in.
- ROW Cleanup and Restoration

For conventional construction, the key to all of these activities is the access system to the tower sites. In particular, access roads for concrete vehicles take a more robust road than grillage type foundations which only require a road for backhoe or excavator access and steel material delivery.

For mountainous terrain, access becomes a significant factor of cost as construction equipment have limits to incline, which consequently requires longer and more expensive roads and longer trips between towers.

4.3.2 Aerial Construction

As noted, with the maturity of the construction trade, most overhead transmission projects utilize helicopters for the line construction. The most common use of a helicopter is for stringing of the conductor. Stringing involves using a small helicopter to pull a rope into stringing dolleys, which is then attached to a high strength pulling cable which is eventually attached to the conductor. In addition, these small helicopters are utilized to transport workers between working sites.

For environmental or accessiblity reasons, some areas of lines may require aerial construction for more than stringing reasons. Towers and foundations will sometimes be constucted with aerial techniques. The helicopters necessarily are larger and more expensive to haul materials and sometimes equipment to the tower sites to perform the construction. These techniques are almost always more expensive than conventional construction and only used by a contractor when required.

4.3.3 Line Crossings

The number of overhead line crossings will have an impact on the level of production for transmission line construction. These line crossings will have temporary facilities known as guard structures built on each side of these crossings. The process of pulling conductor into place will be slowed based on the criticality of these crossings and impacts they could have.

Guard structures will also be built over roads and railroads. For particularly wide highways, a specific guard structure configuration that creates a net above the road may be required to protect traffic from the stringing operations during construction in case the conductor were lost during the stringing work. In addition to the crossing fixtures associated with this work, traffic control procedures may be required during these operations.

4.4 Land Use

Overhead transmission line construction is impacted by the type of terrain it crosses. As noted earlier, accessibility significantly impacts the line construction process. Primary terrain types that impact EHV lines include mountainous, rural, urban, and agricultural. In urban and agricultural properties, local officials or property owners will prefer a smaller footprint tower than a lattice tower – typically a single steel pole type.

For agricultural properties, the irrigation systems, typically center pivot sprinkler systems, require coordination with the farmers on the route alignment, structure type, and structure placement.

Rural

As noted, access for equipment is the primary factor in construction conditions. As such, rural areas may present easier locations for line construction. Safety and traffic control concerns are the primary factors that favor rural over urban construction. Since rural areas are generally undeveloped, the type of terrain the transmission line must traverse is important to construction. As noted in the underground section of this report, the different terrains a transmission route may encounter include flat, rolling hills, mountains, agricultural, and wetlands or other large water bodies/obstructions. A disadvantage to rural areas is the possible limited accessibility to the route corridor for construction and future maintenance.

The type of terrain and soil conditions will greatly impact the cost of installing an overhead transmission line.

- Flat terrain – This type of terrain is the easiest type of terrain to perform overhead line construction. The ground type, e.g. rock, sand, silty, etc., will have a large impact on the ease and cost of construction. Typically, a construction road is constructed along the full length of the line to allow for access along the line right-of-way during the many phases of the construction project.
- Rolling hills – For slopes less than 10%, similar access to flat terrain is typical as most construction equipment is sufficient to utilize this type of road.
- Mountainous – For higher slope access, access roads will necessarily be longer, more difficult to construct and traverse, slowing construction. Depending on the severity of terrain, a construction contractor may choose to perform construction without access and utilize aerial techniques.
- Agricultural – Many lines are routed through agricultural properties that require coordination with farmers on route and structure location, and center pivot grounding mitigation.
- Wetlands, water bodies– These areas of construction are difficult access and construction areas as well as potential helicopter construction areas. For large water crossing, specialty tall towers may need to be constructed.

The typical right-of-way width for a 500kV overhead transmission line is 200 feet.

Urban/Suburban Construction

Situations where 500kV EHV lines are constructed in urban/suburban areas are rare. Public and agency opinion will almost always require these lines to be routed away from populated areas. In instances where these lines are required to be placed in urban/suburban areas, the predominant structure type is a single steel pole. Urban/suburban construction requirements include the following:

- Traffic control requirements
- Time of work day requirements – in some instances limiting work days to 6-8 hours.
- Environmental Monitoring.
- Public Relations coordination
- Sophisticated crossings designs including overhead netting placed over railroads and/or major highway crossings.
- Coordination with local utilities where crossings or adjustments are required
- Cathodic and fields studies for parallel utility or railroads
- Property and road repair coordination.

Although urban/suburban construction generally has ideal construction access, the rate of production is often much slower due to the numerous coordination efforts and safety concerns associated.

4.5 Electrical Considerations

In addition to the impedance, corona, and losses impacts associated with the line design, electric and magnetic fields studies are generally performed. Please refer to section 3.5.2 for a definition of electric and magnetic fields.

As opposed to an underground cable which only has an associated magnetic field, the term EMF is applicable to an overhead transmission line as it has both electric and magnetic fields associated with it. Considerable research has been performed on the study of EMF's as related to health effects. While conclusive evidence has not been established, at least two states have established standards for EMF. These standards generally establish a maximum field level at the edge of right-of-way.

For an overhead line, the mitigation to reduce these fields is typically the conductor configuration. Specific tower types which place the conductor bundles in a configuration whereby the field effects cancel one another can be used where EMF is a project concern. Generally, this is in urban and suburban settings.

The magnetic field of an overhead line is generally less than equivalent underground line due to the distance of the conductors from the ground.

4.6 Maintenance

Overhead transmission lines are regularly patrolled for standard maintenance concerns – broken insulators, bird contamination, loose hardware, etc. Because of the tower types and material utilized, these lines generally don't require as much maintenance as lower voltage lines. The typical schedule for line patrols is twice yearly, one aerial and one from the ground.

Standard repair material is typically stocked for emergency events – e.g. tornados, fires – that can destroy large portions of a line. Generally, emergency material is stocked to re-build one to three miles of line.

4.7 Fault Locating

Location of faults on an overhead line is relatively simple with the sophisticated communications equipment associated with the transmission lines. An overhead outage is generally analyzed by operations personnel and the outage location estimated for patrolmen review. The patrolmen will then drive or fly to the estimated location of the fault to determine the cause. Preparations for repair are generally made within a few hours of an event, depending on accessibility of the line. Depending on the severity of the outage, repair of overhead lines are generally repaired within a few days. In instances of a severe weather related event that damages multiple towers, these outages can last up to 2-3 weeks.

5.0 UNDERGROUND CONCEPTUAL DESIGN

5.0 UNDERGROUND CONCEPTUAL DESIGN

The length of the proposed routes exceeds the "critical cable length" of 50 miles for a 500kV XLPE AC cable system, various designs were investigated to determine a feasible conceptual design for this project. As previously mentioned, the longest installed 500kV AC cable system is only 25 miles in length. This project would be the longest 500kV AC cable system installed anywhere in the world. The following factors were considered.

- Reactive Compensation – Since the length of both routes exceeds the "critical cable length" for a 500kV cable system, the amount of capacitance and the size of the charging current is the main design consideration for the underground cable system. Various designs were investigated and it was determined that the only way to control the capacitance and the charging current is to install reactive compensation at each end and at intermediate points along the route.

- Installation Methods – Spanning a vast project area, installation methodology may further be altered by geological conditions to include rock or sand. In these locations alternate methods of installation may be required which often times have adverse affects to both schedule and budget. Furthermore, steep grades along the route may require supplementary engineering and/or alternate routing; while additional wetland areas often times require a non-evasive installation technique.

- Right-of-Way – Route segments encroaching on urban areas will typically encounter the most stringent design and permitting guidelines however right-of-way can often be developed into existing roadway designs. In locations where the duct separation must be reduced, additional ampacity models will need to be developed during final cable design to ensure proper operation of the cable system. Furthermore, an all inclusive geotechnical report for the entire route, returning soil thermal resistivity values, water table depths, and ambient soil temperatures, will need to be performed to ensure cable design. For preliminary development of the east and west alignments, it has been assumed that the minimum right-of-way (ROW) width required is 60 feet, however additional ROW where available should be utilized. To maintain long term flexibility of right-of-way and provide for road design around terrain and obstacles, standard 150-foot right-of-way will be obtained and most or all of it cleared. Because additional ROW is available for the western route, the alignment has been developed on a 150 foot ROW. All ROW must be cleared prior to cable installation and should be maintained to ensure system reliability.

- Environmental – It has been assumed the route can be constructed using the open cut, HDD, and J&B conceptual designs. All major wet land areas have been assumed that an HDD will be required for crossing, while major roadways have been designed with J&B crossings. During final route design, the trench details will need to be finalized to account for cable design, splicing/manhole locations, crossing requirements, land user agreements, easement requirements, and any county, state, and federal permitting requirements. Appendix A provides a discussion of the potential environmental impacts from construction, operation, and maintenance of an underground 500kV transmission line.

- Access Roads – During construction, temporary construction roads will be required to install both the duct banks and the manholes. Typically construction roads are developed within the right-of-way or with temporary construction permits and easements, and are designed to handle all foreseen loading requirements of material and construction equipment. After duct bank and manhole installation, the construction roads can be abandoned, or where required refurbished to their original state. Permanent access roads will need to be maintained to each manhole location for future maintenance and cable replacement.

5.1 Cable System Design

POWER investigated various trench configurations, number of cables per circuit and cable sizes to determine the appropriate designs for each route. Each cable system was analyzed using the following design criteria:

• Ultimate Ampacity Rating	4560 Amps
• Load Factor	75%
• Bonding Method	Cross-Bonded
• Conductor Type/Material	Segmental/Copper
• Insulation Type	XLPE
• Thermal Resistivity (p, rho)	
➢ Native Soil	90°C-cm/W
➢ Concrete Encasement	60°C-cm/W at 6% moisture
• Ambient Temperature	
➢ Earth	20°C
➢ Air	30°C
• Maximum Conductor Operating Temperature	
➢ Steady State	90°C
➢ Emergency	105°C
• Depth/Spacing	Varies depending on installation method

5.1.1 Open Cut Trench Design

Since the proposed alignments are almost all entirely rural installations, POWER has assumed a maximum trench depth of 5 feet, allowing for approximately 3 feet of cover. While other underground facilities along the route appear to be minimal, it is anticipated that some existing utility crossings will be encountered. Their crossings will need to be determined during final routing design, but in most cases can be crossed either above or below by means of open cut trenching. Where large crossings are required, J&B or HDD installation may be required. Figure 5-1 shows a conceptual design for all open cut trench installations to be placed within a minimum 60 foot right-of-way; predominantly in rural areas. To meet specified power transfer requirements, four cables per phase are required resulting in construction of four independent duct banks; one per set of cables.

Figure 5-1 Open Cut Trench Design

5.1.2 Trenchless Design

Along each of the proposed routes, a significant number of crossings exist that would require trenchless technology to install the cable system. These crossings include but are not limited to:

Crossing	Segment	Length (ft)	Construction Type
Eastern Route			
Cowlitz River	Segment F	1,100	HDD
Interstate 5/Railroad	Segment F	560	J&B
Coweeman River	Segment F	300	HDD
Kalama River	Segment K	600	HDD
Highway 503	Segment K	200	J&B
Lake Merwin #1	Segment W	1,000	HDD
Lake Merwin #2	Segment W	1,000	HDD
Canyon Creek	Segment O	450	HDD
Lewis River	Segment O	500	HDD
Little Washougal River	Segment 51	1,100	HDD
Camas Slough #1	Segment 52	1,300	HDD
Camas Slough #1	Segment 52	1,300	HDD
Western Route			
Cowlitz River	Segment 4	1,100	HDD
Interstate 5/Railroad	Segment 9	560	J&B
Coweeman River	Segment 9	450	HDD
Kalama River	Segment 9	500	HDD
Lewis River	Segment 25	1,200	HDD
East Fork Lewis River	Segment 25	600	HDD
Salmon Creek	Segment 25	200	HDD
Interstate 205	Segment 25	400	J&B
Camas Slough #1	Segment 52	1,300	HDD
Camas Slough #1	Segment 52	1,300	HDD

HDD Design

Figures 5-2 and 5-3 show a conceptual design for a large crossing HDD installation. The design has been developed utilizing typical design criteria as well as assumed environmental restrictions on depth and setbacks. Because of the depth required to install the product casing, the cable installation must be modified to four larger cables per phase to meet the target system ampacity. This larger cable reduces the total cable length that can be placed on a standard shipping reel, thus restricting the maximum HDD length to approximately 1,300 feet. With a minimum casing separation of 20 feet, the right-of-way width must be increased to approximately 100 feet.

It is anticipated that HDD installations will be utilized at all major waterway crossings as well as any crossings in excess of approximately 600 feet, or the maximum distance of a J&B installation. Because some segments have large waterway crossings, in excess of the 1,300-foot limitation of the HDD installation, alternate routing, multiple shorter drills, more cables per phase or other cable delivery methods may be required.

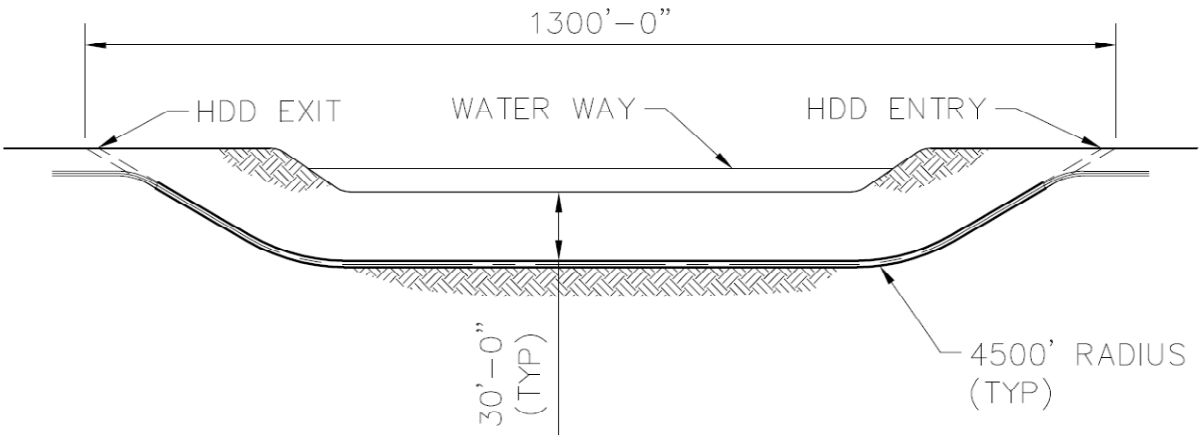


Figure 5-2: HDD Layout

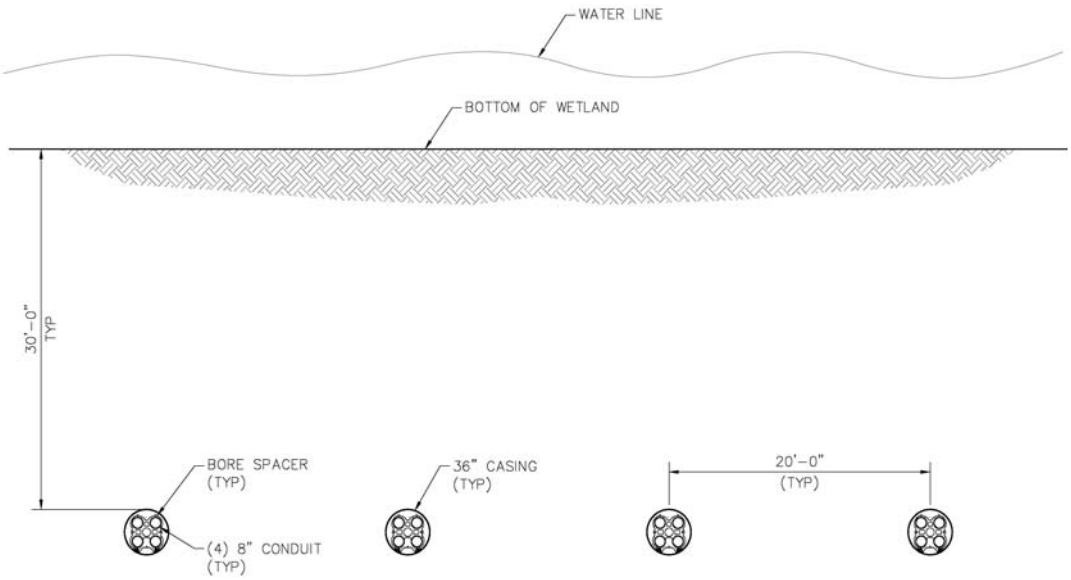


Figure 5-3: HDD Cross-Section

Jack and Bore

Figures 5-4 and 5-5 show a typical Jack and Bore (J&B) installation. For this Project, it has been assumed that all major roadways within each route will be crossed using the J&B method. Using a J&B will minimize construction impacts to the general public, and when while more expensive than an open cut trench, the installation method general is more accepted by the public and governing agencies.

The typical J&B layout for this Project will utilize a 10 foot wide by 40 foot long jacking pit and a 10 foot by 10 foot receiving pit from which the product casing will be installed. It has been assumed that one J&B will be required for each set of cables, the length of installation will not be greater than 600 feet, and the depth of installation will not adversely affect the cable ampacity. However, the depth of installation is typically governed by existing infrastructure and/or crossing requirements set forth by governing agencies. During final design, cable ampacity should be verified during J&B design to ensure proper operation of the system.

Magnetic field calculations have not been performed for a J&B installation, as the field will be minimized based on the depth of installation. It can therefore be deduced that the field strength will lie between that of an open cut installation and an HDD.

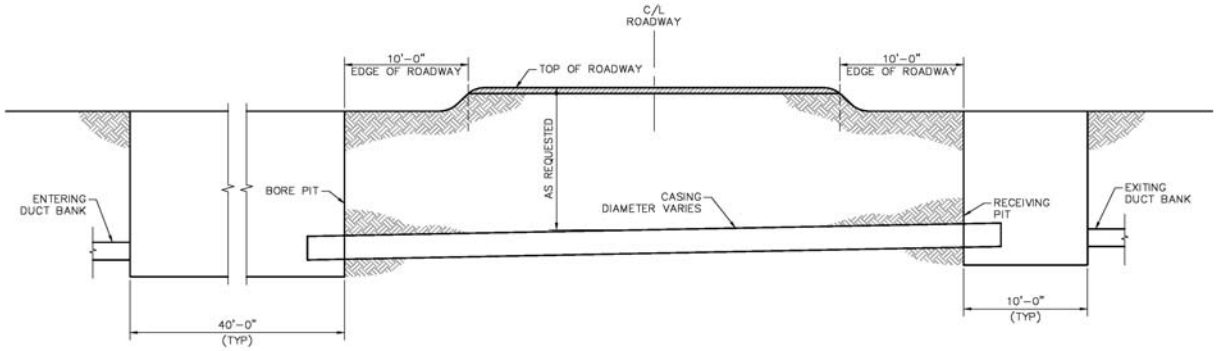


Figure 5-4: Jack and Bore Layout

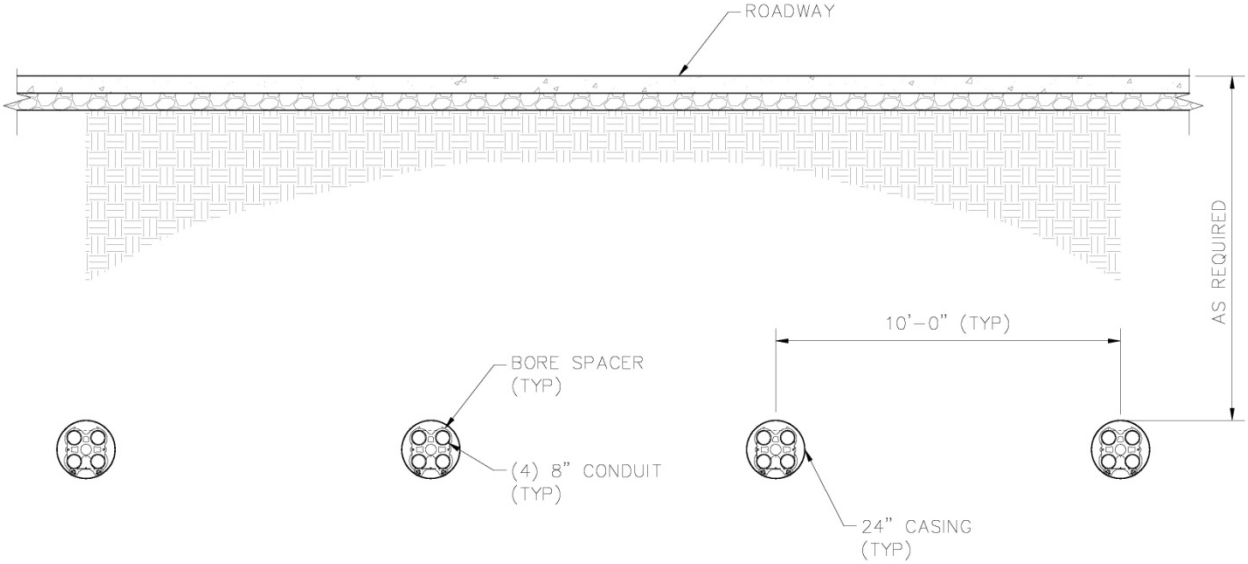


Figure 5-5: Jack and Bore Cross-Section

5.2 Electrical Characteristics

POWER performed preliminary cable ampacity and electrical characteristics calculations. POWER used CYME International's Cable Ampacity Program (CAP) to model the proposed cable system. Based on the designs developed for the ultimate rating, POWER investigated the number of cables per circuit that would need to be installed today to meet the initial ampacity rating of each design option. Table 5-1 shows the results of the ampacity calculations for each installation method. Table 5-2 shows the electrical characteristics for the cable size and routes.

Because the J&B installation is negligible in length, and has been assumed to have similar operating characteristics to that of an open cut installation, electrical characteristics have not been included.

TABLE 5-1 AMPACITY SUMMARY

CABLE TYPE	DESIGN	CABLE SIZE (KCMIL)	NO. CABLES/ CIRCUIT	AMPACITY/ CABLE (A)	TOTAL CKT MAX AMPACITY (A)	MINIMUM ROUTE ROW (FT)	MINIMUM TRANSITION SITE ROW (FT)
XLPE	Duct Bank	3500	4	1140	4560	60	400 x 200
	HDD	5000	4	1140	4560	100	400 x 200

TABLE 5-2 ELECTRICAL DESIGN SUMMARY

CABLE TYPE	DESIGN	CABLE SIZE (KCMIL)	DESIGN LENGTH (MI)	NO. CABLES/ CIRCUIT	SHUNT CAPACITANCE/ CABLE (µF/MI)	TOTAL SHUNT CAPACITANCE (µF/CKT)	REACTIVE CHARGING POWER/ CABLE (MVAR/MI)	REACTIVE CHARGING POWER (MVAR/CKT)	CHARGING CURRENT/ CABLE (A/MI)	TOTAL CHARGING CURRENT/CKT (KA)
EASTERN ROUTE	Duct Bank	3500	74.22	4	0.284	252.94	8.93	7953.4	30.95	27.57
	HDD	5000	1.78	4	0.316	6.75	9.92	211.9	34.36	0.73
WESTERN ROUTE	Duct Bank	3500	67.05	4	0.284	228.51	8.93	7185.1	30.95	24.90
	HDD	5000	1.44	4	0.316	0.932	9.92	171.42	34.36	0.63

Based on the large capacitance and charging current values indicated above, it was determined that intermediate reactor stations would be required. Using a rudimentary electrical model it was determined that a minimum of two intermediate reactor stations and reactors at both substation ends would be required. A minimum of four cables per phase would be needed to achieve the required real power transfer from one end of the route to the other. The preliminary size for these intermediate reactor stations would be approximately 200 foot wide and 700 foot long. Figure 5-6 shows the relationship of the required real ampacity to the available ampacity of a 3500 kcmil 500kV AC cable adjusted for the charging current.

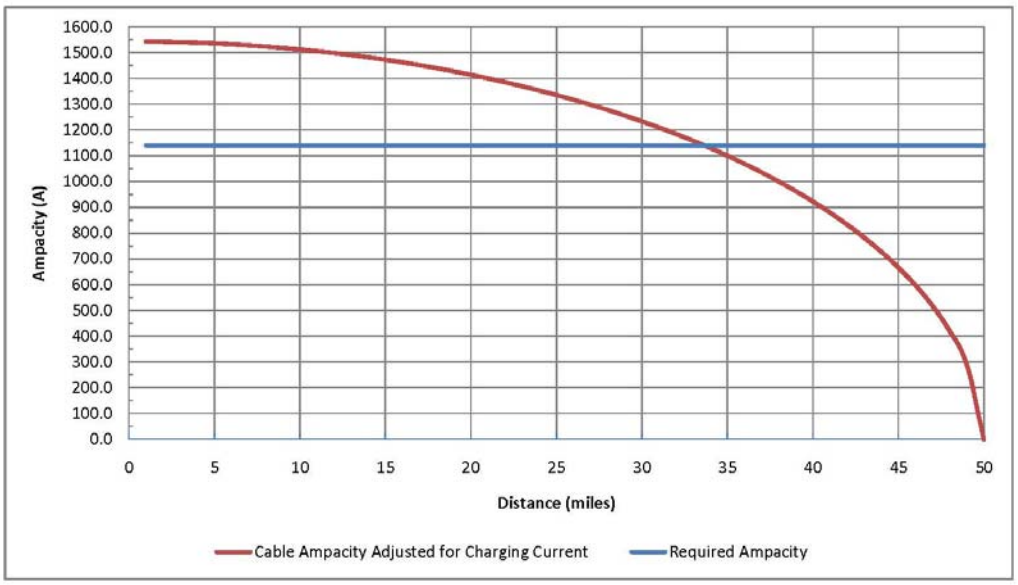


Figure 5-6: Required Current vs. Cable Rating

Based on this graph, the longest distance the proposed cable system could be installed without reactive compensation and still achieve the required real power transfer would be about 33 miles. So, in order to achieve the required real power transfer, the conceptual design is based on the circuit being broken up into three equal lengths. While conceptually the proposed design appears to work, it is important to note again that no detailed system analysis has been performed on the BPA existing transmission system. Before considering this design further, a detailed system analysis must be performed to determine the effect of this proposed system on BPA's existing system.

5.3 Magnetic Field Calculations

Figures 5-7 and 5-8 show the magnetic field for the open cut trench and HDD designs, respectively. The calculations are based on 100 Amps per cable. It should be noted that the magnetic field is highly dependent upon the actual installation, cable phasing, phase rotation, system operating conditions, and while close, the relationship is not linear.

5.4 System Operation

General day-to-day operation of the cable system would consist of all cables in service acting as a current divider to delivery one fourth of the power transfer requirement. In this manner the cable system would function in a standard mode of operation designed to meet the target transfer requirements while remaining within the cable's operating requirement. In the event of a cable failure or during determined outage windows, it is possible to operate the cable system at a reduced capacity with only three, two, or even one, cable per phase. Operating without all cables per phase would reduce the power transfer characteristics but it would allow for the system to remain in operation.

If one set of cables were removed from service, the cables would need to be independently grounded to maintain electrical isolation from the cables remaining in service. This can be done at the transition stations via ground jumpers, three position circuit breakers, or grounding switches.

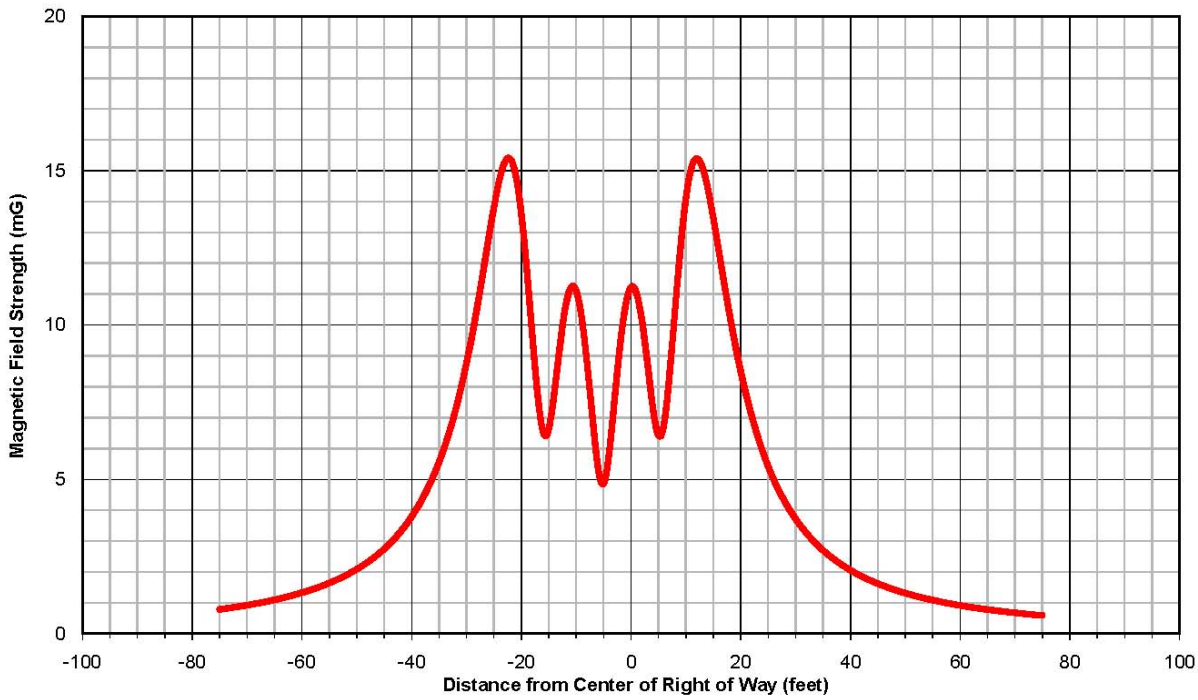


Figure 5-7: Open Cut Trench EMF Calculations

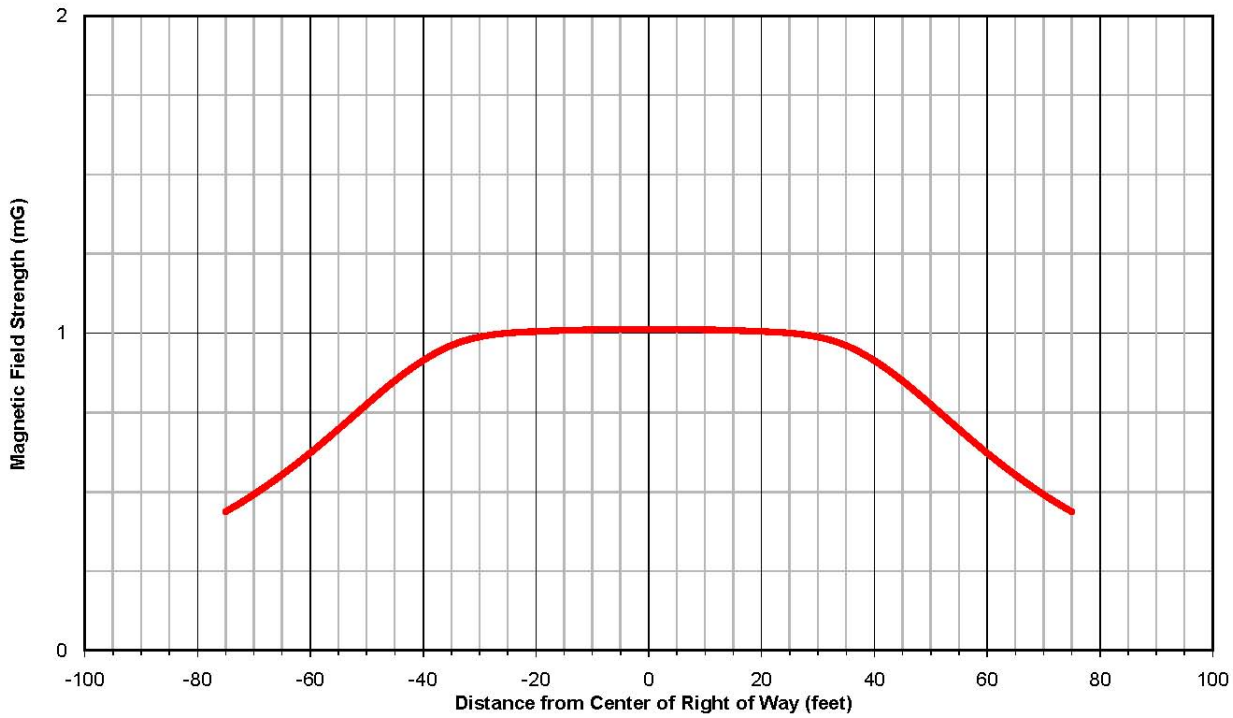


Figure 5-8: HDD EMF Calculations

6.0 OVERHEAD CONCEPTUAL DESIGN

6.0 OVERHEAD CONCEPTUAL DESIGN

POWER has prepared conceptual designs and preliminary estimates based on the BPA identified routes. The western route will parallel an existing 230kV transmission line within an existing BPA right-of-way. Although the line will have less clearing and access costs due to the use of existing right-of-way, the material and construction costs will be higher as the new line will attempt to match the structure locations of the existing lines it parallels and will require more structures than the Eastern Route, even though the Eastern Route is longer.

6.1 Facilities Design

The conceptual design of the transmission line and consequent cost estimates uses the following BPA standard materials:

- Self Supporting Lattice Towers
- Grillage Foundations
- 3-Bundle "Deschutes" Conductor (1519kcmil ACSR/TW, 1.3" diameter, 1.61 lb/ft)
- ½" EHS Overhead Ground Wires

All of these materials are standard BPA materials. For a project of this magnitude, the materials for this line would be ordered specifically for the line. However, once the line is built, the line will have a strong supply of repair material due to the use of these standard materials.

The cost estimates are relatively similar on a cost per mile basis primarily due to the overall mileage. The Western Route is slightly more expensive on a per mile basis due to the aforementioned requirement to parallel an existing lower voltage line. More material and construction locations are required on the Western Route as opposed to the Eastern Route (339 total towers –Eastern Route vs. 364 total towers – Western Route). In addition, the Western Route utilizes some double and even triple circuit towers that the Eastern Route does not utilize. These multi-circuit towers are much heavier and more costly to build than the traditional single circuit towers. Due to these factors, the Western Route has an estimated eight percent (8%) more steel weight than the longer Eastern Route.

The Eastern Route is a so-called "greenfield" line, i.e. new right-of-way and line location. The estimated clearing and access costs for the Eastern Route are approximately 50% higher than the Western Route. This increase in the access costs "balances" the increased material cost of the Western Route, the reason for the relatively similar per mile costs between the two estimates.

6.2 Constructability

Both lines assumed traditional construction techniques. The Western Route utilizes and existing road networks in place for access. Necessary road building would consist of spur roads from the existing road network to a tower site. Vegetation clearing for the Western Route is less as well due to existing cleared right-of-way for the lines in place. For the Eastern Route, new access and clearing will be required. This will impact schedule and cost of the line.

6.3 Special Construction Areas

Both routes include an overhead crossing of the Columbia River. These crossings will require specialty towers (up to 300 feet tall) to have sufficient clearance over the river. Depending on the placement of these towers, the foundations to support them will be exceptional. If the towers are placed in soft or swampy soils, the foundations may require piling and pile caps. Rocky terrain would likely utilize a grouted foundation.

7.0 COST ESTIMATES

7.0 COST ESTIMATES

The cost estimates are based on pricing obtained from manufacturers in summer 2010 and recent underground and overhead projects. There are many factors that affect the overall cost of a transmission line. These factors are:

1. Market Volatility. Recent increases in the cost of copper have resulted in a significant increase in the cable cost for underground lines while similar impacts from aluminum and steel prices will impact the overall cost of an overhead line.

2. Contractor/Manufacturer availability.

3. Subsurface conditions. For underground lines, the type and depth of soil and rock that must be excavated to place the cable can dramatically impact the cost. For example, construction costs in rock formations are significantly higher than construction costs in clay soils. The presence of existing underground facilities also presents a significant uncertainty when estimating the cost of an underground project. For overhead lines, the rock can also impact the cost of the structure foundations.

4. For overhead lines, the accessibility of the line will have a significant impact on the overall project.

7.1 Cost Estimate Assumptions

1. Costs represent direct cost to BPA and do not include internal staff costs or interest accrued during construction.

2. Costs are in 2010 dollars. No escalation included.

3. Materials used in the cost estimates meet all applicable industry standards.

4. Cross-bonding of XLPE cable sheaths was assumed.

5. Construction would be performed by qualified craftsmen experienced in installing high voltage underground and overhead transmission systems.

6. BPA to obtain all environmental, local, state, and federal permits as required. The estimates in this document do not include these costs.

7. BPA to obtain all necessary right-of-way and property. The estimates in this document do not include these costs.

8. No spare material has been included.

9. 15% contingency has been added to material and labor costs.

10. Reactive compensation costs have been included at 75% of the required compensation.

11. Rock excavation costs were estimated based on geological study provided by BPA for each route. Rock is assumed to be drilled and blasted.

12. Large waterways and wetlands have been assumed to be crossed by HDD.

13. Major roadways have been assumed to be crossed by J&B.

14. Access roads for the underground have been assumed to be similar in design and length to that of an overhead option.

15. The clearing required for the underground and the overhead has been assumed to be 60-foot wide and 150-foot, respectively, for 80% of the eastern route length. The clearing required for the western route has been assumed to be 150-foot wide for both lines for 50% of the route length.

16. Construction management and design engineering has been included.

17. All materials have an 8% sales tax included

7.2 Underground Cost Estimates

TABLE 7-1 UNDERGROUND COST ESTIMATES

	Eastern Route	Western Route
Length, miles	76	68.5
Design Engineering	$9,041,000	$8,118,000
Construction Management	$56,372,000	$49,457,000
Material	$1,505,930,000	$1,328,440,000
Construction	$485,195,000	$394,444,000
Testing and Energization	$4,083,000	$3,441,000
Subtotal Cost	$2,060,621,000	$1,783,900,000
Contingency	$309,100,000	$267,590,000
Total Cost	$2,369,721,000	$2,051,490,000

7.3 Overhead Cost Estimates

TABLE 7-2 OVERHEAD COST ESTIMATES		
	Eastern Route	Western Route
Length, miles	76	68.5
Design Engineering	$3,630,000	$3,530,000
Construction Management	$8,468,000	$8,237,000
Material	$38,622,000	$38,349,000
Construction	$82,349,000	$79,314,000
Testing and Energization	$0	$0
Subtotal Cost	$133,069,000	$129,430,000
Contingency	$18,146,000	$17,650,000
Total Cost	$151,215,000	$147,080,000

7.4 Cost Estimates Comparison

TABLE 7-3 COMPARISON COST ESTIMATES			
Route/Installation	Length (mi)	Overhead Cost	Underground Cost
Eastern Route	76	$151,215,000	$2,369,721,000
Western Route	68.5	$147,080,000	$2,051,490,000

Appendix A – Environmental Report

January 21, 2011

BONNEVILLE POWER ADMINISTRATION

Environmental Impacts Associated with Overhead and Underground 500-kV Transmission Line Construction, Operation and Maintenance Activities

PROJECT NUMBER:
119864

PROJECT CONTACT:
Brian Furumasu
EMAIL:
Brian.Furumasu@powereng.com
PHONE:
(503) 293-7124

POWER ENGINEERS

Environmental Impacts Associated with Overhead and Underground 500-kV Transmission Line Construction, Operation and Maintenance Activities

PREPARED FOR: *BONNEVILLE POWER ADMINISTRATION*

PREPARED BY: *BRIAN FURUMASU*
(503) 293-7124
BRIAN.FURUMASU@POWERENG.COM

WENDY HOSMAN
(208) 788-0409
WENDY.HOSMAN@POWERENG.COM

REVISION HISTORY		
DATE	REVISED BY	REVISION
01/21/2011	Wendy Hosman	0

TABLE OF CONTENTS

1.0 INTRODUCTION 1

2.0 DESCRIPTION OF RESOURCES IMPACTED BY OVERHEAD AND UNDERGROUND 500-KV TRANSMISSION LINE CONSTRUCTION, OPERATION AND MAINTENANCE ACTIVITIES 1

2.1 LAND USE 1
2.1.1 Classifications of Land Use 1
2.2 BIOLOGICAL RESOURCES 2
2.3 GEOLOGICAL AND SOIL RESOURCES 2
2.4 WATER RESOURCES 2
2.5 CULTURAL RESOURCES 3
2.6 VISUAL RESOURCES 3

3.0 ENVIRONMENTAL IMPACTS ASSOCIATED WITH OVERHEAD AND UNDERGROUND 500-KV TRANSMISSION LINE CONSTRUCTION, OPERATION, AND MAINTENANCE 4

3.1 OVERHEAD TRANSMISSION LINES 4
3.2 UNDERGROUND TRANSMISSION LINES 5
3.2.1 Frac-out Event 6
3.2.2 Increased Soil Temperature 6
3.2.3 Fluid Leaks 7
3.3 LAND USE 7
3.3.1 Agriculture – Overhead Line Impacts 7
3.3.2 Agriculture – Underground Line Impacts 8
3.3.3 Forests – Overhead Line Impacts 8
3.3.4 Forests – Underground Line Impacts 9
3.3.5 Parks, Recreation, and Preservation – Overhead Line Impacts 9
3.3.6 Parks, Recreation, and Preservation – Underground Line Impacts 10
3.3.7 Residential – Overhead Line Impacts 11
3.3.8 Residential – Underground Line Impacts 11
3.3.9 Commercial – Overhead Line Impacts 11
3.3.10 Commercial – Underground Line Impacts 12
3.3.11 Public Facilities – Overhead Line Impacts 12
3.3.12 Public Facilities – Underground Line Impacts 12
3.3.13 Industrial – Overhead Line Impacts 12
3.3.14 Industrial – Underground Line Impacts 13
3.3.15 Transportation and Access – Overhead Line Impacts 13
3.3.16 Transportation and Access – Underground Line Impacts 14
3.3.17 Land Use Mitigation Techniques 14
3.4 BIOLOGICAL RESOURCES 16
3.4.1 Vegetation Resources 16
3.4.2 Wildlife Resources 22
3.4.3 Biological Resources Mitigation Techniques 27
3.5 GEOLOGICAL AND SOIL RESOURCES 33
3.5.1 Soil Erosion and/or Compaction – Overhead Lines 33
3.5.2 Soil Erosion and/or Compaction – Underground Lines 34

3.5.3 Reclamation Constraints Due to Soil Type – Overhead and Underground Lines 34
3.5.4 Disturbance or Access Limitations to Mineral Resources – Overhead and Underground Lines 34
3.5.5 Disturbance to Unique Geological Features – Overhead Lines 35
3.5.6 Disturbance to Unique Geological Features – Underground Lines 35
3.5.7 Disruption of Soil Profile – Overhead Lines 35
3.5.8 Disruption of Soil Profile – Underground Lines 36
3.5.9 Geological and Soil Resources Mitigation Techniques 36
3.6 WATER RESOURCES 37
3.6.1 Disturbance to Surface Water Flows and Floodplains – Overhead Lines 38
3.6.2 Disturbance to Surface Water Flows and Floodplains – Underground Lines 38
3.6.3 Disturbance to Wetlands – Overhead Lines 38
3.6.4 Disturbance to Wetlands – Underground Lines 39
3.6.5 Disturbance to Groundwater – Overhead Lines 39
3.6.6 Disturbance to Groundwater – Underground Lines 40
3.6.7 Water Quality Degradation – Overhead Lines 40
3.6.8 Water Quality Degradation – Underground Lines 41
3.6.9 Water Resources Mitigation Techniques 41
3.7 CULTURAL RESOURCES 43
3.7.1 Ground Disturbance – Overhead and Underground Lines 43
3.7.2 Visual and Audible Intrusions – Overhead Lines 43
3.7.3 Visual and Audible Intrusions – Underground Lines 44
3.7.4 Vandalism – Overhead and Underground Lines 44
3.7.5 Increased Visitation – Overhead and Underground Lines 44
3.7.6 Cultural Resources Mitigation Techniques 44
3.8 VISUAL RESOURCES 46
3.8.1 Visual Resource – Overhead Lines 46
3.8.2 Visual Resources – Underground Lines 49
3.8.3 Visual Resources Mitigation Techniques 50
3.9 PUBLIC HEALTH AND SAFETY 52
3.9.1 Electric and Magnetic Fields (EMF) – Overhead and Underground Lines 52
3.10 VEGETATION MANAGEMENT MITIGATION TECHNIQUES 53
3.10.1 Manual and Mechanical 53
3.10.2 Chemical 53

4.0 SUMMARY 55

4.1 RELATIVE ENVIRONMENTAL IMPACT SEVERITY OF OVERHEAD VERSUS UNDERGROUND 500-KV TRANSMISSION LINES 56

5.0 REFERENCES 59

LIST OF TABLES

TABLE 1 LANDFORM CONTRAST MATRIX 47
TABLE 2 CONSTRUCTION OF 500-KV TRANSMISSION LINES 57
TABLE 3 MAINTENANCE AND OPERATIONS OF 500-KV TRANSMISSION LINES 58

1.0 INTRODUCTION

This report provides a discussion of the potential environmental impacts from construction, operation, and maintenance of an overhead and underground 500 kilovolt (kV) transmission line. A description of the types of environmental resources which may be impacted by a new overhead and underground 500-kV transmission line is provided, followed by a discussion of potential environmental impacts which may occur to these resources. The environmental impacts presented are general impacts and they do not relate to a specific project, location, or project proponent. Therefore, the environmental impacts and associated mitigation measures in this report may or may not apply to any particular project. This Environmental Report is meant to serve as a general guide for 500-kV transmission line project proponents to assist in assessing the potential environmental impacts for their own specific projects.

2.0 DESCRIPTION OF RESOURCES IMPACTED BY OVERHEAD AND UNDERGROUND 500-KV TRANSMISSION LINE CONSTRUCTION, OPERATION AND MAINTENANCE ACTIVITIES

This assessment of various environmental outcomes focuses on those resources most likely to be affected during the construction, operation, and maintenance of a new 500-kV transmission line project. For purposes of this assessment, a generic or programmatic approach is used to describe construction techniques, affected environment, and environmental impacts.

Resources typically affected by overhead and underground 500-kV transmission line construction, operation, and maintenance activities include the following:

- Land Use
- Biological Resources
- Geological Resources and Soils
- Water Resources
- Cultural Resources
- Visual Resources

2.1 Land Use

Most transmission line construction projects cross many miles of countryside, traversing numerous land uses and property ownerships. Certain types of land uses are more compatible with transmission line construction and operation than others. Some land uses are more prone to short-term or temporary disruption occurring during the construction phase, and these uses can be promptly resumed after the transmission facilities are installed (DOE and DOI 2007).

2.1.1 Classifications of Land Use

There are many land uses that can be affected by construction, operation, and maintenance of 500-kV transmission lines. The major land use categories are as follows:

- **Agriculture:** lands used for agriculture production (e.g., farm fields, row crops, irrigated lands, orchards, nurseries, pastures, rangelands, etc.).

- **Forests:** lands primarily occupied by trees (includes commercial, private, and public forests).

- **Parks, recreation and preservation areas (also sometimes called conservation areas):** land areas where the established or proposed land use is primarily for recreational enjoyment, or to protect and preserve a valuable environmental resource. Examples include significant ecological areas, wilderness areas, areas of critical environmental concern, environmentally sensitive habitats, wildlife refuges, preserves, rivers, floodplains, vacant urban lands, general rural lands, golf courses, national parks, local or regional parks, campgrounds, fairgrounds, and playgrounds.

- **Residential:** single family residences, multi-family residences such as condominiums or apartments, townhouses, and mobile home parks.

- **Commercial:** retail stores, shopping centers, professional offices, business parks, retail plant nursery, and hotels/ motels.

- **Public Facilities:** educational institutions, religious facilities, health care buildings, government offices, police and sheriff stations, fire stations, public parking facilities, correctional facilities, day care centers, cemeteries, hospitals, and nursing homes.

- **Industrial:** lands used for mineral extraction such as open pit mines (including mining claims), oil wells, oil refineries, tank farms, substations, gravel pits, concrete plants, solid and hazardous waste landfills, and manufacturing.

- **Transportation and access:** the existing network of access to lands in the area. This includes interstate highways, parkways and roads, airports, railroads, park and ride lots, bus, truck, and railroad terminals.

2.2 Biological Resources

Biological resources refer to all the species living together in an area. Biological resources can be divided into two broad categories: vegetation and wildlife. Biological resources can be affected by construction, operation, and maintenance of an overhead or underground 500 kV transmission line.

Vegetation is a general term for the plant life of a region. It refers to ground cover life forms, structure, spatial extent or any other specific botanical or geographic characteristics, including cultivated, ornamental, domestic, and native plants.

Wildlife includes all living creatures that are a part of the natural ecosystem that are not tamed or domesticated. Wildlife includes, but is not limited to, birds, reptiles, fish, amphibians, and mammals.

2.3 Geological and Soil Resources

Geological resources are based on geology -- the materials the earth is made of, the processes that act on those materials, the products formed, and the history of the planet and its life forms since its origin. Soils are a type of geological resource. Soils are described as a naturally occurring, unconsolidated, or loose covering of broken rock particles and decaying organic matter (humus) on the surface of the earth, capable of supporting life.

2.4 Water Resources

Water resources is a general term for the availability (the location, spatial distribution, or natural fluctuations of water), accessibility (given availability, whether people can access it), and quality

(whether accessed water is free of contaminants and safe for consumption) of water. There are four categories of water resources that can be affected by construction, operation, and maintenance of overhead and underground 500-kV transmission lines:

- Surface water
- Wetlands
- Floodplains
- Groundwater

2.5 Cultural Resources

Historic property as defined by (36CFR800.16(1)(1)) means any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register of Historic Places maintained by the Secretary of the Interior. This term includes artifacts, records, and remains that are related to and located within such properties. The term also includes properties of traditional religious and cultural importance to an Indian tribe or Native Hawaiian organization and that meet the National Register criteria.

For the purposes of this report, three categories of cultural resources are considered, which can be affected by construction, operation, and maintenance of overhead and underground 500-kV transmission lines. These include:

- Prehistoric and historic archaeological resources
- Architectural resources
- Traditional cultural properties

Prehistoric and historic archaeological resources are locations where human activity has measurably altered the earth or left deposits of physical remains (e.g., stone projectile points, bottles). Federal acts and regulations (e.g., NHPA, 36 CFR part 800) use the term “prehistoric” to refer to archaeological resources associated with Native Americans prior to contact with Euro-Americans. This term is also commonly understood to mean cultural resources that pre-date the use of written records for an area. Historic archaeological resources are generally those that post-date Euro-American contact with Native Americans.

Architectural resources are standing buildings or structures and may include houses or cabins, barns, dams, lined canals, and bridges.

Traditional Cultural Properties (TCPs) can be defined generally as one that is eligible for inclusion in the National Register because of its association with cultural practices or beliefs of a living community that (a) are rooted in that community's history, and (b) are important in maintaining the continuing cultural identity of the community (Parker and King, 1998).

2.6 Visual Resources

Visual resources refer to the natural and man-made features in the project area and include cultural and historic landmarks, landforms of particular beauty or significance, water surfaces, and vegetation. Together these features form the overall impression that a viewer receives of an area or its landscape character.

3.0 ENVIRONMENTAL IMPACTS ASSOCIATED WITH OVERHEAD AND UNDERGROUND 500-KV TRANSMISSION LINE CONSTRUCTION, OPERATION, AND MAINTENANCE

This section provides an assessment of potential environmental impacts of overhead and underground 500-kV transmission lines and associated structures, access roads, construction activities, and materials, and operation and maintenance of the line on land use, biological, geological, water, cultural, and visual resources. Environmental impacts are defined as modifications to the existing condition of the environment that can be brought about by the implementation of a project.

Various impacts can result from project activities directly or indirectly. These impacts can either be beneficial, adverse, or neutral and can last for the long term or short term. Long-term impacts are sometimes permanent, but are categorized as long lasting. Long-term impacts are those that remain substantial throughout the life of the project or beyond. Short-term impacts are temporary and are those that result in changes to the environment during construction, but revert to a pre-construction condition at or within a few years of the end of construction. Impacts can vary in intensity from no change, to a slightly discernible change, to a full modification of the environment.

Construction impacts from overhead and underground 500-kV transmission lines are a result of installation of the infrastructure including substations, development of new access roads and right-of-way (ROW) clearing. Operation and maintenance impacts from overhead and underground 500-kV transmission lines are a result of required regular inspections and maintenance to identify problems caused by weather, vandalism, and vegetation. Inspection and maintenance activities can potentially interfere with regular land use activities and environmental resources.

Road maintenance is necessary to maintain access to transmission facilities; to prevent damage to the road; maintain safety by reducing dust, washboards, and graveling; and to preclude adverse impacts to resources resulting from lack of road maintenance. The potential adverse impacts of road maintenance are considered in the context of performing maintenance versus possible consequences of not maintaining roads.

Vegetation management is typically a major maintenance activity on overhead and underground transmission line corridors. Vegetation on ROW and access roads is controlled and managed by a variety of methods, including trimming, mowing, and use of herbicides. In general, utilities strive to remove intrusive vegetation or direct tall-growing vegetation away from transmission facilities and the ROW.

3.1 Overhead Transmission Lines

Construction of overhead 500-kV lines involves ground disturbance for the foundation(s) of each of the structures for structure support, and also requires heavy lifting equipment during construction with either conventional cranes or a heavy duty helicopter to set the tower structures and pull the transmission conductors.

Typically a drill rig with power auger would be used to excavate pole and tower foundations. Excavation activities would require access by the necessary equipment including a power auger or drill, crane, material trucks, and ready-mix trucks. After excavation is complete, steel reinforced cages would be placed into the excavated holes. Anchor bolts would be installed in the foundation template form. Concrete would be poured to the required height for the foundations. Poles or tower structures would be placed on foundation anchor bolts as soon as the foundations are ready.

Steel pole or tower sections and associated hardware would be transported to work areas by truck. Structures would be assembled within the work area and hoisted in place by a large crane or helicopter.

Once the structures are in place, a pilot line would be pulled (strung) from structure to structure via helicopter. The line would be threaded through the stringing sheaves on each pole. A larger diameter, stronger line would then be attached to the pilot line and strung through the sheaves. The former line is referred to as the sock line and the latter as the pulling line. Finally, the conductor would be attached to the pulling line and strung through the sheaves. This process would then be repeated until the conductor is pulled through all the sheaves. Conductor splicing would be required at the end of a conductor reel or if a conductor is damaged during stringing.

Initial ROW clearing would be conducted to the extent necessary to provide safe and reliable operation of electric lines and to maintain the health of the vegetation in the ROW. Numerous studies conclude that the use of stable, low-growing, less intrusive plant communities can be one of the most effective vegetation management tools on overhead transmission ROW (Bramble and Byrnes, 1983; Nesmith et al., 2008). Documented benefits of this vegetation management approach include improved cost effectiveness, service reliability, safety, aesthetic appeal, as well as decreased fire risk, and wildlife habitat enhancement. However, there can also be detrimental environmental impacts associated with vegetation management activities.

Typically existing roads would be used wherever feasible to access the line for construction, but temporary roads are often required to access all portions of the line. Temporary access would run the entire length of the line within the ROW with permanent access to transmission line structures and substations.

Environmental impacts from overhead transmission lines can be a direct result of the type of structure, structure heights, structures spans, and ROW width. These construction components will vary depending on the particular project and terrain that must be crossed. Typical structure heights range from 150 to 200 feet. Structure heights are typically kept at 200 feet or less because structures over 200 feet would need to comply with FAA requirements of having blinking red aircraft warning lights installed and the structures may be required to be painted in bands of orange and white. Major river crossings will typically have taller structures on each side of the river to allow a complete span of the river. Typical structure spans are between 1,000 to 1,400 feet and a typical ROW width is approximately 200 feet.

3.2 Underground Transmission Lines

The construction of underground 500-kV transmission lines requires a large amount of ground disturbance since open cut trenching is the most common method of installation. In this method, a backhoe or excavator is used to dig a trench of the required width and depth in accordance with the design for the installation. Trenches for 500-kV transmission lines are approximately three to four feet wide and six to ten feet deep in typical terrain. Reclaimed soil is used as backfill and to even out existing grades. If groundwater or storm water inflow is encountered during trenching, dewatering and disposal of the water is required. To prevent cave-ins, sheeting and shoring of the trench side walls using plywood or other materials is required whenever the trench bottom is deeper than five feet. Sheeting and shoring may be avoided where it is possible to step back the trench. Additional ground disturbance may result if step back trenching is used.

Conduits are used to allow for ease of pulling the 500-kV cables and are placed in the trench in an arrangement to minimize thermal effects and provide a location for the splicing of the cables for continuity of the line (500 kV will require four, eight-inch diameter conduits, where one conduit will be used as a spare in the event of a cable failure for ease of pulling a replacement cable). Buried manholes

are required if the actual distance of the underground segment exceeds the length of a reel of cable; typical cable reel lengths are 1,500 to 1,700 feet depending on the actual cable type and limitation on delivery of the cable reels (as large as 14 feet in diameter and weight of 55,000 to 75,000 pounds, depending upon the cable length and the conductor size). Typical 500-kV manholes are 30 feet in length, 10 feet wide and eight feet high to allow for the splicing and "racking" of the cables. Access to the cables is limited only to the manholes.

Transition stations are required to terminate the underground cables and to connect to the overhead transmission line. Transition stations are typically four to five acres each, depending upon switching schemes or system composition requirements, and located on both ends of the underground circuit. The stations are completely fenced and would be secured for safety reasons, similar to conventional electrical substations.

Trenchless installation methods require the installation of an entry and exit pit approximately 20 feet by 40 feet with a depth sufficient for the casing product. The entry and exit pit for directional drilling would be much smaller than other trenchless methods. The number of pits required on a given project depends on the length of the project. There would also be temporary disturbance around the entry and exit pits from equipment and workers.

Underground ROW widths can be limited to the area containing the line and an area on each side of the line to protect the line from unintentional excavation damage and for access. Depending on the construction techniques and project requirements, this width can vary from 40 to 100 feet. An unimpeded path suitable for heavy excavation equipment is required along the entire cable ROW to provide access for maintenance and repair crews. For underground installation in streets, the space requirements are usually limited to about the size of the duct bank, since the transmission line must share the space available in the street with other utilities.

3.2.1 Frac-out Event

A frac-out event occurs when excessive drilling pressure is applied and drilling mud propagates vertically toward the surface through fractured bedrock or overlying soils. This event has the potential to cause damage to environmental resources at the site of the frac-out and beyond. The damage can vary depending on the severity and location. Impacts would result from subsurface soils being spread over the land surface. Small frac-out events in urban settings or highly disturbed areas may be considered as a low, short term impact. A large frac-out event (temporary or long term) may be considered to have high impacts in areas of intense agricultural production; where there are rare, threatened and endangered species; in or near rivers, streams, wetlands or other water resources; on or near steep slopes or erosive soils; if there are cultural resources in the area; or if near a visually sensitive area.

3.2.2 Increased Soil Temperature

Heat produced by the operation of an underground line raises the temperature a few degrees at the surface of the earth above the line. This is not enough to harm growing plants, but it can cause premature seed germination in the spring. Heat could also build up in enclosed buildings near the site. According to an EPRI report titled Study of Environmental Impact of Underground Electric Transmission Systems, this local increase in soil temperature becomes negligible (even at maximum load conditions) at distances of 15 to 20 feet from the trench center line (EPRI, 1975).

3.2.3 Fluid Leaks

Both high pressure fluid filled and self contained fluid filled cables most commonly utilize an insulating fluid that can be released to the environment from underground cables through leaks in pipe joints, from corrosion, or by accidental damage to the cable system. The two most common types of dielectric fluid are alkylbenzene (which is used in making detergents) and polybutene (which is chemically related to styrofoam).

A fluid leak can migrate downward through the soil or may preferentially follow a migration path along the pipe backfill material and along intersecting utilities. Depending on the volume of fluid released, the soil properties, and the depth to groundwater, the fluid may reach the groundwater and accumulate as a lens or plume floating on the water table, potentially impacting nearby wells. Fluid-reaching storm sewers or other conduits may discharge to waterways and degrade surface water quality. In addition, the release and degradation of alkyl benzene could cause benzene compounds to show up in plants or wildlife (benzene is a known carcinogen). Alkyl benzene is also slow to degrade in the environment.

Any soil contaminated with leaking dielectric oil is classified as a hazardous waste. This means that any contaminated soil or water must be remediated. Contaminated areas (soil and water) must be delineated, characterized, and cleaned up. Costs associated with these activities can rapidly escalate because of the diffusive nature of the dielectric fluids, especially in water. Older cable systems can be more prone to leaks and seeps and thus may present higher risk.

3.3 Land Use

Siting a line through highly sensitive land uses (e.g., historic sites and structures), intensive land uses, including residential and commercial developments, and public facilities in thickly settled areas, can be a challenge when constructing, operating and maintaining overhead and underground 500-kV transmission lines. Other land uses, such as some forms of agriculture, including rangeland and pasture, are somewhat more amenable to the presence of a 500-kV transmission line with little to no long-term impact to livestock grazing within the ROW.

All land uses in the area at or near the overhead or underground 500-kV transmission line can be temporarily disrupted by construction, operation, and maintenance activities such as noise, dust, and construction traffic. Heavy construction equipment or maintenance equipment on temporary and permanent access roads could also cause a temporary disturbance to adjacent land uses, including temporary loss of access. Existing utility lines (e.g., telephone, cable, gas, etc.) may require relocation or can be damaged as a result of construction of the overhead transmission line possibly leading to disruption of service. Mechanical vegetation management can leave piles of vegetation debris on or nearby the ROW, which can create obstacles or hazards for various land users.

3.3.1 Agriculture – Overhead Line Impacts

While most agriculture activities can take place under 500-kV transmission lines, if the towers are placed in active farm fields, then the area around the tower base will be taken out of production. The presence of new project components and ROW can also permanently disrupt active farming operations by dividing or fragmenting agricultural fields, obstructing access, impeding the delivery and use of water for livestock and irrigation, reducing the efficiency of windbreaks, impeding aerial spraying, and/or disrupting the operation of farm equipment.

Two types of land classified under the agricultural land use heading, pasture and rangeland, are quite adaptable to overhead electric transmission facilities in that once construction is completed, there would

be little to no long-term impacts (a few hundred square feet per structure site). Also, orchards (depending on the height of the trees in respect to the overhead conductors), vineyards, and Christmas tree plantations and nurseries might be compatible within most of the ROW environment.

The Conservation Reserve Program (CRP) is a cost-share and rental payment program under the United States Department of Agriculture, and is administered by the Farm Service Agency. CRP is a voluntary program for agricultural landowners whereby they can receive annual rental payments and cost-share assistance to establish long-term, resource conserving covers on eligible farmland. CRP lands that are crossed by an overhead transmission line require a Farm Service Agency assessment of the adverse effects on the participant's CRP acreage. If the Farm Service Agency determines that the use will have adverse effects on CRP acreage, the affected acreage may be terminated and refunds assessed.

Agricultural land, when located on or near a transmission ROW, can be significantly impacted if adequate care is not taken when managing ROW vegetation. Agriculturally significant plants or crops should not be harmed when controlling undesirable vegetation on the ROW.

3.3.2 Agriculture – Underground Line Impacts

Impacts to agricultural land uses from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from an overhead 500-kV transmission line with the following exceptions.

Long term negative impacts to agricultural lands would result from the construction of underground transmission lines. In order to operate and perform maintenance on the line, the ROW for the underground lines must be kept clear at all times. Some farming activities cannot be performed over the top of underground transmission lines as tillage equipment can contact and damage the underground installation and disrupt the thermal backfill that is used to dissipate heat from the installation. Orchards, vineyards, Christmas tree plantations, and nurseries would not be compatible with an underground transmission line because the roots may interfere with the underground system and their presence would not be acceptable for maintenance of the ROW either.

Grasses are used to stabilize the surface of the underground installation. In some cases, grazing is a compatible use on the ROW if the project is located in pastures or range land.

A frac-out event, as well as fluid leaks, may disrupt agricultural activities and may potentially destroy agricultural products and long term production of the soil through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt agriculture activities and production. Increased soil temperatures may cause premature seed germination in the spring which may affect agriculture production.

Trenchless installation methods, such as directional drilling, would be able to preserve the above-ground agriculture resources. Temporary disturbance may occur around the entry and exit pit(s) from equipment and workers. Permanent disturbance would occur at the entry and exit pit areas as vegetation removal would be required for permanent access to this area.

3.3.3 Forests – Overhead Line Impacts

Installation of an overhead transmission line may not be compatible with applicable forest management plans or designated forest conservation uses. When clearing a new ROW in heavily forested areas without substantial topographic relief (no deep ravines, gorges, and valleys), all tall-growing tree species usually must be removed from the entire ROW, and prevented from growing in the future for the secure

and safe operation of the transmission line. Some tall trees along the outside edges of the ROW may need to be removed individually as they may be deemed dangerous due to their age and potential of falling, etc.

However, complete and total clear cutting (i.e., removal of all woody biomass), need only occur on those portions of the ROW devoted to access roads and support structure sites. In other ROW locations, vegetation, many shrubs, and some low stature trees may be kept intact to act as residual cover. In road-side screens and stream-side buffer zones, some of the taller-growing species can be kept in place if they are currently well below the conductors. Taller-growing tree species can then be removed over time as other more desirable vegetation begins to grow and develop, thereby keeping the screens and buffers sufficiently vegetated at all times. All merchantable timber felled within the ROW and from along its outside edges can be piled in such a way that enables the underlying fee owner to retrieve this resource or otherwise make these logs available for salvage operations in an environmentally acceptable manner (Miller, 2007). If the land is used for logging operations, the transmission line ROW would be lost for productive logging activities, but logging operations could continue outside the ROW.

In some instances, particularly in mountainous terrain, support structures can be placed on high points and the height of the structures increased to span longer distances with greater ground clearance. In these situations, trees which may grow taller can often be retained in ROW locations that have sufficient line to ground distances and many forestry related activities can proceed unaltered. In other situations, with only slightly increased conductor heights, some lower stature trees can still be maintained within the ROW, along with trees that have a slow growth rate (i.e., their annual height increment is marginal); although, in most instances all trees are removed within the ROW.

3.3.4 Forests – Underground Line Impacts

Long term negative impacts occur to timber producing forestlands from the construction of underground transmission lines using trenching methods. In order to operate and perform maintenance on the line, the ROW for the underground lines must be kept clear of trees, including deep ravine, gorge, and valley crossings, therefore unavailable for timber production or management.

Trenchless installation methods, such as directional drilling, would be able to preserve the above-ground forestry resources. Temporary disturbance may occur around the entry and exit pit(s) from equipment and workers. Permanent disturbance would occur at the entry and exit pit areas as tree removal would be required for permanent access to this area.

A frac-out event, as well as fluid leaks, may disrupt and/or destroy adjacent forests and forestry activities and may potentially destroy forest products and long term production of the soil through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt forest resources and activities.

Trenchless installation methods, such as directional drilling, would be able to preserve the above-ground forest resources. Temporary disturbance may occur around the entry and exit pit(s) from equipment and workers. Permanent disturbance would occur at the entry and exit pit areas as vegetation removal would be required for permanent access to this area.

3.3.5 Parks, Recreation, and Preservation – Overhead Line Impacts

Outdoor recreation activities such as hiking, camping, birding, and hunting are most affected by transmission construction activities, but impacts can also be longer term in some places depending on the level of vehicle use associated with the operations and maintenance of the transmission project. Short- and long-term impacts associated with the degradation in the quality of the visual landscape would also

likely occur in some areas. Some areas may become more accessible, with increased opportunities for recreational activities in previously inaccessible (or less accessible) areas, while other areas may become less accessible (DOE and DOI, 2007).

Many parks, intensive recreation sites, special conservation areas, all federally designated wilderness areas[1], as well as properties on the National Register of Historic Places and many other areas deemed to be ecologically sensitive or environmentally critical will, in most instances, be precluded from having a transmission line routed through them. Such distinctively classified areas contain natural resources or other cultural and historic features that are viewed as having special values and status, and are to be preserved and protected from irreparable damage.

Unauthorized access to the ROW via all terrain vehicles (ATVs) and the use of other off-highway motorized vehicles (e.g., 4X4s and snowmobiles) and additional vehicles (mountain bikes) on the ROW access roads by recreational users could cause trespass-related impacts. These can cause an increase in litter and noise, as well as illegal hunting and dumping.

Lands with conservation easements which are crossed by an overhead transmission line (if allowed under the easement) require an assessment by the administrator of the conservation easement regarding the adverse impacts from the construction, operation, and maintenance of the line. The organization holding the conservation easement may require specific rehabilitation or restoration of the property. In the worst case, the property may no longer meet the requirements of the conservation easement, in which case it would be rescinded.

Projects crossing parks, and recreation and preservation areas, which received grant funding from the Land and Water Conservation Fund can require the granting of a ROW across the property. If the project requires a conversion of land, this would constitute a conflict with the Land and Water Conservation Fund and may not be possible.

3.3.6 Parks, Recreation, and Preservation – Underground Line Impacts

Impacts to parks, recreation and preservation areas from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from an overhead 500-kV transmission line with the following exceptions.

Since the underground ROW has minimal vegetation, this may increase unauthorized access to the ROW via all terrain vehicles (ATVs) and other off-highway motorized vehicles (e.g., 4X4s and snowmobiles) and other modes of transportation (mountain bikes) resulting in trespass-related impacts. These can cause an increase in litter and noise, as well as illegal hunting or dumping.

Underground transmission lines lack overhead structures with the exception of the two transition points, which lessen the visual impact on special management areas. However, maintenance of the ROW in certain areas could be negative due to the creation of differences in vegetation. For example, an underground transmission line installed through a forested area requires the elimination of trees during construction and ROW maintenance, thus disrupting the visual continuity of the forest.

[1] However, the Wilderness Act of 1964 includes a special provision for the establishment of transmission lines within or across a Wilderness Area that is located within a national forest. Section 4(d) provides the following text regarding these transmission lines: Within wilderness areas in the national forests designated by this chapter, the President may, within a specific area and in accordance with such regulations as he may deem desirable, authorize prospecting for water resources, the establishment and maintenance of reservoirs, water-conservation works, power projects, transmission lines, and other facilities needed in the public interest, including the road construction and maintenance essential to development and use thereof, upon his determination that such use or uses in the specific area will better serve the interests of the United States and the people thereof than will its denial (Public Law 88-577, Section 4[d]).

There would be no noise impacts from operation of the underground transmission line.

A frac-out event, as well as fluid leaks may disrupt and/or destroy adjacent parks, recreation, and preservation resources through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt these resources.

Trenchless installation methods, such as directional drilling, may be able to preserve the above-ground parks, recreation, and preservation resources. Temporary disturbance may occur around the entry and exit pit(s) from equipment and workers. Permanent disturbance would occur at the entry and exit pit areas as vegetation removal would be required for permanent access to this area.

3.3.7 Residential – Overhead Line Impacts

Depending upon the proximity to the facility, and the intervening vegetation and other viewing limitations, residential occupants may be able to see the conductors and/or the support structures. In the foreground view area, poles are often preferred over lattice towers while steel lattice towers are preferred when viewing at a distance or in the background view area. If the residences are located within a few yards of the ROW, they may hear noise from corona discharge when the lines are wet.

The removal of existing buildings, including residential dwellings and related structures, might be required for a project ROW, as they might be incompatible with construction, operation, and maintenance of an overhead transmission line. The location of the project ROW within platted subdivisions can preclude or impair future development or planned activities.

3.3.8 Residential – Underground Line Impacts

The removal of existing buildings, including residential dwellings and related structures, would be required for a project ROW using trenching methods, since they are incompatible with construction, operation, and maintenance of an underground transmission line. The location of the project ROW within platted subdivisions can preclude or impair future development or planned activities.

There would be no noise impacts from operation of the underground transmission line.

A frac-out event, as well as fluid leaks, may disrupt and/or destroy adjacent residences through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt residences.

3.3.9 Commercial – Overhead Line Impacts

Buildings of any kind are directly incompatible with a high voltage electric transmission line ROW. Lines are purposefully routed around large buildings or commercial complexes. Lone or small commercial facilities may need to be removed if they end up being within a ROW, much like single residential buildings, if no other routing alternatives are economically viable. However, many 500-kV transmission lines are located over outdoor storage areas on lands classified as commercial. Parking lots surrounding many commercial establishments are likewise often compatible adjacent land uses, depending upon the presence and height of lights and other factors.

Impacts to people who work and visit commercial areas would be similar to residential impacts as described in the residential overhead section.

3.3.10 Commercial – Underground Line Impacts

The removal of existing buildings including commercial buildings and related structures would be required for a project ROW using trenching methods since they are incompatible with construction, operation, and maintenance of an underground transmission line. The location of the project ROW can preclude or impair future commercial development or planned activities.

There would be no noise impacts from operation of the underground transmission line.

A frac-out event, as well as fluid leaks, may disrupt and/or destroy adjacent commercial properties through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt commercial properties.

3.3.11 Public Facilities – Overhead Line Impacts

Major public building and institutional structures are often avoided during the routing of lines, and larger buffer zones are sometimes used around these facilities (e.g., schools) (French et al., 2008). The removal of existing buildings including public facilities and related structures might be required for a project ROW as they could be incompatible with construction, operation, and maintenance of an overhead transmission line. The location of the project ROW can preclude or impair future public facility development or planned activities.

Impacts to people who work and visit public facilities would be similar to residential impacts described in the residential overhead section.

3.3.12 Public Facilities – Underground Line Impacts

Generally, city parks and city/county-owned properties like public education land areas are deemed unacceptable for underground transmission lines, but the removal of existing buildings including public facilities and related structures would be required for a project ROW using trenching methods since they are incompatible with construction, operation, and maintenance of an underground transmission line. The location of the project ROW can preclude or impair future public facility development or planned activities.

There would be no noise impacts from operation of the underground transmission line.

A frac-out event, as well as fluid leaks, may disrupt and/or destroy adjacent public facilities through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt public facilities.

3.3.13 Industrial – Overhead Line Impacts

Due to the often long-term industrial nature of these properties, potential problems may be encountered when attempting to build a transmission line over and/or in an industrialized area. Previously unknown soil contamination associated with industrial contamination (e.g., solvents, hydrocarbons, heavy metals, etc.) could be encountered during substation or access road grading or excavation of support structure sites, potentially affecting the health of workers or the public. During grading or excavation work in such industrial environments, diligent efforts must be made to observe the exposed soil for visual evidence of contamination. If visual contamination indicators are observed during construction, all work must stop until the material is properly characterized and appropriate measures are taken to protect human health and the environment. The utility must comply with all local, state, and federal requirements for sampling

and testing, and subsequent removal, transport, and disposal of these hazardous wastes (California Public Utilities Commission and DOI, 2006).

Intensive land uses such as major mineral extraction activities and most active mining is difficult to route a transmission line through because of heavy equipment activity, worker safety, potential excavation around structure bases, waste stockpiling, and mining material between structure spans decreases safety heights from conductor to ground. However, limited scale mining activities, such as gravel pits and some quarry operations, can be spanned. No surface blasting is allowed under or near conductors and support structures. Construction of a 500-kV transmission line over areas of known mineral assets can render these resources inaccessible.

3.3.14 Industrial – Underground Line Impacts

Trenching activities may encounter unknown soil contamination associated with industrial uses potentially affecting the health of workers and/or the public as described under the Impacts to Industrial Areas from Underground Construction section above.

The removal of existing buildings, including occupied dwellings and related structures, would be required for a project ROW using trenching methods since they are incompatible with construction, operation, and maintenance of an underground transmission line. The removal of existing buildings may not be required for a project ROW using trenchless methods. The location of the project ROW can preclude or impair future industrial development or planned activities.

Underground transmission lines may be incompatible with some industrial land uses such as mines, gravel pits, and landfills as the ROW would become inaccessible and unusable for such activities.

There would be no noise from the underground transmission line.

A frac-out event, as well as fluid leaks, may disrupt and/or destroy adjacent industrial properties through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt industrial properties.

3.3.15 Transportation and Access – Overhead Line Impacts

Transportation and access impacts will be temporary during construction of an overhead 500 kV transmission line. Construction of the project may result in roadway closures at locations where the construction activities are within ROW of public streets and highways. Construction vehicles might have to utilize public and private roads to access the transmission line ROW during construction, which increases dust, noise, and overall traffic in the short term. If public and private roads are used, long-term impacts are minimal from vehicles accessing the ROW for periodic maintenance of the ROW and/or overhead transmission line.

Construction activities can interfere with emergency response by ambulance, fire, paramedic, and police vehicles. Potential roadway segments most impacted are two-lane roadways, which provide one travel lane per direction. On roadways with multiple lanes, the loss of a lane, and the resulting increase in congestion, can lengthen the response time for emergency vehicles to pass through the construction zone. Additionally, it is possible that emergency services may be needed at a location where access is temporarily blocked by the construction zone.

There is potential for damage to roads by vehicles and equipment entering and leaving the project area. An increase in trips can damage roads because of the increased weight, which is especially of concern in

areas with greater amounts of rain and freezing. Project construction temporarily increases traffic (project trip generation) on adjacent roads and highways, which can create problems when there are increases in traffic due to tourism. Depending on location, construction personnel will likely access worksites using primary and secondary roadways in the project area. The impacts on roads are short term and related to the movement of personnel and equipment during construction.

3.3.16 Transportation and Access – Underground Line Impacts

Impacts to transportation and access from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from an overhead 500-kV transmission line with the following exceptions.

With the use of trenching methods, an unimpeded path suitable for heavy excavation equipment is required along the entire cable ROW to provide access for maintenance and repair crews. This may reduce the need for access roads to the ROW and reduce impacts to transportation, particularly during operation and maintenance activities.

Installation of a transmission line using trenching methods may disrupt transportation and access to properties to a large degree because of the amount of ground disturbance required for trenching. Installation of a transmission line using trenchless methods, such as directional drilling, may not disrupt transportation or access at all or to a very small degree if the project is drilling underneath a highway, street, or road.

A frac-out event, as well as fluid leaks, may disrupt and/or destroy adjacent transportation or access resources through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt transportation and access.

3.3.17 Land Use Mitigation Techniques

The following mitigation techniques could be used to minimize impacts on land use resources during construction, operation, and maintenance of an overhead and/or underground 500-kV transmission line. For vegetation management mitigation techniques, see section 3.10.

1. Repair or replace existing property improvements to the original condition prior to disturbance if they are damaged or destroyed by construction activities.

2. Install, repair, or replace fences and gates to their original condition prior to disturbance if they are damaged or destroyed by construction activities. Close or lock gates as agreed to by landowners.

3. Leave existing roads used for construction in a condition equal to or better than their pre-construction condition.

4. Project facilities, including structures and access roads, can be installed along property lines or in the location that creates the least potential for impact to the property or adjacent properties and their uses.

5. Locate construction staging areas next to existing roads, when practical.

6. Make appropriate arrangements with landowners to remove livestock where necessary.

7. Coordinate with farmers to ensure access to livestock feeding and watering stations, as well as continued access across the ROW for farm equipment.

8. Limit new or improved accessibility into the area by off-highway and other motorized vehicles by coordinating with the appropriate agencies and underlying landowners. Physically close appropriate roads using boulders, tank traps or gates.

9. Do not apply paint or permanent discoloring agents to rocks or vegetation to indicate survey limits or construction activity.

10. At residences, align the ROW to the main road to reduce impact on the residences whenever possible.

11. Compensate landowners for short-term use and damages associated with construction activities.

12. Use warning signs at all designated trail and roadway crossings, and station flaggers during construction for all state, federal, county, and local roads and highways. Identify appropriate detour routes for local road users.

13. Notify all utilities of construction to incorporate their facility location on the construction drawings. Prior to construction, flag and/or stake the locations of all utility lines.

14. Obtain necessary and appropriate land use permits.

15. Time construction activities, whenever practical, to minimize disruption of normal seasonal activities for agriculture (planting and harvesting) and non-irrigated rangeland as well as avoid peak-use periods (e.g., weekends and holidays) at parks, recreation, and preservation areas. Coordinate construction activities with relevant agencies and landowners prior to construction.

16. Provide advance notice of construction, operation or maintenance activities to landowners and residents potentially affected by these activities. Provide adequate access to existing land uses during periods of construction and, notify landowners of alternative access. Avoid nighttime construction near noise-sensitive land uses (e.g., residences and campers at recreation sites).

17. When possible, avoid construction and operation disturbance of agricultural soil during the wet season. Minimize the use of heavy equipment on agricultural land to avoid soil compaction. Reduce the amount of soil compaction by working when the ground is frozen, using equipment with additional and wider tires to distribute the weight of the vehicle. Till severely compacted areas after construction is completed.

18. Obtain required encroachment permits or similar legal agreements for each affected roadway. Such permits may be needed for roads crossed by the transmission line, as well as for parallel roads where transmission line construction activities require the use of the public ROW (e.g., temporary lane closures).

19. Coordinate in advance with emergency service providers to avoid restricting movements of emergency vehicles. Have local agencies notify respective police, fire, ambulance, and paramedic services. Notify local agencies of the proposed locations, nature, and duration of any construction activities, and advise of any access restrictions that impact their effectiveness.

20. Project design and construction should comply with applicable regulations associated with railroads/railways in the project area. Obtain required permits for entering railroad ROW from the appropriate railroads/railways.

21. Coordinate with agricultural landowners to ensure subsurface tower structures will not interfere with blading or tilling activities, where feasible.

22. Use existing public roads to the extent possible when performing construction, operation, and maintenance activities. Use dust-control measures in sensitive areas, as needed, when performing access road maintenance.

23. Avoid vehicle traffic on the ROW except as needed to maintain the ROW and for transmission line maintenance and repair.

24. Restrict all operation and maintenance vehicle movement outside the ROW to pre-designated access or public roads.

25. Develop and follow an appropriate maintenance program for transmission line systems and ROW.

3.4 Biological Resources

Constructing, operating, and maintaining a 500-kV transmission line without disrupting, changing or destroying biological resources can be a challenge, although some areas are more sensitive than others due to the type of resource. Rare, threatened, and endangered species and habitats are particularly susceptible to negative impacts from construction, operation, and maintenance of a 500-kV transmission line. The impacts to biological resources are discussed below and are divided into two categories: vegetation resources and wildlife resources.

3.4.1 Vegetation Resources

Vegetation resource impacts from construction, operation, and maintenance of a 500-kV transmission line can result in the following:

- Disruption of existing vegetation
- Change in habitat type or vegetation composition
- Habitat fragmentation
- Disruption of rare, threatened, and endangered plant species and habitat
- Introduction of invasive plant species

3.4.1.1 Disruption of Existing Vegetation from Overhead Lines

At a minimum, all woody vegetation must be removed from access road locations, structure sites, equipment storage areas, and assembly work areas. The access roads and structure sites require complete clear cutting of all vegetation. Typically the construction contractor will find an open field, existing storage yard or graveled parking lot for equipment storage areas, which would not require vegetation clearing, but the disturbance could be significant because of the level of equipment activity. However, ROW locations can be more selectively cleared to remove only the tall-growing species (virtually every tree as well as some tall-growing shrubs) found within the ROW. In this general ROW situation, most shrubs can be left, along with all herbaceous vegetation. In some other special ROW locations, such as

roadside screens and streamside buffer zones, clearing can be more selective as to require only the removal of vegetation over a certain height.

The critical height over which the vegetation must be removed in these special consideration areas is dependent on the distance of the conductor to the vegetation at each specific location. Greater conductor clearances may allow the retention of more trees (e.g., many low-stature trees and tall shrubs) for a greater period of time. As the remaining trees continue to grow they will have to be trimmed, or most likely removed in the future. This leisurely removal will allow other vegetation to invade the buffer zone or screen, some of which will be low-growing species that will be perpetually retained. In other ROW situations where exceptional ground-to-conductor clearances exist, (such as in deep ravines and gullies, valley bottoms, or gorges and canyons), all vegetation can often be retained.

Other disruption factors affecting existing vegetation are the chosen methods of log handling and slash disposal. Often, trees felled on the ROW are limbed and topped. The remaining logs are then moved to piles at a ROW location from which merchantable timber products can be easily extracted. The remaining slash materials are bunched into piles and sometimes windrowed along the outside edges of the ROW. In clearing situations that are located on steep slopes or where tree density is light, the felled trees are bucked, topped, limbed, and further lopped into smaller pieces and scattered about the ROW. Other disposal methods may include burning the slash, and chipping or carting it away for off-site disposal. Vehicular movement for the transport of logs and the handling of slash can often scarify the ROW soils to some extent.

Vegetation resources may be impacted by operation and maintenance activities due to heavy-duty maintenance vehicles and equipment leaving established access roads and crushing plants. Vegetation may also be impacted when accidental oil or fuel spills occur. Road maintenance activities can result in reduction or removal of streamside vegetation through brushing activities, possibly resulting in water temperature increases. The risk of temperature increases is highest in very small streams. Road maintenance involving brush removal can reduce stabilizing vegetation on both cut and fill slopes, contributing to erosion impacts.

The purpose of vegetation management activities associated with transmission line ROW is to remove or cut intrusive vegetation (target vegetation) growing on or near the ROW. Target vegetation includes trees and shrubs growing in the ROW or off the ROW that can grow into, fall into, or otherwise interfere with transmission lines. The same is true for underground transmission ROW. A properly maintained underground ROW must be kept clear of trees and large shrubs that could interfere with the underground line directly (with their roots) or indirectly (by removing soil moisture needed to adequately cool the conductors) (Wisconsin Public Service Commission, 2004). Non-target vegetation can also be impacted by general vegetation management activities including accidental trampling or killing of plant species, increased exposure to sunlight and weather, increased noxious weed growth, and/or changes in soil nutrient levels and soil moisture.

3.4.1.2 Disruption of Existing Vegetation from Underground Lines

Impacts to vegetation resources from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from an overhead 500-kV transmission line with the following exceptions.

Trenching activities disrupts the existing vegetation no matter what type of vegetation exists. Trenching can damage the root systems of existing trees next to the ROW to the extent that the trees are weakened or killed. A properly maintained underground ROW must be kept clear of trees and large shrubs because they could interfere with the underground line directly (with their roots) or indirectly (by removing soil

moisture that is needed to adequately cool the conductors) (Wisconsin Public Service Commission, 2004). Trees and large shrubs cannot be re-planted in the ROW of underground transmission lines; however, grass or similar vegetation may be used.

Trenchless methods, such as directional drilling, will not disrupt the existing vegetation to the extent of trenching because the vegetation will remain intact. Temporary disturbance may result from equipment and workers near the exit and entry pits and permanent disturbance of existing vegetation would result from excavation of the pits and permanent access to these locations.

A frac-out event, as well as fluid leaks, may disrupt and/or destroy vegetation resources through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt and/or destroy vegetation resources both within and outside the ROW.

3.4.1.3 Change in Habitat Type or Vegetation Composition from Overhead Lines

Changes in habitat types or vegetation composition can occur within the transmission line ROW, but results may vary significantly depending on the type of habitat being impacted. Also, vegetation recovery rates will depend on soil type, landform, precipitation regime, and other physical features of the disturbed sites.

Vegetation removal operations for overhead transmission lines largely depend on the height of the natural vegetation present and the ground to conductor clearances. Forests will by necessity usually be substantially and permanently altered (over the life of the line) to form a variety of low-growing, sun-loving, early successional plant communities. Some shrub communities, as well as old-field vegetation, can remain almost entirely intact (except at structure sites and access roads). Rangeland, grasslands, and many desert plant communities can be virtually unaffected from general ROW clearing, as none would be needed. Also, areas containing only short stature trees, such as a juniper and pinion pine forest, might coexist within the ROW. Only a few taller specimens may need to be removed from under the maximum sag portion of the line due to the general low height and slow growth rate of these and similar species.

More studies need to be conducted in this area, but a lack of native species recovery exists in certain ecosystems where areas are severely disturbed such as clearing of the ROW and installation of overhead transmission line structures and components, as indicated in the following studies.

In the Mojave Desert, Lathrop and Archbold discovered that disturbed areas from transmission line construction and control areas may appear to have similar vegetation covers, biomasses, and densities, but the similarities often vanished when qualitative aspects were examined, such as proportion of long-lived species and presence of characteristic dominants (Lathrop & Archbold, 1980).

A study by Thibodeau and Nickerson revealed that overhead transmission line construction did not have a substantial, long-term negative impact on a forested wetland. Except for differences in size and maturity, the forested wetland vegetation recovered in two years from nearly total destruction caused by construction (Thibodeau & Nickerson, 1986). A similar study examined the response of vegetation communities to overhead transmission line construction in three different wetland types: a cattail marsh, a forested swamp, and a shrub/bog wetland. While both the cattail marsh and forested swamp recovered within a few years, measures of plant community composition in the shrub/bog wetland were still lower, compared to controls after ten years (Nickerson, Dobberteen, & Jarman, 1989).

Stylinski and Allen investigated the impacts of severe disturbance (construction, heavy-vehicle activity, soil excavation, landfill operation, and tillage) on shrub communities in southern California. Their study

revealed that these disturbances led to the conversion of indigenous shrublands to exotic annual communities with low native species richness. The cover of native species remained low on disturbed sites even 71 years after initial disturbance ceased. The study supported their hypothesis that altered stable states can occur if a community is pushed beyond its threshold of resilience (Stylinski & Allen, 1999).

It may be concluded from these studies that certain ecosystems are more resilient than others to disturbance caused by overhead transmission line construction, and that permanently altered vegetation communities can occur if pushed beyond their thresholds of resilience. Shrub/bog wetlands, as well as arid and semi-arid ecosystems, appear to be particularly susceptible to permanent damage from overhead transmission line construction.

Additionally, because the vegetation composition within the ROW must be kept free of large trees and shrubs, a permanent early successional habitat is created. The creation of these open and early successional habitats in a ROW is beneficial to some species and detrimental to others.

Creation of early successional plant communities composed of an assortment of locally extant and readily available low-growing native woody shrubs, herbs (forbs and grasses/sedges), ferns, vines, reeds, and other forms of plant life can be positive if the ROW is located in a predominately forested setting. These ROW conditions replicate old-field plant communities that are becoming landscape rarities in many locations, thereby increasing or restoring this unique vegetation community. The juxtaposition of these two different plant community types; one a forest and the other a mixture of low growing plants, creates a unique transition area from one habitat type to another where rare plants might thrive. In general, when a ROW is created within a region that is primarily forested, the benefits of this new unique habitat along with the "edge effect" may be positive overall as seen with the Karner Blue Butterfly described below.

In Wisconsin, transmission ROW has a positive effect on the federally endangered Karner Blue Butterfly, where blue lupine, a plant vital to the butterfly's survival, is increasing in abundance because of the open areas in the overhead transmission line ROW (Willyard et al., 2004). The Karner Blue Butterfly serves as an example of a positive outcome of ROW corridors.

3.4.1.4 Change in Habitat Type or Vegetation Composition from Underground Lines

Impacts due to changes in habitat type or vegetation composition from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from an overhead 500-kV transmission line with the following exceptions.

With trenching methods, all vegetation would be removed from installation of the trench and transmission line, and the remainder of the ROW would need to have low growing vegetation to provide access for maintenance vehicles. This may create a relatively uniform habitat type and reduced species diversity than existed prior to construction.

With trenchless methods, such as directional drilling, there would be no changes to the existing habitat type or vegetation composition because the surface soil and vegetation would not be disturbed.

3.4.1.5 Habitat Fragmentation from Overhead Lines

Habitat fragmentation can occur with construction of an overhead 500-kV transmission line, but results will vary depending on the plant species composition both within the ROW and adjacent to it. Impacts seem to be species-specific and localized. Whether or not the ROW provides a net ecological benefit, the "edge effect," or constitutes an ecological threat in the form of fragmentation, is dependent on the overall

landscape conditions surrounding the ROW and cannot be discerned solely by the sheer presence of the ROW or by the condition of the vegetation on the ROW alone (Albrecht et al., 2000).

The literature on the ecological impacts of fragmentation focuses on reduced habitat area, species isolation, and increased habitat edge. Plants that are isolation, area, or edge sensitive will be negatively affected by fragmentation; however, plants that are not sensitive to fragmentation may be unaffected or positively affected by the separation if it results in an increase in habitat or favorable conditions for these species.

With regard to reduced habitat area, a survey of twenty transmission line corridors in the forests of northern Kentucky reveals that construction of a single power line corridor within forests, already fragmented by development activities, may render forest patches unsuitable for plant species requiring large forest interior habitats (Luken et al., 1990).

The habitat fragmentation impacts of roads on the landscape include dissecting vegetation patches, increasing the edge-affected area, decreasing interior area, and increasing the uniformity of patch characteristics, such as shape and size (Reed et al., 1996).

3.4.1.6 Habitat Fragmentation from Underground Lines

Impacts due to habitat fragmentation from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from an overhead 500-kV transmission line with the following exceptions.

Trenchless methods would not disturb the existing habitat so impacts to habitat fragmentation would be low except for the areas where entry and exit pits are needed, as all vegetation would be removed from these areas for installation and permanent access. Trenchless methods may still result in impacts from habitat fragmentation unless the entire transmission line is completed using trenchless methods.

3.4.1.7 Disruption of Rare, Threatened, and Endangered Species and Habitats from Overhead Lines

Direct and indirect impacts to plants that are listed as threatened and endangered species are a major environmental concern when building a new 500-kV transmission line. This is because of the official status given these plants due to their low population numbers and the general tendency for such listed species to be less resilient to habitat alterations than other more commonly found plants. Other plant species may be considered as rare in a given area for having low population numbers, a very narrow endemic range, and/or fragmented habitat. In some instances these rare plants are provided various types of protection (e.g., protected plants) by state or local laws, or are otherwise considered a species of concern for various reasons. Temporary disturbances can have adverse impacts on plant populations with very limited ranges. Specific impacts are dependent on the exact species status within or near the proposed ROW and other habitat requirements with respect to the location of particular project activities.

Roads and ROWs create habitat edge, particularly in forested settings, which enhances local plant species diversity and has a positive effect on some individual species, typically those that are habitat generalists and are already common in the landscape. As a result, increased local diversity often comes at the expense of global species diversity, as rare plants are replaced by common ones. This phenomenon causes ecosystems to lose complexity (Willyard, 2004). Although, it is possible that rare and unique plant species may take the opportunity to exploit the newly created ecological niches and, to the extent

that some may be protected listed plants, the presence of the ROW may actually induce the occupancy of these species of concern.

Rare plant species may also be affected by the introduction of invasive plant species, not only in the ROW, but also near the edges of the ROW, if the invasive species encroach into these areas.

3.4.1.8 Disruption of Rare, Threatened, and Endangered Species and Habitat from Underground Lines

Impacts to rare, threatened, and endangered plant species and habitat from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from an overhead 500-kV transmission line with the following exceptions.

Trenchless methods, such as directional drilling, will not disrupt the rare, threatened, and endangered plant species to the extent of trenching because the vegetation will remain intact. Temporary disturbance may result from equipment and workers near the exit and entry pits, and permanent disturbance of existing vegetation would result from excavation of the pits and permanent access to these locations.

A frac-out event, as well as fluid leaks, may disrupt and/or destroy rare, threatened, and endangered plant species through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt and/or destroy these special status plant species both within and outside the ROW.

3.4.1.9 Introduction of Invasive Plant Species - Overhead Lines

Noxious weeds and invasive plants can pose serious threats to the composition, structure, and function of native plant communities (Olson, 1999). Noxious weeds produce abundant seed, have fast growth rates, and can displace native species (Olson, 1999). Project activities that disturb the ground and the subsequent loss of native vegetation can make an area vulnerable to noxious weed invasions (Olson, 1999). In addition, open roads can serve as corridors for weed spread. Noxious weed seeds can be carried in the undercarriage of vehicles and distributed along roadway; the movement of animals or humans can facilitate the spread of invasive species into previously inaccessible areas. Invasive species monopolize ecosystems and often out-compete native vegetation, which in turn negatively affects the animals dependent on these habitats.

A study in the southern California shrublands found that sites with severe disturbance from activities such as soil excavation and heavy-vehicle equipment consisted of 60 percent non-native annual species compared with undisturbed sites that were primarily covered with native shrub species (68 percent) (Sylinski & Allen, 1999).

Clearing of new ROW may open fresh environments for these deleterious plant species (alien, exotic, non native species that are invasive and may be listed as noxious weeds that also may be legally classified as undesirable) to occupy. Although 500-kV transmission lines corridors are often viewed as a potential habitat and/or corridor for movement of invasive species, they do not, in most cases, undergo the degree of continuous disturbance that many exotic invasive species seem to prefer. Although, if invasive plant species are not controlled within the ROW, their populations may increase, thus displacing more native vegetation.

3.4.1.10 Introduction of Invasive Plant Species – Underground Lines

Impacts due to introduction of invasive plant species from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from an overhead 500-kV transmission line with the following exceptions.

Since underground installation requires continuous disturbance along the length of the trench and the ROW requires plants with minimal root systems and little variety, this has the potential of enhancing the establishment of invasive plant species.

Trenchless methods will not disrupt the existing vegetation; thereby, reducing the introduction of invasive species. Temporary disturbance may result from equipment and workers near the exit and entry pits. Permanent disturbance of existing vegetation would result from excavation of the pits and permanent access to these locations, creating opportunities for invasive species to get established.

3.4.2 Wildlife Resources

Many of the major impacts to wildlife resources associated with overhead transmission lines are connected with ROW preparation and transmission line, substation, and access road construction. Impacts to wildlife resources from these activities could result in the following:

- Habitat and population fragmentation
- Habitat loss and reduced species abundance
- Wildlife displacement and disturbance
- Disruption of rare, threatened, and endangered species
- Herbicide toxicity
- Avian interactions (overhead only)

3.4.2.1 Habitat and Population Fragmentation from Overhead Lines

Concern for habitat fragmentation is increasing in wildlife management (Baker & Knight, 2000) and is considered a global concern for biological diversity (Knight et. al., 2000). Species decline and shifts of animal distributions have led to a more modern focus on the causes of habitat fragmentation and the effect this may have on wildlife. Avian responses to habitat fragmentation included life cycle alterations, increased parasitism, and habitat affinity associations (Weller et al., 2002; Knight et al., 2000). Habitat removal and fragmentation as a result of transmission line construction can alter wildlife migration corridors and dispersal orientation, and isolate wildlife populations and their gene pools. This significantly weakens the wildlife community.

The impacts of fragmentation by roads may be similar to that of fragmentation by a ROW. Fragmentation by roads is known to change landscape structure, directly and indirectly affecting species. Road-avoidance behavior is characteristic of large mammals such as elk, deer, bighorn sheep, grizzly, and wolf. Avoidance distances of 100 to 200 meters are common for these species (Lyon, 1983). Road density is a useful index for the effect of roads on wildlife populations (Forman et al., 1997). Some studies show that a few large areas of low-road density, even in a landscape of high average road density, may be the best indicator of suitable habitat for large vertebrates (Rudis, 1995).

There is strong evidence that forest roads displace some large mammals and certain birds (such as spotted owls and marbled murrelets), and that displaced animals may suffer habitat loss as a result. Impacts of

roads on small mammals and songbirds are generally described as less severe, with changes expressed as modifications of habitat that cannot readily be classified as detrimental or beneficial.

Roads and ROW also create habitat edge (Mader, 1984; Reed et al., 1996); increased edge changes habitat in favor of species that use edges, referred to as edge specialists. The introduction of edge specialists is often to the detriment of species that avoid edges or experience increased mortality near or along edges, referred to as habitat interior specialists (Marcot et al., 1994). The continuity of a road system or ROW can create a corridor by which edge-dwelling species of birds and animals can penetrate the previously closed environment of continuous forest cover. Species diversity can increase, and increased habitat for edge-dwelling species can be created.

In general, road building and ROW clearing fragments habitat, and creates habitat edge, modifying the habitat in favor of species that use edges. Edge-dwelling species are generally not threatened, however, because the human-dominated environment has provided ample habitat for them.

Habitat removal and fragmentation as a result of road or ROW clearing can alter wildlife migration corridors and dispersal orientation, as well as isolate wildlife populations and their gene pools. This significantly weakens the wildlife community.

Habitat fragmentation affects wildlife regardless of the location, but the degree to which wildlife is affected, and the species-specific impacts, as they relate to construction of an overhead transmission line cannot be definitely concluded. Construction of access roads directly applies, but construction of the ROW, while similar to a road, is dissimilar enough that direct comparison may be less effective. Roads completely remove all vegetative matter and thus nearly all wildlife habitats, while a ROW is allowed to return to a state resembling pre-construction depending upon the pre-construction habitat.

3.4.2.2 Habitat and Population Fragmentation from Underground Lines

Impacts to habitat and population fragmentation from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from construction of an overhead 500-kV transmission line with the following exceptions.

Underground transmission lines may not fragment grassland habitat if the grassland habitat is allowed to return to a pre-construction state.

Trenchless methods would not disturb the existing habitat so impacts due to habitat and population fragmentation would be low except for the areas where entry and exit pits are needed as all vegetation and nearly all wildlife habitats would be removed from these areas for installation and permanent access. Trenchless methods may still result in impacts from habitat and population fragmentation due to ROW preparation unless the entire transmission line is completed using trenchless methods.

3.4.2.3 Habitat Loss and Reduced Species Abundance from Overhead Lines

Direct habitat losses can result from the conversion of existing wildlife habitat to access road surfaces and other transmission facilities requiring nearly bare ground. Also, one existing habitat type (e.g., a forest) may be lost as a result of some ROW preparation activities (e.g., selective clearing), as the habitat may be converted or changed (e.g., to a shrubland). In general, wildlife species abundance will decline with any reduction in the size or quality of the habitat. The extent that ROW habitat conversion (e.g., from forest to shrubland) may result in reduced wildlife species abundance will depend on the amount of fragmentation already existing in the landscape and exactly what types and amounts of habitat are being lost or gained. If the general landscape surrounding the ROW is already fragmented, then additional

fragmenting will only serve to exacerbate the problem. If there is a nearly continuous or extensive habitat type covering the region (e.g., forests), creation of the ROW and its attendant edge may add a new desired disturbance regime to the locale. Thus the newly created ROW can have a positive effect for early successional species by providing a new, but distinctly unique habitat (i.e., a low-growing habitat that is early successional in nature and generally sun loving). In this instance, early successional species will thrive, but habitat interior specialists will suffer negative impacts and will cease to exist in and around the ROW.

As the number of fragments increase in a given area, the core area size used by interior habitat specialists decreases, reducing the patches uninterrupted by human disturbance. The amount of edge area grows with the increase of fragments, and habitat connectivity decreases with increased fragmentation (Knight et al., 2000). Decreased connectivity may favor the habitat generalist wildlife species over the forest or grassland specialist species, threatening species richness or diversity at regional scales (Knight et al., 2002). Habitat generalists, such as coyotes, skunks, raccoons, and brown-headed cowbirds, use road corridors and ROW to easily access the interior forest or grassland. These predators and nest parasites can have direct impacts on interior habitat adapted species populations. Opening up forest, and to a lesser degree shrubland habitat, also increases solar exposure during winter months creating earlier forage exposure for several species.

Vegetation control activities also have a potential impact on aquatic life in areas where the ROW crosses over or is adjacent to riparian zones. Riparian plants and trees provide food for fishes and other animals, and habitats for insects that supplement fish diets. Riparian vegetation also provides shade to maintain cool stream temperatures and insulate the stream from heat loss in winter.

The loss of riparian vegetation is a long-term, direct impact of ROW vegetation management activities. When riparian vegetation is removed or pruned, stream shading is immediately reduced, resulting in stream temperature increases. Erosion impacts occur when soil-stabilizing riparian vegetation is removed. Erosion increases turbidity and sedimentation, potentially impacting fish feeding success. In some cases, increased sedimentation can keep fry from emerging or it can fill in deeper pools preferred by some fish species.

However, one study conducted on a forested transmission ROW in New York found a greater abundance of fish associated with ROW streams than in nearby forested streams (Peterson, 1993). The study suggests that tree canopy removal in the ROW increased sunlight in the riparian zone. This facilitated dense low-growing vegetation to grow on stream banks, which stabilized stream bank soils, minimizing erosion. In contrast, the forested stream banks were largely vegetation free, which contributed to erosion related impacts.

Insects used for biological control of undesirable vegetation may act as a food source, enhancing habit for birds and other wildlife.

3.4.2.4 Habitat Loss and Reduced Species Abundance from Underground Lines

Impacts to habitat loss and reduced species abundance from construction, operation, and maintenance of an underground 500-kV transmission line would be similar as impacts from construction of an overhead 500-kV transmission line with the following exceptions.

With trenching methods, riparian areas are typically avoided, but in the instance where they may be disrupted by installation of an underground transmission line, there may be a large impact from the loss of riparian habitat and species.

3.4.2.5 Wildlife Displacement and Disturbance from Overhead Lines

Construction, operation, and maintenance of transmission lines, underground or overhead, may provide temporary or permanent wildlife disturbance by displacing animals from their typical habitat. Disruption comes from increased noise levels (e.g., construction); increased vehicle traffic (e.g., construction, maintenance, recreation use); and facility presence (e.g., tower structures, manholes, access roads, and pad-mounted equipment). Helicopter patrols can adversely affect wildlife, particularly big game species during birthing periods (Bridges et al., 1997). Most wildlife occupying a project area are displaced during construction, and some species such as nesting birds and amphibians, are vulnerable to mortality from the physical disruption of soils and vegetation.

Impact to fisheries can result from increased sediment in streams or rivers. Potential impacts are greatest during and immediately after construction. Fish tend to avoid streams or stream reaches with high-suspended sediment levels. Deposited sediment affects the reproductive success of salmonids. Sediment can coat eggs and embryos, and fill the interstitial spaces of the redd (nest for depositing eggs) so completely that the flow of water containing oxygen is impeded or stopped, resulting in mortality. Another problem occurs when sedimentation on the streambed produces a consolidated armor layer through which emerging sac fry cannot penetrate, resulting in entombment of the fry (Waters, 1995). Salmonids are particularly sensitive to sediment in spawning gravels. Therefore, increases in instream sediment deposition are undesirable and are avoided whenever possible.

In areas where the ROW crosses riparian zones, the cleared ROW has the potential to impact aquatic life. Riparian vegetation has many influences on the stream ecosystem. Riparian vegetation produces food for fish and other animals, and habitat for insects that supplement the diet of fish. Riparian vegetation also forms a protective canopy that helps maintain cool stream temperatures in summer and insulates the stream from heat loss in winter. Since the influence of riparian vegetation generally decreases as streams get larger, small streams are likely to experience more severe impacts than large streams as a result of riparian vegetation removal (Murphy and Meehan, 1991).

Many types of vegetation can often be left in place when the ROW is very selectively cleared in these riparian zones. Although most tall-growing tree species can not be allowed to mature to their full heights within the ROW proper, they can be retained for some time when conductor to ground clearance allows, which is often common in these low lying stream bottoms. To minimize disruption in these riparian buffer zones, individual trees can be felled as needed over time, which allows for the maximum retention of vegetation and provides an ample period to permit the establishment of new vegetation.

Vegetation management activities on overhead and underground 500-kV transmission corridors can temporarily or permanently disrupt wildlife by displacing animals from their habitat. Trees are utilized for nesting, perching, hunting, shelter, and food, providing habitat for birds, mammals, and insects. Tree-dwelling wildlife can be disturbed and/or displaced when trees are removed or pruned. Increased noise levels and vehicle traffic from vegetation control equipment and vehicles can temporarily disturb animals causing them to flee the area. Ground-nesting birds, amphibians, and reptiles are vulnerable to mortality from the physical disruption of soils and vegetation caused by vegetation control equipment.

3.4.2.6 Wildlife Displacement and Disturbance from Underground Lines

Wildlife displacement and disturbance from construction, operation, and maintenance of an underground 500-kV transmission line would be similar to impacts from construction of an overhead 500-kV transmission line with the following exceptions.

Disturbance of some wildlife species would be short-term and direct due to trenching activities. Displacement of some wildlife species, dependent on underground habitat, would be permanent due to installation of the underground 500-kV transmission line and associated equipment.

Although riparian areas are typically avoided with the use of trenching methods, the loss of riparian habitat would be a long-term, direct impact of underground transmission line construction resulting in displacement of riparian dependent wildlife species. Some types of vegetation, as indicated in studies described in the overhead section, take years to recover; trees and large shrubs are not allowed to mature within the permanent ROW.

3.4.2.7 Disruption of Rare, Threatened, and Endangered Plant Species and Habitat from Overhead Lines

Direct and indirect impacts to listed endangered and threatened wildlife species populations, or even their candidate species, are a major environmental concern when building a new overhead 500-kV transmission line. This is due to the official status given these species with low population numbers, and the general tendency for such listed species to be less resilient to habitat alterations than other more commonly found fauna. Even temporary disturbances can have adverse impacts. Breeding habitat is especially important because disruption during breeding season can reduce productivity for the entire year. Specific impacts are dependent on the species' habitat requirements and the exact location of transmission related facilities.

Other wildlife species of concern may be those that are rarely found, or are unique to the project vicinity, or are considered special status species. The impacts to these species that should be considered include the potential for substantial interference with the movement of native resident or migratory fish or wildlife species, or with established native resident or migratory wildlife corridors, or activities that impede the use of wildlife nursery sites.

Vegetation management changes to the ROW can potentially have significant impacts on wildlife species with home ranges that are limited to the ROW. Wildlife species with broader home ranges can either be temporarily displaced or experience minor impacts from the ROW vegetation management activities.

3.4.2.8 Disruption of Rare, Threatened, and Endangered Plant Species and Habitat from Underground Lines

Impacts to rare, threatened, and endangered wildlife species and habitat from construction of an underground 500-kV transmission line would be similar to impacts from construction of an overhead 500-kV transmission line with the following exceptions.

Although riparian areas are typically avoided with the use of trenching methods, the loss of riparian vegetation would be a long-term, direct impact of underground transmission line construction resulting in displacement of riparian dependent wildlife species. Some types of vegetation, as indicated in studies described in the overhead section, take years to recover; trees and large shrubs are not allowed to mature within the permanent ROW.

The impacts of trenchless methods to rare, threatened, and endangered wildlife species would be low due to the lack of surface disturbance. Temporary disturbance may result from equipment and workers near the exit and entry pits, and permanent disturbance of existing vegetation would result from excavation of the pits and permanent access to these locations.

A frac-out event, as well as fluid leaks, may disrupt and/or destroy rare, threatened, and endangered wildlife species through the displacement of subsurface soils onto the land surface and result in soil contamination. Any required clean-up activities may also disrupt and/or destroy these special status wildlife species both within and outside the ROW.

3.4.2.9 Herbicide Toxicity – Overhead and Underground Lines

Modern herbicides used for ROW vegetation management have been studied in considerable detail, enabling researchers to assess the impacts of herbicides, including the results of interactions of chemicals with biological systems. The key to safe and effective use of herbicides is the principle of dose response. As dose increases, so also does the effect. For every compound there is a dose below which no effect can be detected. Risk analysis allows different products to be compared to determine if expected exposure will result in toxic impacts (Norris et al., 1997).

Common herbicides examined in detail as part of the Environmental Impact Statement for Vegetation Management on Electric Utility ROW on the Allegheny National Forest (and used commonly throughout the U.S.) were found to have very low toxicity "with virtually no potential for reproductive or genetic effects" and were not found to cause cancer. This EIS pointed out that "every chemical, whatever its source, can cause toxic impacts at some dose; no truly non-toxic chemical exists". Safe use of these products is based on knowing the pattern of toxicity for each herbicide, as well as the doses at which toxicity occurs and the doses below which no effect takes place. While use of registered herbicides according to label requirements does not pose detrimental environmental consequences, misuse of these products may result in significant harm. Methodologies have been developed to monitor the off-target application of herbicides that could pose avoidable risks to water resources (Norris et al., 1997).

The most dramatic impacts of herbicides on non-target plants and animals often result from the habitat alterations they cause by killing the targeted weeds. For example, loss of invasive riparian plants can cause changes in water temperature and clarity that can potentially impact the entire aquatic community, and the physical structure of the system through bank erosion. Removing a shrubby understory can make a habitat unsuitable for certain bird species, and expose small mammals to predation.

3.4.3 Biological Resources Mitigation Techniques

The following mitigation techniques can be used to minimize impacts on biological resources during construction, operation, and maintenance of an overhead or underground 500-kV transmission line. For vegetation management mitigation techniques see section 3.10.

1. Restrict all construction vehicle movement outside the ROW to pre-designated access, contractor-acquired access, or public roads.

2. In construction areas where recontouring is not required, leave the vegetation in place wherever possible and maintain the original contour to avoid excessive root damage and allow for resprouting. Limit disturbance to overland driving where feasible to minimize changes in the original contours.

3. Prior to construction, instruct all supervisory construction personnel on the protection of biological resources. The construction contract can address:

    a. Federal, state and tribal laws regarding plants and wildlife, including collection and removal.
    b. The importance of biological resources and the purpose and necessity of protecting them.

c. Methods for protecting sensitive resources, including instruction on wildlife policy to prohibit unauthorized off-road vehicle use in the project area, and to discourage wildlife harassment and littering.

4. Adhere to Section 7 of the Endangered Species Act (1973) as specified by the U.S. Fish and Wildlife Service (USFS), Biological Opinion of the USFS, and other appropriate agencies.

5. Delineate the boundaries of sensitive plant populations with clearly visible flagging or fencing based on surveys completed prior to construction. In the event any special-status plants require relocation, obtain permission from the appropriate agencies. If avoidance or relocation is not practical, the topsoil surrounding the plants can be salvaged, stored separately from the subsoil, and spread during the restoration process.

6. Develop a noxious weed and invasive plant control plan in consultation with the appropriate agencies and local weed control districts to minimize the impacts of noxious weeds due to proposed project activities. The plan can address measures to minimize the spread of noxious weeds and invasive plants and control methods after construction.

7. Train the contractor on methods for cleaning equipment, identification of problem plant species in the project area, and appropriate project procedures when an invasive or noxious weed is located. Supply the contractor with a list and pictures of noxious and invasive species that may exist in the project area.

8. Promptly seed disturbed areas following completion of construction activities to reduce the potential for the spread and establishment of noxious weeds and invasive plants. Seeding of appropriate plant cover should occur as soon as possible following construction and during the optimal time period for establishment of desirable plant species.

9. Apply herbicides for weed control by qualified personnel according to the label instructions. Orient spray units to minimize drift and chemical entry into streams. Use spray buffer strips along streams to reduce or eliminate the impacts of herbicide spraying on aquatic environments.

10. Limit ground disturbance to what is necessary to safely and efficiently install the proposed facilities.

11. Prepare a revegetation plan in consultation with the appropriate agencies. The plan can specify the disturbance types and their appropriate revegetation techniques to be applied for all proposed project work areas and access roads. Techniques could include reseeding native or other acceptable vegetation species with certified weed-free seed. The plan can include approved management and maintenance procedures for ongoing use of access roads and temporary work areas.

12. Erosion and sediment control measures can be specified and meet the requirements of the Clean Water Act.

13. Install barriers along travel ways bisecting the underground transmission line easement to minimize erosion potential and encourage vegetation regeneration. Barriers may include gates and post/pole fencing, in addition to the use of natural obstacles such as rocks, logs, planted native shrubs, and vegetation slash.

14. Avoid sedimentation loading downstream and impacts on fisheries at specific stream crossings by scheduling trenching operations to occur through streams during dry or low flow periods.

15. Modify or curtail construction activities during sensitive periods (e.g., nesting and breeding) for candidate, proposed threatened and endangered, or other sensitive animal species.

3.4.3.1 Avian Interactions

Avian interactions would be largely limited to overhead 500-kV transmission structures. Typically, avian species utilize overhead transmission facilities for perching, hunting, roosting, and nesting purposes in areas where natural supports (e.g., trees) are uncommon. Birds landing on or colliding with transmission lines and associated support structures can result in outages and bird fatalities. Power line electrocutions and collisions are not the primary causes of bird mortality and population reductions. Habitat loss is the most significant cause of avian population declines worldwide. However, as discussed above, the creation of ROW can result in habitat loss for interior specialist species and overhead transmission installations can have direct impacts on bird populations. In turn, avian populations have direct impacts on transmission facilities. Many avian-transmission interactions result in power outages negatively impacting electric service reliability, as well as increasing costs associated with power delivery.

Avian interactions and 500-kV transmission impacts can be divided into the following general categories:

- Collisions
- Electrocutions
- Outages
- Habitat Enhancement

3.4.3.1.1 Collisions

Avian collisions occur when flying birds are unable to avoid overhead transmission wires or structures and strike the facilities, typically resulting in injury or death. Collisions are more likely to occur in conditions of poor visibility or when birds are flushed by a disturbance. Some bird species are more prone to power line collisions depending upon their morphology, flocking habits, and flight behavior (Roig-Soles and Navaso-Lopez, 1997). Large, heavy, less maneuverable species such as cranes, herons, swans, and geese are more likely to collide with transmission lines. Transmission line placement can also have a large influence on collision potential. Transmission lines placed near avian concentration areas, such as large wetland complexes, or bisecting high use areas, such as roosting and feeding areas, can result in higher instances of collisions with transmission lines. In the case of a large-conductor, such as a 500-kV line, birds rarely collide with the conductors. Instead, birds will increase in altitude to avoid the large diameter conductors and collide with the smaller, overhead groundwire above. It is estimated that 174 million birds are killed every year by colliding with both distribution and transmission power lines (APLIC, 2006).

V-guyed structures are occasionally used for large transmission lines such as 500-kV. In these instances, the guy-wires supporting the V shaped structure would increase the likelihood of avian collision with the transmission line supporting structures. Numerous studies have noted avian collisions with guy-wires on radio antennas (Avery and Beason, 2000; Crawford and Engstrom, 2001; Manville, 2001).

3.4.3.1.2 Electrocutions

Thousands of birds are electrocuted every year by distribution and transmission facilities, including, raptors, crows, ravens, vultures, herons, owls, pelicans, and pigeons (APLIC, 2006). Avian electrocutions are far more common on distribution lines (i.e., 60 to 70-kV) than on transmission lines because the distance between wire conductors or distances between wires and their support structures are greater on transmission facilities than on distribution facilities. Avian electrocutions occur when a bird either touches two conductors at the same time (phase-to-phase) or when it simultaneously comes in contact with an energized conductor and the transmission support structure causing electric current to go through the bird body to ground (phase-to-ground). A bird's propensity to be electrocuted is also driven by its size (i.e., wingspan), hunting habits, nesting habits, and weather conditions. Wet feathers are known to be more conductive than dry feathers, thus making birds more vulnerable to electrocutions during rain (APLIC, 2006).

3.4.3.1.3 Outages

Bird collisions and electrocutions do not necessarily result in bird-caused outages. Additional bird-related outage causes include:

- Nesting materials causing phase-to-phase or phase-to-ground conditions.
- Prey remains come in contact with energized conductors or equipment.
- Damage caused by pecking or acid degradation from accumulation of fecal contamination reducing component life expectancy.
- Long streams of excrement (streamers) discharged from large birds causing flashovers.
- Large flocks perching on lines and taking off at the same time, causing oscillation in the line and flashovers.

Avian-related outages detrimentally impact system reliability, increase revenue loss due to outages, and increase costs associated with power restoration and equipment repair. Many utilities have increased their efforts (and costs) to implement bird management programs as bird populations continue to use transmission line corridors for habitat.

Avian-related outages would be rare on a 500-kV transmission line. 500-kV transmission lines are typically large, with enough distance between conductors to avoid coming into contact with prey remains, streamers, or fecal contamination. The typical distance between conductors is likely too large for flashovers to occur from oscillation after large flocks perch and take off from a line. Spacing of the conductors on a 500-kV transmission line is also typically too large for nesting material to cause a phase to phase or phase to ground connection; however contact of nesting material with energized phases can cause the nest to catch on fire and cause wildfires.

3.4.3.1.4 Habitat Enhancement

Numerous scientific studies conclude that overhead 500-kV transmission line corridors can provide valuable habitat for edge specialist avian populations. The wire and border zones provide for the foraging and nesting of edge specialist species. Wire zones are those habitats which fall directly within the maintained ROW. Boarder zones are those habitats where the maintained ROW stops and the previously existing habitat resumes. Boarder zones are also referred to as edges. Initial ROW clearance in a forest habitat will cause an initial decrease in the local bird population, but as early successional plant and shrub habitats develop, a net increase in bird populations typically occurs as new species move in (Bramble et

al., 1987). In addition, ongoing maintenance activities do not detrimentally impact bird populations or bird species diversity if timed outside of the nesting season (Bramble et al., 1986).

Bird species that nest in brushy or grassy vegetation created by the wire and boarder zones are particularly prevalent on transmission ROW. On the State Game Lands 33 Research and Demonstration Project in central Pennsylvania, the abundance of birds along the ROW was about seven times higher than in the adjacent forest and nearly four times as many birds were observed in the shrubby border zones than in the wire zones (Yahner et al., 2002).

Transmission structures also provide suitable habitat for raptors and owls that employ perch-and-dive hunting techniques. Transmission towers and poles provide a perching support with widespread views of the surrounding hunting area. One study demonstrated that raptor density significantly increased following construction of a 245 kV overhead transmission line in Colorado (Stahlecker, 1978). However, this may be to the detriment of prey populations below overhead transmission lines. Numerous studies have noted the deleterious impacts of overhead transmission lines on greater sage grouse (*Centrocercus europhasianus*), a candidate species for the Federal Endangered Species Act (Graul 1980, Braun 1998, Aldridge and Brigham 2002, Braun et al. 2002, Knock et al. 2003).

A telemetry study conducted in California from 1998 – 2000 found that transmission lines may have negative impacts on sage grouse lek attendance at distances of over 12 miles. The data also showed that the mean survival of adult greater sage grouse increased as the distance from a transmission line increased. However, it was concluded that the data did not indicate that these impacts may be limiting to the population for leks more than three miles from the transmission line (Armentrout and Hall 2005).

Many bird species also use transmission structures as nesting sites. For example, 133 pair of raptors and ravens were successfully nesting on transmission towers within 10 years of construction of a 500-kV transmission line in the Snake River Valley of Idaho and Oregon (Steenhof et al., 1993). In general, there is greater clearance between conductors on transmission spans, and support structures allow sufficient space and support for birds to nest without causing significant problems for electrical operations (APLIC, 2006). But, as previously discussed, nests that are located above insulators or conductors may cause equipment failures and outages due to nest materials, prey remains, or fecal contamination. Also, birds utilizing transmission towers or poles are more likely to be electrocuted or collide with conductors.

However, this too may have a deleterious effect on threatened and endangered species. Corvids (Corvids are the family of birds that includes ravens and crows) are known to be one of the major nest predators of greater sage grouse (Watters et al, 2002), and a major source of mortality to federally threatened desert tortoise (*Gopherus agassizii*; Boarman, 2003).

3.4.3.2 Avian Interaction Mitigation Techniques

The following mitigation techniques can be implemented to minimize impacts on bird populations resulting from the construction, operations, and maintenance activities of overhead 500-kV transmission lines:

- Develop and implement a comprehensive Avian Protection Plan (APP) or at least portions of an APP. An APP's purpose is to minimize utility impacts to bird populations while, at the same time, facilitate safe and reliable electric service. The following 13 components of an APP can be considered (APLIC, 2006; Liguori and Burress, 2008):
    - **Corporate Policy:** Develop a statement and policy committing a utility to balance the protection of avian species with providing safe, reliable, and cost effective service. The

statement typically includes provisions for avian interaction and mortality reporting, efforts toward avian-friendly design and construction, and regulatory compliance.

- **Training:** Training can be provided to all leadership, management, supervision, engineers, design, and field personnel on avian interaction issues and applicable utility policies including, but not limited to regulatory compliance, construction and design standards, nest management, and incident reporting. Ongoing supplemental training can be provided as needed.

- **Permit Compliance:** Develop and communicate utility processes under which employees secure necessary permits related to avian interaction issues.

- **Construction and Design Standards:** Utilities can consider avian interactions during the design and construction of new transmission facilities as well as during ongoing operations and maintenance efforts. Bird-safe construction and retrofitting options include, but are not limited to installing nesting platforms, anti-perch or perch-friendly devices, and/or requiring sufficient clearance between phases or phases and grounds.

- **Nest Management:** Develop, implement, and train employees on nest management procedures including, but not limited to nest siting, nest removal, and how to obtain applicable nest relocation or removal permits.

- **Avian Reporting System:** Develop an avian interaction reporting system. Utilize a database to track trends associated with avian interactions in order to identify concern areas with high incident frequencies.

- **Risk Assessment Methodology:** Focus efforts cost effectively by identifying and prioritizing areas and structures that pose the greatest risk for avian mortalities. Conduct a risk assessment by evaluating available data related to avian electrocutions, nesting areas, established migratory bird flyways, prey populations, perch availability, and other factors contributing to avian-utility interactions.

- **Mortality Reduction Measures:** Develop a mortality risk reduction plan that identifies and prioritizes options for reducing avian electrocutions and outages (high priority monitoring areas, lines to be retrofitted, etc.) and set a task completion schedule.

- **Avian Enhancement Options:** Develop an avian enhancement plan that incorporates initiatives to enhance avian populations and habitat through use of nesting platforms, managing habitat to attract migratory birds or prey for raptors, or working collaboratively with organizations and/or agencies that are involved in such efforts.

- **Quality Control:** Develop provisions or policies designed to ensure quality control and continuous improvement related to the utility's avian interaction management efforts.

- **Public Awareness:** Document and communicate avian conservation efforts to agencies and the public. Communication efforts can facilitate program buy-in and a positive public image.

- **Key Resources for Troubleshooting:** Identify resources and personnel who are capable of being avian interaction experts. For example, environmental specialists can assist operations and maintenance personnel with identifying retrofit opportunities designed to maximize bird protection and system reliability.

- **Installation of bird flight diverters:** Identify preferred bird flight diverter to be installed on lines in problem areas such as wetlands, river crossings, and landscape features which may attract birds.

3.5 Geological and Soil Resources

Constructing, operating, and maintaining a 500-kV transmission line without disrupting, changing or destroying geological and soil resources can be a challenge, although some areas are more sensitive than others due to the type of resource. Erosive and compaction prone soils are particularly susceptible to negative impacts from construction, operation, and maintenance of a 500-kV transmission line. Impacts on geological and soil resources from ROW construction of an overhead 500-kV transmission line can result in the following:

- Soil erosion and/or compaction
- Reclamation constraints due to soil type
- Disturbance or access limitations to mineral resources
- Disturbance to unique geological features
- Disruption of soil profile

3.5.1 Soil Erosion and/or Compaction – Overhead Lines

Soils impacted by an overhead 500-kV transmission line are primarily associated with structure installation, substation and access road installation, material storage and staging areas, ROW vegetation clearing, and maintenance vehicle access. These disturbances, although temporary (e.g. construction and any reclamation), may result in an increase in soil erosion and compaction levels. Actual erosion depends on factors at a particular site such as weather events, soil properties, slope, and adjacent vegetation or lack thereof. Vegetation creates a canopy covering the soil, and root systems bind soils reducing runoff and erosion. Erosion rates can increase significantly when vegetation is removed.

Potential soil erosion hazards vary depending on the use, conditions, and textures of the soils. The properties of soil which influence erosion by rainfall and runoff are ones that affect the infiltration capacity of a soil, and those which affect the resistance of a soil to detachment and being carried away by falling or flowing water. Additionally, soils on steeper slopes would be more susceptible to erosion due to the impacts of increased surface flow (runoff) on slopes where there is little time for water to infiltrate before runoff occurs. Soils containing high percentages of fine-grained sand and silt and having low densities (loose, uncompacted), are generally the most erodible. As the clay and organic matter content of these soils increases, the potential for erosion decreases. Clays act as a binder to soil particles, thus reducing the potential for erosion.

Potential long term impacts may result in the following: a decrease in productivity due to erosion and/or compaction; difficulty in reclaiming unstable soils; and irreparable damage to low productivity soils. Wheeled vehicles and heavier vehicles result in higher impacts, with the potential for longer term impacts.

Soil erosion can occur along the ROW primarily at individual construction sites. The potential for erosion is most likely to occur during the construction phases of a project when clearing, excavation, and fill operations are most intense. Until vegetation is re-established, borrow pits, ROW access roads, stream crossings, staging areas, and structure construction sites are especially vulnerable to erosion. Road maintenance activities may also contribute to soil erosion.

Grading for new project facilities (e.g., substations and access roads) would disturb large areas and the upper soil surface and protective vegetation will be loosened or removed. Planned areas of grading and disturbed surfaces might become susceptible to wind and water erosion, which would result in soil loss and potential sedimentation in nearby water resources.

Transmission construction activities can impact the water quality downstream from the affected disturbance area. The disturbance comes from clearing, grading, excavations, drilling, or blasting to construct support structures, and associated facilities. Other causes are heavy equipment traffic near staging areas, access roads, and at other critical work locations along the ROW. Water quality may be affected by sedimentation from nearby or upstream construction activities.

All soils crossed by underground or overhead 500-kV transmission lines can be impacted by vegetation management activities. Disturbance or loss of vegetation can result in increased soil erosion. Vegetation control equipment and vehicles can increase soil compaction. Moderate or severe soil compaction affects soil productivity potential. The extent of compaction depends on soil moisture content and the physical characteristics of a particular soil type. Compaction tends to be less severe when soils are dry and more severe when soils are moist to wet.

3.5.2 Soil Erosion and/or Compaction – Underground Lines

Extensive erosion control measures may be required (e.g. silt fencing, fiber rolls, sedimentation trap/basin, temporary swales or dikes, instream sediment trapping devices, etc.) when trenching methods are used because a trench is dug the entire line length and the ROW is totally cleared. In areas with hilly terrain and erosive soils, significant erosion and sedimentation impacts could arise from trenching methods. Underground construction does not have the flexibility to avoid unstable areas encountered by the line route; thus the potential for impacts to unstable areas may be substantial.

Use of trenchless methods, such as directional drilling, would result in no impact to surface soils except where the entry and exit pits reside. There may be temporary as well as permanent impacts at the pit sites due to excavation of the pits and disturbance from workers and equipment. Soils would be displaced from drilling and insertion of the transmission line. These displaced subsurface soils would most likely be removed from the site if not usable at the entry and exit pit areas.

3.5.3 Reclamation Constraints Due to Soil Type – Overhead and Underground Lines

Soils developed on Cretaceous shales and intrusive and lacustrine sediments are more difficult to reclaim and revegetate due to their chemical composition and mechanical weathering products. Cretaceous shales and lacsutrine sediments often produce highly saline soils, and intrusive rocks generally weather to granular sands with little nutrient availability. Soils with low water holding capacity are also more prone to impacts from compaction.

Use of trenchless methods would reduce reclamation constraints due to soil type because there would be no surface soil disturbance except at the entry and exit pit locations.

3.5.4 Disturbance or Access Limitations to Mineral Resources – Overhead and Underground Lines

A new overhead transmission line may disturb, limit or prevent access to mineral resources such as mines, quarries, or oil or gas fields due to installation of the ROW, structures, access roads, and facilities.

3.5.5 Disturbance to Unique Geological Features – Overhead Lines

ROW construction activities associated with the construction of an overhead 500-kV transmission line have the potential to disturb unique geological features of a particular area. The transmission line can disrupt the visual quality of the geological feature or there may be direct disturbance if construction of an access road or installation of a structure is adjacent or directly in line with the particular feature.

3.5.6 Disturbance to Unique Geological Features – Underground Lines

Impacts to unique geological features from construction of an underground 500-kV transmission line using trenching methods would be significant because the feature would be irreplaceable or irreparably damaged due to installation of the trench and equipment.

Trenchless methods could reduce or eliminate impacts to unique geological features if the transmission line could be installed under the feature without disturbance.

3.5.7 Disruption of Soil Profile – Overhead Lines

Vegetation management activities can affect soils and geological resources by altering soil nutrient levels. Impacts to soil resources can occur from inversion of the soil profile, loss of structure, and alteration of soil chemistry. For example, removing brush cover can, over time, reduce the amount of carbon in the soil, especially if revegetation does not occur. Removing nitrogen-fixing plants can also reduce soil nitrogen levels and impact plant productivity. Removing vegetation can also create erosion impacts. Erosion allows increased water to leach soluble nutrients and transport organic matter and nutrients offsite, thereby reducing soil productivity potential.

Accidental liquid spills (e.g., herbicides, oil, and hydraulic fluids) can cause soil contamination. The potential impacts on soil contamination can be localized and limited in their extent and magnitude, if appropriate best management practices and other mitigation measures are implemented in a timely fashion.

An herbicide's persistence in soils is often described by its half-life (also known as the DT50). The half-life is the time it takes for half of the herbicide applied to the soil to dissipate. The half-life gives only a rough estimate of the persistence of an herbicide, since the half-life of a particular herbicide can vary significantly depending on soil characteristics, weather (especially temperature and soil moisture), and the vegetation at the site. Dissipation rates often change with time (Parker and Doxtader, 1983). For example, McCall et al. (1981) found that the rate of dissipation increased until approximately 20% of the applied herbicide remained, and then declined. Nonetheless, half-life values do provide a means of comparing the relative persistence of herbicides.

The distribution of an herbicide in the soil is determined primarily by the amount, type, and surface area of clays and organic matter in the soil; the amount and quality of soil moisture; and soil temperature and soil pH (Helling et al., 1971). Most natural soils have pH values between five and eight. Rainfall and the amount of leaching that has occurred strongly influence these values. In wet areas and/or coarse soils, cations (positively charged ions) can be leached out, leaving the soil acidic. In arid and semi-arid regions, soils retain cations and are more alkaline. Acidic soils can also be found in wetlands where organic acids lower the soil's pH.

3.5.8 Disruption of Soil Profile – Underground Lines

Impacts to soil resources from trenching methods can occur from inversion of the soil profile, loss of structure, and mixing of layers as the trench is backfilled. These impacts may also occur at the entry and exit pit locations when trenchless methods are used. This may result in increased erosion and compaction and less productive soil for vegetation. Underground 500-kV transmission lines using trenching methods require the importation of select thermal backfill in many instances. The sources of these materials can be located many miles from the project area. Borrow sites for these materials result in significant disturbances to the soil profiles of the borrow area and can contribute to land use and erosion impacts at the borrow sites without proper reclamation and stabilization techniques, such as reseeding, fiber rolls, biofilter bags, temporary storm drain systems, etc.

Impacts from vegetation management of the ROW would be similar to the description under section 3.5.7.

3.5.9 Geological and Soil Resources Mitigation Techniques

The following mitigation techniques may be used to reduce impacts from construction, operation, and maintenance of overhead and underground 500-kV transmission lines. For vegetation management mitigation techniques see section 3.10.

1. Restrict all construction vehicle movement outside the ROW to pre-designated access, contractor-acquired access, or public roads.

2. In construction areas where re-contouring is not required, leave the vegetation in place wherever possible and maintain the original contour to avoid excessive root damage and allow for re-sprouting. Limit disturbance to overland driving where feasible to minimize changes in the original contours.

3. Implement suitable precautionary measures following identification of soils with high erosion potential and/or soluble salt content so suitable precautionary measures can be properly planned and implemented.

4. Erosion and sediment control measures must be specified and meet the requirements of the Clean Water Act.

5. Limit ground disturbance to that necessary to safely and efficiently install the proposed facilities. Avoid soil-disturbing actions during periods of heavy rain or wet soils.

6. Maintain long-term adequate ground cover and soil structural characteristics by:

    a. Stockpiling topsoil removed during construction activities and salvage and reapply during restoration.
    b. Retain plant debris to be left on-site as much as practical to serve as mulch.
    c. Reclaim disturbed erodible soils as quickly as possible, or apply protective covers where necessary.

7. Install barriers along travel ways, bisecting the underground transmission line easement to minimize erosion potential and encourage vegetation regeneration. The barriers can lower soil impacts by discouraging motorized vehicle access and travel. Barriers may include gates and post/pole fencing in addition to the use of natural obstacles such as rocks, logs, planted native shrubs, and vegetation slash.

8. Use existing public roads and conduct all construction activities in a manner that minimizes soil disturbance to the extent possible. Use dust-control measures during road construction in sensitive areas, as required. Leave all existing roads in a condition equal to or better than their condition prior to construction of the transmission line.

9. Conduct a field verification of all landslide-prone areas and make appropriate adjustments as needed.

10. Prepare a geotechnical report prior to construction to address risks to structures and roads due to potential seismicity and liquefaction.

11. To facilitate revegetation and minimize soil compaction, target only severely compacted areas for disking (ripping), with the depth extending to subsoils if necessary.

12. To minimize erosion and sedimentation transport, temporary control measures (e.g., silt fences, straw bale fences, terracing, water bars, matting, settling ponds, or other erosion control techniques) can be installed prior to and during construction in graded or disturbed areas, steep slopes that exceed 30%, and in other sensitive areas.

13. Monitor stabilization methods and revegetation success for a minimum of two growing seasons or until 75-80% revegetation is achieved as approved by the appropriate agency or landowner.

14. Promote soil restoration in sloped disturbance areas with placement of the appropriate amount and type of erosion control material.

15. Complete a thorough survey of the proposed project ROW to avoid any unique geological features.

16. Limit construction and vehicle travel during periods of excessive soil wetness to prevent rutting and compaction.

17. Use rubber-tired work vehicles instead of tracked vehicles to reduce environmental impacts on soil resources.

3.6 Water Resources

Constructing, operating, and maintaining a 500-kV transmission line without disrupting, changing, or destroying water resources can be a challenge, although some areas are more sensitive than others due to the type of resource. Wetlands are particularly susceptible to negative impacts from construction, operation, and maintenance of a 500-kV transmission line. Impacts to water resources from construction, operation, and maintenance of an overhead or underground 500-kV transmission line can result in the following:

- Disturbance to surface water flows and floodplains
- Disturbance to wetlands
- Disturbance to groundwater
- Water quality degradation

3.6.1 Disturbance to Surface Water Flows and Floodplains – Overhead Lines

Physical changes to surface water resources from the installation of an overhead 500-kV transmission line are directly linked with the runoff from the land surface. An increase in surface water runoff entering a stream can produce the following impacts: an increase in downstream flow; an increase in channel width or depth; erosion of the stream's bed and/or banks; and build up of sediment in a stream.

During construction, some streams or waterways may need to be crossed by access roads. Such direct impacts on the stream environment can cause erosion of the streambed and banks causing increased sediment loads and downstream aggradations. The need to selectively clear some riparian vegetation may affect surface water flows and floodplains.

Construction near surface water has the potential to alter localized drainage patterns of the area. A permanently altered drainage pattern can temporarily increase erosion and sedimentation until the banks are stabilized, eliminate the previous riparian corridor while eliminating non-riparian vegetation in the new corridor, harm wildlife, or damage existing land uses. If drainage patterns are altered, this can change floodwater flows and associated floodplains. Encroachment into a floodplain or watercourse by a permanent aboveground project feature, such as the tower leg of a support structure, can result in flood diversions, or erosion (localized scouring).

Additionally, streams or waterways may need to be diverted during construction. In addition to impacts on aquatic wildlife, riparian vegetation, and recreation activities, the diversion of streams or waterways during construction of an overhead 500-kV transmission line can affect surface water flows and floodplains.

Vegetation management can affect surface water (ponds, lakes, wetlands, streams, and rivers) and groundwater (wells and aquifers) resources when vegetation is cut or removed. Vegetation control activities can impact water resources by increasing surface runoff, causing erosion, facilitating sedimentation, reducing shading, increasing water temperatures, and inhibiting nutrients from entering the water by limiting plant debris buildup.

3.6.2 Disturbance to Surface Water Flows and Floodplains – Underground Lines

Impacts to surface water flows and floodplains from construction of an underground 500-kV transmission line would be similar to impacts from construction of an overhead 500-kV transmission line with the following exceptions.

Disturbance from trenching activities could be substantial because of the soil, vegetation, and hydrological disturbance required for installation of the trench and transmission line, particularly if crossing waterways or water bodies as they would be disrupted, altered, or destroyed by the trenching activities.

Trenchless methods are often used to cross waterways or water bodies in the transmission line ROW because this method does not disrupt or destroy the resource; although, it opens the potential for impacts from a frac-out event. A frac-out event under a waterway or water body would introduce sediment to the water resource and if the discharge of subsurface soil is large enough it may disrupt surface water flows.

3.6.3 Disturbance to Wetlands – Overhead Lines

ROW preparation (clearing of trees within the ROW and access roads) and facility construction (substations, support structure foundations and/or erection work zones) of an overhead transmission line

can temporarily or permanently alter wetland systems. Because wetland systems are a unique combination of hydrology, soils, and vegetation, disrupting one of these conditions may irreversibly damage the wetland ecosystems processes.

Certain functions and values of wetlands can be permanently adversely affected during the construction of overhead transmission lines, substations, and access roads, such as the conversion of a forested wetland to an herbaceous wetland in the permanently maintained utility line ROW. As discussed under the vegetation resource section, Thibodeau and Nickerson (1986) reported on the impacts of utility ROW construction and maintenance on the vegetation of a forested wetland and found that except for differences in size and maturity, the vegetation recovered in two years from nearly total destruction caused by construction. Maintenance of the ROW, that included the periodic removal of tall-growing species, led to the formation of a plant association different from the one occurring naturally, but as diverse and species rich.

In another study (also discussed under the vegetation resource section), Nickerson et al. (1989) reported on the long term impacts of construction of an overhead utility ROW through a cattail marsh, forested swamp, and shrub/bog wetland, and discovered that both the cattail marsh and forested swamp recovered within a few years, while the plant composition of the shrub/bog wetland plant was still lower after ten years.

If a wetland system cannot be spanned or avoided by an overhead transmission line, the potential for irreversible damage to the wetland system is substantial.

3.6.4 Disturbance to Wetlands – Underground Lines

Impacts to wetlands from construction of an underground 500-kV transmission line would be similar to impacts from construction of an overhead 500-kV transmission line with the following exceptions.

Disturbance from trenching activities could be substantial because of the soil, vegetation, and hydrological disturbance required for installation of the trench and transmission line, particularly if crossing wetlands as they would be disrupted, altered, or destroyed by the trenching activities.

Trenchless methods are often used to cross wetlands in the transmission line ROW because this method does not disrupt or destroy the resource; although, it opens the potential for impacts from a frac-out event. A frac-out event under a wetland would introduce sediment and if the discharge of subsurface soil is large enough it may permanently impact the wetland by destroying or altering the vegetation, wetland hydrology, and hydric soils.

3.6.5 Disturbance to Groundwater – Overhead Lines

In general, groundwater is often found near the surface in the vicinity of substantial surface water bodies. In other areas (e.g., mountainous regions), groundwater can occur at great depths. When located at a shallow depth (i.e., on the order of tens of feet), groundwater is more susceptible to adverse impacts associated with construction, maintenance, and surface spills; and changes in recharge (DOE and DOI, 2007).

Excavations for overhead 500-kV transmission line foundations which encounter such groundwater close to the surface can temporarily or permanently alter groundwater flows by changing the underground channels and/or pools that exist. This has the potential of affecting existing domestic wells.

Dewatering the transmission support structure foundation site is often necessary in areas with high water tables (tens of feet from the surface). The main dewatering techniques include: barriers, sump and ditches, wellpoint systems, deep-well systems, and cutoffs. These techniques can impact the existing water table, potentially increase soil erosion, increase surface water downslope, and potentially impact adjacent land use, vegetation, and wildlife depending on where, in what quantity, and the duration of the water diversion activity.

Soil compaction from access roads and compacted backfills at structure sites can alter ground surface percolation rates, which can subsequently affect groundwater recharge to underlying aquifers.

3.6.6 Disturbance to Groundwater – Underground Lines

Impacts to groundwater from construction of an underground 500-kV transmission line would be similar to impacts from construction of an overhead 500-kV transmission line with the following exceptions.

If groundwater or storm water inflow is encountered during trenching, dewatering and disposal of the water is required.

Trenchless methods may impact groundwater resources due to a frac-out event. Subsurface soils from a frac-out event may flow into groundwater resources and alter the nature, flow, and quality of the groundwater by introducing sediments.

3.6.7 Water Quality Degradation – Overhead Lines

The quality of surface water in regards to 500-kV transmission line construction activities is primarily influenced by the presence of sediment, microbes, pesticides, and nutrients. Surface water quality is also affected by the amount of solar radiation received and the shade-producing vegetation in the riparian area that, in turn, affects water temperature, as well as other water quality factors such as flow rates, total suspended solids, total dissolved solids, turbidity, and changes in dissolved oxygen, salinity, and acidity. Construction near surface water has the potential to directly impact the quality of these water resources through erosion or discharge of materials.

The period of highest potential impact from overhead transmission projects is during and immediately following construction from the ROW work sites, staging areas, or access roads. Construction in ephemeral drainages, when waterless, could deposit sediment on the dry streambed, which could then be available for transport to the stream system when flows resume.

Maintenance vehicles and road maintenance can disturb water resources, resulting in compaction and/or erosion impacts that can directly or indirectly affect water quality. Performing road maintenance can result in severe rutting and gullying during wet periods, resulting in large amounts of sediment into the watershed. Ground disturbance from road blading, particularly where the road is immediately adjacent to streams, constitutes the greatest risk from increased sediment production. Other activities such as culvert and ditch maintenance can also increase sediment delivery to streams. However, lack of road maintenance can result in serious impacts to streams as well. This includes washouts, as well as increased risk of vehicle accidents, which may introduce potential toxic fuels to streams. This is especially critical when roads are adjacent to streams with sensitive species.

ROW clearing requirements can affect riparian vegetation ability to positively influence water quality characteristics. Water quality of surface waters can also be directly impacted through the accidental release of pollutants such as fuel, lubricants, or antifreeze during construction.

Using herbicides for vegetation control that are not labeled for aquatic use can also potentially affect water resources. Water resources can be contaminated by overspray, or when herbicides drift, volatilize, leach through soils to groundwater, or are carried in surface or subsurface runoff. Amounts of leaching and runoff are largely dependent on total rainfall the first few days after an application. Total losses to runoff generally do not exceed five to ten percent of the total applied, even following heavy rains (Taylor and Glotfelty, 1988). High soil adsorption capacity, low rates of application and low rainfall reduce total runoff and contamination of local waterways (Bovey et al., 1978).

3.6.8 Water Quality Degradation – Underground Lines

Impacts to water quality from construction of an underground 500-kV transmission line would be the similar to impacts from construction of an overhead 500-kV transmission line with the following exceptions.

Water quality degradation from trenching activities could be substantial because of the soil, vegetation, and hydrological disturbance required for installation of the trench and transmission line. Erosion and sedimentation of waterways and water bodies may temporarily alter the water quality.

Trenchless methods are often used to cross waterways or water bodies in the transmission line ROW because this method does not disrupt or destroy the resource; although, it opens the potential for impacts from a frac-out event. A frac-out event under any water resource would introduce sediment, which may temporarily impact water quality. If the discharge of subsurface soil is large enough and flows directly, or even indirectly, into a water resource, it may impact water quality over an extended period of time.

A fluid leak from the underground transmission line may temporarily or permanently impact water quality if the contaminants in the fluid spread into nearby water resources. Clean-up activities from a fluid leak may further impact water quality by spreading the contaminants around.

3.6.9 Water Resources Mitigation Techniques

The following mitigation techniques can be used to minimize impacts on water resources during construction, operation, and maintenance of an overhead or underground transmission line. For vegetation management mitigation techniques see section 3.10.

1. Restrict all construction vehicle movement outside the ROW to pre-designated access, contractor-acquired access, or public roads.

2. Prior to construction, instruct all supervisory construction personnel on the protection of water resources. The construction contract can address:

    a. Federal, state and tribal laws regarding water resources.
    b. The importance of water resources and the purpose and necessity of protecting them.

3. Build roads at right angles to the streams and use existing public roads to the extent possible. Install culverts where needed. Conduct construction activities in a manner that minimizes disturbance to vegetation, drainage channels, and stream banks.

4. Develop a crossing for vehicles and construction equipment and create an appropriate undisturbed vegetation buffer. If the soil within the vegetation buffer is disturbed prior to construction, install sediment barriers across the transmission line ROW.

5. Install culverts or temporary work bridges across all streams that are flowing at the time of construction to provide access to the work areas on both sides of the streams. This will minimize stream bank degradation, erosion, and sediment into the waterway.

6. Have all construction vehicles and equipment traffic travel around wetland areas when possible.

7. Locate staging areas for stream and wetland crossings a minimum of 50 feet away from the stream bank or edge of designated wetland areas. Install the appropriate sediment traps and/or filter barriers as needed. Limit the size of the staging area to the minimum amount needed to construct the crossings. All construction equipment must be kept out of flowing stream channels except when absolutely necessary to construct crossings. Clean, washed gravel can be used in stream crossing construction activities to reduce solid suspension in adjacent surface waters.

8. Store hazardous materials, chemicals, fuels, and lubricating oils a minimum of 500 feet from stream banks, wetlands, or municipal watershed areas. Refuel equipment or vehicles no closer than 300 feet from a stream bank or wetland. Monitor onsite vehicles and equipment for leaks, and conduct regular preventative maintenance to reduce the chance of petroleum leaks. Develop a spill prevention plan to address containment and cleanup of spills affecting surface waters.

9. Remove trench topsoil from the streambed for segregated stockpiling in adjacent upland areas. When possible, place trench spoil at least 10 feet away from stream banks at all stream crossings. When this cannot be accomplished, locate the spoil pile in the stream in such a manner as to prevent undue flow restrictions. Prevent the flow of spoil off the construction ROW. Set aside streamside woody shrubs with attached root wads during construction for reestablishment along stream banks following construction.

10. Backfill the transmission line in such a manner as to prevent additional disturbance of previously undisturbed soil in streambeds or wetland areas.

11. Salvage wetland topsoil containing wetland plant parts and seeds to an approximate depth of 12 inches and stockpile adjacent to the trench. Stockpile excavated subsoil separately from the salvaged topsoil.

12. Restore streambeds, banks, and wetlands as near to pre-construction contours as possible and reseed. Place boulders in original locations and set to the original soil line. Facilitate channel recovery by retaining and re-establishing woody shrubs after construction is complete. If existing shrubs cannot be salvaged, obtain native shrubs from nearby nurseries and plant if required by permits or the restoration techniques specific to the project. Ground matting (excelsior blankets) can be installed on slopes of stream banks to accelerate vegetation stabilization.

13. Backfill the trench with previously excavated subsoils and place the salvaged topsoil on top of the trench and disturbed areas within the construction zone.

14. Allow no vehicle traffic on the ROW except as needed to maintain the ROW, and for transmission line maintenance and repair except in cases where the access road is jointly used by underlying landowners or others.

15. Pre-approve the use of water for construction activities such as dust suppression.

16. Apply herbicides for weed control and other vegetation management activities following the established tenets of Integrated Vegetation Management according to the label instructions and by

qualified personnel under the supervision of a certified pesticide applicator. Orient spray units to avoid streams and drift to minimize chemical entry into streams. Use spray buffer strips along streams to reduce or eliminate the impacts of herbicide spraying on aquatic environments.

17. Avoid sedimentation loading downstream and impacts to fisheries at specific stream crossings by scheduling trenching operations to occur through streams during dry or low flow periods.

18. Support structures can be located, if feasible, to avoid active drainage channels, and to minimize the potential for damage by flash flooding. Diversion dikes or other structural enhancements are required to divert runoff around the base or leg(s) of structures if the location in an active channel cannot be avoided. In floodplains, appropriate design of support structure footing foundations, such as raised foundations and/or enclosing flood control dikes, will be used to prevent scour and/or inundation by a 100-year flood.

3.7 Cultural Resources

Constructing, operating, and maintaining a 500-kV transmission line without disrupting, changing or destroying cultural resources can be a challenge, although some areas are more sensitive than others due to the type of resource. Unknown and undocumented cultural resources are particularly susceptible to negative impacts from construction, operation, and maintenance of a 500-kV transmission line. Impacts to cultural resources from construction, operation, and maintenance of an overhead and underground 500-kV transmission line can result in the following:

- Ground disturbance
- Visual and audible intrusions
- Vandalism
- Increased visitation

3.7.1 Ground Disturbance – Overhead and Underground Lines

Cultural resources are non-renewable resources. Any disturbance to the vertical and horizontal distribution of artifacts and other pertinent cultural material is permanent and irreparable. Even temporary or short-term activities associated with transmission line construction that can crush or destroy surface or subsurface artifacts, or evidence of past activities, can cause permanent damage to these vulnerable resources. Therefore, cultural resources are very sensitive to any construction activities that result in ground disturbance such as earthmoving for support structure foundations and substations, cut and fill for building the access road system, ROW preparation, or underground trenching activities.

Operation and maintenance activities, including vegetation management activities, can damage, destroy, alter eligibility to NRHP, or expose cultural or historical sites, and harm plants with traditional cultural value on sites of traditional cultural value. Heavy equipment or vehicles utilized for maintenance activities can also disturb surface artifacts as a result of soil and erosion impacts.

3.7.2 Visual and Audible Intrusions – Overhead Lines

While the extrinsic value of cultural resources is not affected by the visibility of a transmission structure, some cultural resources and Native American sacred sites may be very sensitive to such visual intrusions in the otherwise natural landscape. Overhead 500-kV transmission lines result in the creation of a ROW, with support structures and overhead conductors that are plainly visible, often for some distances. During the construction phase, this visual imposition can be even greater as the presence and movement of large-

scale machinery, equipment, and the number of vehicles can also contribute to adverse impacts on those cultural resources with a landscape component. Maintenance activities can also cause visual intrusions on cultural resources.

Audible intrusions may also negatively impact some cultural resources and Native American sacred sites where noises outside the "norm" for the area may disrupt activities such as ceremonies, rituals, or the experience of viewing or enjoying the resource. Audible intrusions may come from construction and maintenance machinery, equipment, and vehicles, and noise from corona discharge when the lines are wet if within a few yards of the ROW.

3.7.3 Visual and Audible Intrusions – Underground Lines

The visual quality of cultural resources may be disrupted by the underground ROW which must be kept clear of tall vegetation and structures and provide unlimited vehicle access. The presence and use of maintenance vehicles may also cause visual intrusions on cultural resources.

Audible intrusions may come from construction and maintenance machinery, equipment, and vehicles, but there would be no noise from the underground line itself.

3.7.4 Vandalism – Overhead and Underground Lines

Improved access to a previously remote area may result in increased levels of vandalism to cultural resources. Any increase in the presence of humans in an uncontrolled and unmonitored environment containing significant cultural resources increases the potential for adverse impacts caused by looting (unauthorized collection of artifacts), vandalism, and inadvertent destruction to unrecognized resources (DOE and DOI, 2007). Cultural resources that are visually obvious (e.g., rock art, standing buildings) or become known to many people (e.g., burial sites), or attractive to vandals (e.g., large prehistoric archaeological sites, 19th century trash dumps) are more sensitive than smaller, less visible or well-known resources.

3.7.5 Increased Visitation – Overhead and Underground Lines

Improved access to cultural resources or increased awareness of their presence due to construction of the transmission line may lead to increased visitation. Increased visitation may lead to unintended damage to cultural resources from trampling due to foot or vehicle traffic, damage from touching the resources, or other visitor activities. Increased visitation may also lead to a greater appreciation, knowledge, and support of cultural resources values.

3.7.6 Cultural Resources Mitigation Techniques

The following mitigation techniques can be used to minimize impacts on cultural resources during construction, operation, and maintenance of an overhead or underground transmission line. For vegetation management mitigation techniques see section 3.10.

1. Protection of Historic Properties (36 CFR 800) should be consulted as it describes the steps for identification for historic properties and the mitigation process should any be identified.

2. Prior to transmission line construction and any other surface disturbing activities conduct an inventory of cultural resources within the project area. The nature and extent of this inventory is based upon project engineering details and construction specifications such as types of structures and ROW widths. All cultural resource work must be carried out by qualified professionals. As

part of the inventory, field surveys must be conducted within the ROW to identify cultural resources that can be affected by support structure construction, access road installation, and all other sites affected by transmission line construction and operation. Field surveys need also be conducted along newly proposed access roads, new staging yards, and any other projected impact areas outside of the ROW.

3. Upon completion of the inventory, a treatment plan to mitigate identified impacts on cultural resources must be prepared. Avoidance, recordation, and data recovery can be used as mitigation alternatives. Mitigation may require the relocation of the line, support structure site placement, access road routes, movement of other ancillary or temporary facilities or work areas, where relocation can avoid or reduce damage to cultural resource values. When necessary to relocate the line and any other components of the transmission facility as a method of mitigation, it is recommended that the proposed new locations be inventoried for cultural resources and provide inventory results prior to construction. Any mitigation deemed necessary can be completed prior to undertaking any surface disturbing activities (for the federal government, necessary mitigation must be completed prior to undertaking any surface disturbing activities). If avoidance of specific cultural resources is not feasible, additional treatments must be carried out in consultation with experts in cultural resources.

4. Restrict all construction vehicle movement outside the ROW to pre-designated access, contractor-acquired access, or public roads.

5. Prior to construction, instruct all supervisory construction personnel on the protection of cultural resources. The construction contract can address:

    a. Federal, state and tribal laws regarding antiquities and fossils, including collection and removal.
    b. The importance of cultural resources and the purpose and necessity of protecting them.
    c. Methods for protecting sensitive cultural resources.

6. In the event that potentially historic or cultural resources are discovered during construction, halt all work within 300 feet of the find. Immediately implement the following measures:

    a. Erect flagging to prohibit potentially destructive activities from occurring in a given area.
    b. Utilize an archeologist to make a preliminary assessment of the newly discovered resource.
    c. Notify the appropriate landowner, agencies, and State Historic Preservation Office (SHPO) if the archeologist determines that the discovery represents a potential new site or an undocumented feature of a documented site.
    d. Do not resume construction in the identified area until cleared by the archeologist (all land) and the agencies' authorized officer.

7. Applicable to federal and Indian lands: Pursuant to 43 CFR 10.4(g), the permit holder must notify the authorized officer by telephone (along with written confirmation) immediately upon the discovery of human remains, funerary items, or sacred objects of cultural patrimony. Further, pursuant to 43 CFR 10.4(c) and (d), activities must stop in the vicinity of the discovery and it must be protected for 30 days or until the authorized officer notifies with approval to proceed.

8. Specific agencies may require a cultural resource monitor to be present during construction in areas the agency determines to be culturally sensitive.

3.8 Visual Resources

3.8.1 Visual Resource – Overhead Lines

Constructing, operating, and maintaining a 500-kV transmission line without disrupting, changing or destroying visual resources can be a challenge, although some areas are more sensitive than others due to the type of resource. Highly scenic and/or sensitive areas are particularly susceptible to negative impacts from construction, operation, and maintenance of a 500-kV transmission line.

Direct, long-term impacts are expected in areas where overhead 500-kV transmission lines cross areas of outstanding scenic quality or visual appeal; where lines are in the vicinity of cities, towns, communities, and other population concentrations; and where ROW are near or cross sensitive recreation and transportation viewpoints. Hence a visual environmental impact assessment is a combination of the areas scenic quality coupled with viewer sensitivity (value of the visual landscape to the viewing public). Visual impacts associated with the construction, operation, and maintenance of an overhead 500-kV transmission line could include potential impacts to:

- Views from residents and communities – rural residences and communities dispersed throughout the study area.
- Views from parks, recreation and preservation areas – potential views from existing and proposed facilities and other developed sites including national monuments, state parks, national natural landmarks, proposed wilderness areas, and other public and private recreation areas.
- Views from sensitive transportation corridors – backcountry byways, scenic byways, and other sensitive travel routes.
- Views from sensitive cultural sites – National Historic Landmarks and other National Register sites or districts or historic property potentially eligible to NRHP or TCPs.
- Visual resource management – compatibility with BLM and USFS visual management designations.
- Scenic quality – impacts affecting the inherent aesthetic value of the landscape.

Visual impacts would result from the visibility of the line from sensitive viewpoints and from the contrast of the line with the inherent aesthetic value of the landscape. Potential impacts to views are greatest when there are high sensitivity levels coupled with close views and highly contrasting project elements.

Visual impacts resulting from construction, operation, and maintenance of an overhead 500-kV transmission line can be both short and long term. Short-term visual impacts can result from views of construction activities including the presence and storage of materials, construction workers, equipment, and landform contrasts as a result of any ROW vegetation clearing, as well as from access road grading and foundation excavation. Long-term impacts can result from permanent visual contrasts of the structures and conductors in the ROW, landform contrast, and vegetation contrast.

Structure contrast examines the compatibility of transmission facilities with the existing landscape. The long-term impact of structure contrast would be greatest where there are no other structures (e.g. buildings, existing utilities) in the landscape. One method for determining structure contrast is the presence or absence of existing parallel transmission lines. For example, a new 500-kV steel lattice tower located next to an existing 500-kV steel lattice tower would create a weak contrast, or little structure change to the existing landscape, whereas a new 500-kV steel lattice tower located next to an existing 161-kV wood H-frame structure and transmission line would create a moderate contrast, because the 500-kV line and structure are larger and bulkier than the 161-kV line and structure. The difference in

structure contrast level is due to both the difference in heights and the substantial difference in appearance between the structures.

The long-term impact of landform contrast is created by alteration of landform patterns, exposure of soil, erosion scars, slumping, and other disturbances due to the project that are uncharacteristic of the natural landscape. Landform contrast is largely determined by the degree and duration of ground disturbance due to access roads and construction. Measures of landform contrast include: 1) Access/ground disturbance level (extent of new road construction or improvements to existing roads); and 2) Soil contrast (based upon soil erosion potential).

Levels of access/ground disturbance could be defined as follows:

- Level 1 – Use existing improved roads. Area previously disturbed. Roads generally are in good condition but may require small improvements at stream crossings, steep slope area, and other locations. New ground disturbance would be minimal.
- Level 2 – Use roads that require improvement. Area previously disturbed. Existing two-track or narrow unimproved roads would require improvement to make roads serviceable (e.g. mowing, grading) for construction. Low ground disturbance.
- Level 3 – Construct road in flat terrain (0 to 8 percent). Low to moderate ground disturbance for new access road construction.
- Level 4 – Construct road in sloping terrain (8 to 15 percent). Moderate ground disturbance for new access road construction.
- Level 5 – Construct road in steep terrain (15 to 30 percent). Moderate to high ground disturbance for new access road construction.
- Level 6 – Construct road in very steep terrain (over 30 percent). High to very high ground disturbance for new access road construction.

The level of access/ground disturbance in combination with the soil contrast results in the total landform contrast. The following table is an example of this combination, which can be used to determine the level of landform contrast for a project.

TABLE 1 LANDFORM CONTRAST MATRIX

SOIL CONTRAST	6	5	4	3	2	1
High Erosion Potential	S	S	S	M	W	W
Moderate Erosion Potential	S	S	M	W	W	W
Low Erosion Potential	M	M	W	W	W	W

S = Strong Contrast; M = Moderate Contrast; W = Weak Contrast

The third long-term impact which can result from permanent visual contrast is vegetation contrast. The presence of the overhead transmission line requires a permanent ROW, which includes clearing of all trees and tall shrubs, if present. This condition must be maintained to allow access and maintenance of the line. Vegetation contrast is determined by the diversity and complexity of vegetation types and patterns. Diversity is a major criterion in determining the inherent capability of the landscape to absorb visual changes. The vegetation contrast in relation to vegetation types and patterns is discussed in the following paragraphs.

Changes to overstory vegetation types (coniferous and deciduous trees) would result in a strong contrast rating, particularly with linear transmission lines that require trees to be removed from the entire width of

the transmission line corridor for fire safety or other conditions. The result would be an exposed and unnatural corridor clearing in the canopy layer.

Changes to shrub vegetation types would result in a strong to weak contrast rating. Shrubs removed during initial construction of a transmission line corridor will be allowed to grow back into the ROW and around the tower footings, and may fill in to their original density except along maintenance roads.

Changes to grassland and agriculture vegetation types would result in a broad range of contrast levels due to differences in potential vegetation recoverability and compatibility with the transmission line. Grasses tend to be shorter and less dense in content. Additionally, many grass types have light brown, tan, or gray colors that blend effectively with the soils from which the grasses are growing. While a road through grasslands would be visually obvious initially, grasses on either side of the road cut have the potential to blend with exposed soils. Grasses are also most easily reseeded and will typically grow back into the disturbed ROW more quickly. Impacts to grass vegetation tend to be short-term and less visually dominant.

Changes to sparsely vegetated types would result in moderate to weak contrasts. Low density of vegetation and exposed soils would allow a road cut to be less obvious and blend into the surroundings. However, vegetation may be slow to grow back in disturbed areas.

Bare lands and many urban areas lack natural vegetation and would therefore result in weak vegetation contrasts.

High voltage electric transmission structures (lattice towers or poles), where visible, can potentially create negative visual impacts in almost all landscapes. The support structures and conductors, as well as the insulators, can collectively create substantial visual impacts. A transmission line's visual presence can last from the time it is built throughout the duration of the line usefulness.

Support structures for the 500-kV lines would be a steel lattice tower, or, in some cases, a single steel pole. These structures can be as tall as 200 feet with crossarms as much as 100 feet wide, although typically crossarms are much shorter. Taller structures are generally needed for special situations (e.g., spanning valley or river crossings). Lattice towers have an open framework, but are overall much wider than poles visually. Poles present a single (or sometimes double, i.e., two poles are required), but more dense upright structure, but overall their width is much smaller than that of a lattice tower. Special steel lattice angle or turning towers may be used to bear the extra weight and tension of conductors where a turn occurs in the line. Such angle towers utilize stronger, thicker, steel poles than are used for typical tangent steel lattice towers, and are more substantial than typical towers. Dead-end structures are likewise heavier and similar in appearance due to their need to withstand a collapse of all structures on one side

Under certain conditions, lattice towers tend to blend better than steel poles into the background when viewed from a distance against mountains or vegetation. With their slender beams and open structure, they allow the forms, lines, colors, and textures of the background landscape to show through. Steel poles may create less contrast with the natural environment in foreground views when seen against the sky (i.e., skylined) compared to the "industrial" structural look of lattice towers, which can be visually overbearing at short distances (DOE and DOI, 2007).

Given the relative openness of some nearly treeless landscapes, the viewshed may be quite extensive and the availability of viewing opportunities from travel routes, recreational use areas, and nearby residential and commercial areas can be very high. In such open landscapes and under favorable viewing conditions, support structures and conductors might be visible for many miles, especially if skylined. In areas that

are heavily forested with evergreens and deciduous species, such long views might be restricted and the views of the line may be much more limited in distance. However, in areas of predominately deciduous trees, the viewing analysis conducted to determine the visual impact of the transmission facility must be conducted at a time of year when no leaves are present on the trees to get a more accurate portrayal of the line's visibility.

Tower structures, insulators, and particularly conductors are sometimes subject to specular reflection. That is, at times they may be capable of reflecting light like a mirror. These "mirror images" of light can cause bright reflections of sunlight to appear under certain optical conditions when the sun directly illuminates the reflective surface. These bright reflections can extend the visibility of transmission facilities for several miles.

Indirect, long-term impacts to visual resources from construction, operation, and maintenance of an overhead 500-kV transmission line may include reduced property values or loss or change in property development or land use potential and/or existing uses. While there are no studies indicating that transmission lines reduce property values due to the visibility of the line, in highly scenic and/or sensitive areas, this may occur. Development, land use and potential use may change due to visibility of the large 500-kV line and the associated ROW.

Vegetation management activities can change the visual quality of the landscape and local viewsheds impacted by transmission line ROWs. The following factors influence the impact of vegetation control activities on visual resources:

- Land use (agriculture, forest, rural, urban, transportation)
- Landscape setting and color (desert, mountainous, wetland, grassland, forest)
- Season
- Vegetation cover

Removing tall-growing vegetation can create a sudden, but temporary impact on local visual resources. Long-term visual impacts can result when the removed vegetation acts as a screen for unsightly views. For example, removing a row of trees along the ROW may reveal an open-pit mine and tailings pond otherwise hidden when recreationists use the area.

Herbicide treatment can temporarily affect visual quality by turning the treated vegetation brown. The brown vegetation can be left standing, making the effect more noticeable, but the effect usually lasts less than one year. Mechanical or manual cutting can create brown, dead vegetation as well, but it is typically not left standing after treatment and may be less visible.

3.8.2 Visual Resources – Underground Lines

Direct, long-term impacts are expected in areas where ROW corridors cross areas of outstanding scenic quality or visual integrity; where ROW corridors are in the vicinity of cities, towns, communities, and other population concentrations; and where ROW corridors are near or cross sensitive recreation and transportation viewpoints. Visual impacts associated with the construction of an underground 500-kV project include potential impacts to the same views as described under the visual resource – overhead section above.

Visual impacts resulting from construction of an underground 500-kV transmission line can be both short and long term. Short-term visual impacts can result from views of construction activities including the presence and storage of materials, construction workers, equipment, and landform contrasts from grading

and trench excavation. These short-term visual impacts include the ROW, access roads, and staging areas.

Long-term impacts result from permanent visual contrasts of the ROW corridor. The presence of the underground transmission line requires a permanent ROW, which includes clearing of all trees and tall shrubs, if present. This condition must be maintained for the life of the project to allow access and maintenance of the line.

Underground transmission lines placed in existing developed corridors (e.g., road, utility) are not likely to detract from the existing view area. For example, a ROW through a forest has noticeable differences in vegetation for the first few years. With each successive year, however, the contrast is weaker, and within a few years is not noticeable to the casual viewer. There can be impacts due to loss of roadside vegetation, potentially including notable old trees. Vegetation loss impacts are greatest along more rural or residential streets than roadways in commercial areas.

The most recurring benefit regarding underground 500-kV transmission lines is the aesthetic appeal to a vista without the interruption of utility lines. One aspect of aesthetics that is often overlooked is the overall impact it has on the quality of life. It is often the quality of places where people seek to relax, recharge and revitalize their lives. The state of Hawaii recognizes this by requiring an evaluation on the proximity and visibility of above ground high-voltage transmission systems to high density population areas, conservation and other valuable natural resource areas, public recreation areas, areas of special importance to the tourist industry, and other industries particularly dependent on Hawaii's natural beauty (Martin, 1999).

The environmental impacts to visual resources as a result of trenchless methods would be minimal due to the lack of surface ground disturbance from the trenchless method. Visual resources impacts would result from the installation and required permanent access to the entry and exit pits as all vegetation would be removed from these sites. A frac-out event may also produce visual resource impacts especially if it occurs within a sensitive viewshed as the displaced soil could be very visually intrusive in the landscape.

3.8.3 Visual Resources Mitigation Techniques

The following mitigation techniques can be used to minimize impacts on visual resources during construction, operation, and maintenance of an overhead and/or underground transmission lines. For vegetation management mitigation techniques see section 3.10.

1. When building a new line next to an existing one, match existing and new line support structure types, spacings, heights, and conductor heights to the extent practical.

2. Use non-specular conductors to reduce glare and visual contrast.

3. When crossing highways, rivers and trails, place support structures at the maximum feasible distance from these features to reduce the visual impact. The ROW should also cross these linear features at right angles whenever possible to minimize the viewing area and duration.

4. Place support structures to avoid features and/or to allow conductors to clearly span the feature (within limits of standard tower design) to minimize the amount of sensitive feature disturbed and/or reduce visual contrast (e.g., avoiding skyline situations through placement of tower to one side of a ridge or adjusting tower location to avoid highly visible locations and utilize screening of nearby landforms) (California Public Utilities Commission and DOI, 2006).

5. In deserts and semiarid land areas where views of land scars from sensitive public viewing locations are unavoidable, disturbed soils can be treated with Eonite or something similar to reduce the visual contrast created by the lighter-colored disturbed soils and the darker vegetated surroundings.

6. In forested locales, leave as much vegetation as possible along roads, providing roadside screens and reducing impacts to views down the ROW.

7. In forested environments, lower support structure height to the surrounding vegetation canopy heights.

8. To reduce visual contrast in areas where forested vegetation is removed for access, tower pads or conductor clearance, the clearing edges will be feathered to give a natural appearance.

9. In general, site the new ROW to take advantage of both topography and vegetation as screening devices to restrict views of transmission facilities from visually sensitive areas.

10. Where screening topography and vegetation are absent, use natural-looking earthwork berms and vegetative or architectural screening to minimize visual impacts. Where possible, vegetative screening can be particularly effective along roadways (DOE and DOI, 2007).

11. Use appropriate colored structures, with coatings or paints having little or no reflectivity where possible.

12. Poles may reduce visual impact more effectively than lattice towers in the near view areas, whereas lattice towers may be more visually suitable for more distant.

13. Reduce visual contrast and siltation in construction areas (e.g., marshalling yards, structure sites, or spur roads from existing access roads) where ground disturbance is substantial, by re-contouring and restoring the site. Re-contour the land to the original contours as much as possible. Method of restoration normally consist of loosening the soil surface, reseeding, installing cross drains for erosion control, placing water bars in the road, and filling ditches.

14. In construction areas where re-contouring is not required, vegetation will be left in place wherever possible and original contour will be maintained to avoid excessive root damage and allow for re-sprouting. Disturbance would be limited to overland driving where feasible to minimize changes in the original contours.

15. Restrict all vehicle movement outside the ROW to pre-designated access, contractor-acquired access or public roads where possible.

16. No paint or permanent discoloring agents would be applied to rocks or vegetation to indicate limits of survey or construction activity.

17. To minimize ground disturbance and/or reduce scarring (visual contrast) of the landscape, the alignment of any new access roads or cross-country routes will follow the landform contours in designated areas where practicable, providing that such alignment does not impact resource values additionally.

3.9 Public Health and Safety

3.9.1 Electric and Magnetic Fields (EMF) – Overhead and Underground Lines

An EMF exists wherever electricity is produced or used. EMFs are invisible lines of force that surround any electrical appliance or wire that is conducting electricity. Electric fields are created by voltage; the higher the voltage, the stronger the field. The farther away from the source of the electric field, the weaker it becomes. These fields are easily blocked by walls, trees, and even clothes and skin. Electric fields are measured in kilovolts/meter (kV/m). Magnetic fields only exist when an appliance or transmission line is turned on; the higher the current, the greater the magnetic field. As with electric fields, the strength of the magnetic field dissipates dramatically the further away from the source. However, unlike electric fields that are easily blocked, magnetic fields can pass through walls, clothes, and other barriers. Magnetic fields are measured in milliGauss (mG).

All transmission lines produce EMFs. The fields are the strongest directly under the lines and drop dramatically with distance to the sides of the line. Electric fields from power lines are relatively stable because the voltage does not change. Magnetic fields fluctuate as current changes in response to increasing and decreasing loads.

Undergrounding can eliminate electric fields, but since magnetic fields are hard to block, burying power lines won't keep the magnetic fields from passing through the ground. Additionally, underground lines can produce higher levels of magnetic fields directly above them at ground level because these lines are located closer to the ground surface than overhead lines. The strength of the magnetic field from underground lines falls away more quickly than from overhead lines.

EMF has been studied for more than 30 years by government and scientific institutions all over the world. In 1992, The U.S. Congress directed the National Institute of Environmental Health Sciences to direct the EMF Research and Public Information Dissemination Program. The goal of this program was to provide evidence to clarify potential health risks from EMF exposure. To date, the evidence suggesting that EMF exposures cause health risks is weak.

There are no standards established for safe levels of exposure to EMF. Some organizations have set advisory limits as a precautionary measure. The International Commission on Non-Ionizing Radiation Protection has established a continuous magnetic field exposure limit of 833 mG and a continuous electric field exposure limit of 4.2 kV/m for the general public. The American Council of Governmental Industrial Hygienists has set a Threshold Limit Value for occupational exposure to magnetic and electric fields at 60 Hz (60 cycles per second). Electricity in North America produces EMF at 60 Hz. The Threshold Limit Value for magnetic fields at 60 Hz is 10,000 mG and 25,000 kV/m for electric fields.

3.10 Vegetation Management Mitigation Techniques

The following mitigation techniques can be used to minimize impacts on all of the above environmental resources for vegetation management activities conducted in the ROW for an overhead and underground 500-kV transmission line.

3.10.1 Manual and Mechanical

1. If soil disturbance from vegetation control activity is significant on slopes with potential erosion impacts, re-seed the area with desirable native vegetation or take other erosion control measures as necessary.

2. Leave debris from vegetation cutting, mowing, brush cutting, or weed eating on site, as appropriate, to provide wildlife habitat and nutrients to the ecosystem.

3. Avoid or minimize the amount of vegetation debris falling into or being left in any surface water sources.

4. Avoid using heavy ground-disturbing equipment to clear vegetation on surfaces with slopes greater than 20%.

5. Utilize heavy equipment or trucks only when the ground is sufficiently dry to avoid excessive rutting and potential erosion impacts.

6. Use the tilling technique only in highly disturbed soils.

7. Maintain all equipment, machinery, and vehicles in good working condition to avoid oil or fuel spills. Avoid repairing or washing equipment near surface water sources.

3.10.2 Chemical

1. Strive to select herbicides that are effective against the plant; not likely to drift, leach into groundwater, or wash into streams; are non-toxic to people and other organisms; that are not persistent in the environment; and which are easy to apply.

2. Consider the following site conditions before application: accessibility, proximity to open water, depth to groundwater, the presence of rare species and other sensitive plants or animals, and the site's sensitivity to trampling that can occur when the herbicide is being applied.

3. Orient spray units to avoid direct spray and indirect drift into surface water resources, unless using aquatic herbicides. Use spray buffer strips along surface water resources to reduce or eliminate the effects of herbicide spraying on aquatic environments.

4. Develop safety protocols for storing, mixing, transporting, handling spills, and disposing of unused herbicides and containers before obtaining herbicides.

5. Follow all federal, state, and local regulations regarding herbicide use. Read and follow product labels. It is a violation of federal law to use an herbicide in a manner inconsistent with its label.

6. Require herbicide applicators to have all certificates and licenses required by the state and/or county.

7. Follow all county and state rules and regulations regarding pesticide spills. Develop a spill response protocol. Contact the local fire department or county hazardous materials office for large spills (generally over 100 gallons).

8. When using herbicides, it is critical (and, in some cases, required by law) to keep records of all plants/areas treated, amounts and types of herbicide used, and dates of application. This information can be used to evaluate the project's success, improve methodology, identify mistakes, and protect the environment.

9. Mix a dye with the herbicide so applicators can see which plants are treated and whether the applicators inadvertently sprayed any herbicide on themselves or their equipment.

10. Apply the herbicide at the appropriate time of year for the herbicide's mode of action, the physiology of the target species, and the site conditions. Check the label or consult with the distributor for the best application time under the conditions at the site.

4.0 SUMMARY

Constructing and maintaining overhead and underground 500-kV transmission lines can result in both positive and negative environmental impacts. The particular site and situation will dictate the degree and number of both negative and positive impacts.

The primary negative impacts associated with land use for both overhead and underground transmission lines include:

- Temporary and permanent impacts associated with construction and maintenance activities such as dust, noise, traffic, and access issues;
- Potential temporary disruption of existing utility lines;
- A permanent change/loss in existing land use such as farming, timber production, recreation use, and buildings; and
- Temporary disruption of services such as emergency response, travel, and access.

Additional negative impacts on land use from underground 500-kV transmission lines include:

- The ROW may be incompatible with some uses such as farming, forestry, mines, gravel pits, etc.;
- Some uses may be permanently disrupted such as farming and forestry; and
- Future development or activities may be impaired.

The primary negative impacts on biological, geological, water, and cultural resources for both overhead and underground 500-kV transmission lines are a result of temporary and potentially permanent disruption or destruction of the existing resource, as well as changes that may take place to the resources over time due to the initial disruption and subsequent maintenance activities of the ROW (i.e. habitat fragmentation, habitat loss, introduction of native species, vegetation management, soil compaction, vandalism).

Additional negative impacts on biological, geological, water and cultural resources from underground 500-kV transmission lines include:

- Increased potential for invasive species to establish within the ROW;
- Increased potential for wildlife displacement due to disturbance from trenching activities;
- Lower vegetation diversity within the ROW;
- Increased potential for impacts from ground disturbance from trenching activities;
- Potential for impacts from increased soil temperatures; and
- Potential disruption and/or destruction from a frac-out event (trenchless techniques) or fluid leak.

The primary negative impacts on visual resources from overhead and underground 500-kV transmission lines include:

- Construction activities such as equipment stockpiling, presence of construction equipment and vehicles, and installation activities; and
- The presence and maintenance of the ROW.

The positive environmental impacts of an overhead versus an underground 500-kV transmission line include:

- Greater variety of compatible land uses within the ROW;
- Potentially greater variety of wildlife and vegetation species within the ROW;
- Lower potential for introduction of invasive species; and
- Reduced potential for disturbance to geological, soil, and water resources, and some cultural resources because of the ability to span sensitive features.

The positive environmental impacts of an underground versus an overhead 500-kV transmission line include:

- Lower impact to residential land uses;
- No avian interactions with the line; and
- The aesthetic appeal to a vista without the interruption of utility lines, benefiting visual resources and potentially cultural resources.

A positive environmental effect of both overhead and underground would be that construction and maintenance of the ROW may benefit certain plant and animal species.

In general, the negative environmental impacts of constructing and maintaining an underground transmission line outnumber the negative impacts of constructing and maintaining an overhead transmission line, even though the ROW width is narrower for underground transmission lines. There may be projects, particularly in urban settings, where the positive impacts outweigh the negative impacts of an underground versus an overhead transmission line. Each project must be evaluated based on the particular site, associated environmental resources, project goals, and desired outcome. Application of the described mitigation techniques may also eliminate or reduce the negative impacts to acceptable levels.

4.1 Relative Environmental Impact Severity of Overhead versus Underground 500-kV Transmission Lines

There is an extensive amount of information related to the environmental impacts of overhead and underground transmission line construction, operation, and maintenance. This section has two purposes: 1) to summarize a large volume of material and 2) to provide a concise comparison of potential environmental impacts associated with underground and overhead transmission lines. This section is to simply summarize the options against each other, rather than against existing conditions.

Many variables are not taken into consideration. For example, overhead structure selection (lattice tower versus single pole), and construction mitigation methods are not taken into consideration.

The following tables summarize the environmental impacts associated with overhead and underground transmission lines as described in earlier sections of this report. Potentially beneficial and detrimental environmental impacts are categorized and subjectively assigned descriptions (Similar, Higher, or Lower) comparing relative severity of the environmental impacts between overhead and underground 500-kV transmission line construction (Table 2) and maintenance activities (Table 3).

TABLE 2 CONSTRUCTION OF 500-KV TRANSMISSION LINES Categorization of Potential Environmental Issues that are similar, higher, or lower in impact between Overhead and Underground Transmission Construction.		
ENVIRONMENTAL ISSUES	UNDERGROUND NEGATIVE IMPACTS	OVERHEAD NEGATIVE IMPACTS
LAND USE		
Agriculture	Higher	Lower
Forest	Higher	Lower
Residential	Lower	Higher
Commercial	Similar	Similar
Parks, Recreation, Preserves	Higher	Lower
Public Facilities	Lower	Higher
Industrial	Higher	Lower
Transportation and Access	Similar	Similar
Biological Resources		
Disrupting Existing Vegetation	Higher	Lower
Changing Habitat / Vegetation Composition	Similar	Similar
Habitat / Species Fragmentation	Similar	Similar
Habitat Loss / Reduced Species Abundance	Similar	Similar
Disruption to Rare, Threatened, Endangered Species	Similar	Similar
Introduction of Invasive Species	Higher	Lower
Wildlife Displacement	Higher	Lower
Geological and Soil Resources	Higher	Lower
Water Resources		
Surface Flow and Flood Plains	Higher	Lower
Wetlands	Higher	Lower
Groundwater	Higher	Lower
Water Quality Degradation	Higher	Lower
Cultural Resources		
Ground	Higher	Lower
Visual	Lower	Higher
Vandalism	Similar	Similar
Visual Resources	Lower	Higher

TABLE 3 MAINTENANCE AND OPERATIONS OF 500-KV TRANSMISSION LINES Categorization of Potential Environmental Issues that are similar, higher, or lower in impact between Overhead and Underground Transmission Construction.		
ENVIRONMENTAL ISSUES	UNDERGROUND NEGATIVE IMPACTS	OVERHEAD NEGATIVE IMPACTS
Avian Interactions		
Collisions	Lower	Higher
Electrocutions	Lower	Higher
Habitat Enhancement	Higher	Lower
Soil Temperatures	Higher	Lower
Soil Contamination	Higher	Lower
Soil Compaction	Higher	Lower
Soil Erosion	Higher	Lower
Vegetation Maintenance Frequency / Intensity	Similar	Similar
Plant Community Diversity and Composition	Higher	Lower

5.0 REFERENCES

Albrecht S., R. Hinkle and E. Nathanson. 2000. Habitat fragmentation and biodiversity issues. Topical Report. Gas Research Institute. Des Plaines, IL: 2000. 00/00117.

Aldridge, C.L. and R.M. Brigham. 2002. Sage-Grouse Nesting and Brood Habitat in Southern Canada. Journal of Wildlife Management 66(2): 433-444.

Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: A review. Oikos. 71 (3): 355-366.

Ariaratnam, S.T., Lueke, J.S., Allouche, E.N. 1999. Utilization of trenchless construction methods by Canadian municipalities. J. of Const. Engineering and Mgmt. March/April 1999. pp. 76-86.

Avery, M.L., and R.C. Beason. 2000. Avian mortality at short (< 120 m) communication towers. Pilot Study Research Protocol to the Communication Tower Working Group. 7 pp (manuscript).

Avian Power Line Interaction Committee (APLIC). 2006. *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006*. Edison Electric Institute, APLIC, and the California Energy Commission. Washington, D.C. and Sacramento, CA.

Baker, W. L. and R. L. Knight. 2000. Roads and Forest Fragmentation in the Southern Rocky Mountains. In Forest Fragmentation in the Southern Rocky Mountains. R. L. Knight, F. W. Smith, S. W. Buskirk, W. H. Romme, and W. L. Baker (eds.) University Press of Colorado. Boulder, CO.

Bennett, A.F. 1991. Roads, Roadsides and Wildlife Conservation: a Review. In Nature Conservation 2: The Role of Corridors. D. A. Saunders and R. J. Hobbs (eds.) Surrey, Beatty and Sons. Victoria, Australia.

Boarman, W.I. 2003. Managing a subsidized predator population: reducing common raven predation on desert tortoises. Environmental Management. 32:205-217.

Bovey, R. W., C. Richardson, E. Burnett, M. G. Merkle, and R. E. Meyer. 1978. Loss of spray and pelleted picloram in surface runoff water. Journal Environmental Quality. 7(2): 178-180.

Bramble, W.C. and W.R. Byrnes. 1983. Thirty years of research on development of plant cover on an electric transmission right-of-way. Journal of Arboriculture 9: 67-74.

Bramble, W.C., W.R. Byrnes, and M.D. Schuler. 1986. Effects of special right-of-way maintenance on an avian population. Journal of Arboriculture 12(9): 219-226.

Bramble, W. C., W.R. Byrnes, and R.J. Hutnik. 1987. Management and Environmental Impacts of Electric Power Transmission Rights-of-Way. Environmental Consequences of Energy Production: Problems and Prospects. Majumdar, S. K., Brenner, F.J., and Miller, E.W. (eds.). The Pennsylvania Academy of Science.

Braun, C.E. 1998. Sage-Grouse Declines in Western North America: What Are the Problems? Proceedings of the Western Association of State Fish and Wildlife Agencies 78: 139-156.

Braun, C.E., O.O. Oedekoven, and C.L. Aldridge. 2002. Oil and Gas Development in Western North America: Effects on Sagebrush Steppe Avifauna with Particular Emphasis on Sage Grouse. Transactions North American Wildlife and Natural Resources Conference 67: 337–349.

Bridges, J.M., Barger, M., Chevance, N., Anderson, T., Holt, J., Jones, R., Nelson, E. 1997. Environmental impacts associated with routine transmission line maintenance. p. 19-23 *In* J. Williams, J. W. Goodrich-Mahoney, J. R. Wisniewski, J. Wisniewski (eds.) Proceedings of the 6th International Symposium on Environmental Concerns in Rights-of-Way Management, February 24-26, 1997, New Orleans, Louisiana.

Bureau of Land Management (BLM). 1986a. Manual H-8410-1 – Visual Resource Inventory. BLM. Internet Website: http://www.blm.gov/nstc/VRM/8410.html.

California Public Utilities Commission, U.S. Department of the Interior, Bureau of Land Management. 2006. Final Environmental Impact Report / Environmental Impact Statement Southern California Edison's Devers–Palo Verde 500 kV No. 2 Project (Application No. A.05-04-015). October 2006. Internet Website: http://www.cpuc.ca.gov/environment/info/aspen/dpv2/toc-feir.htm

Chung, T.H., Abraham, D.M., Gokhale, S.B. 2004. Decision Support System for Microtunneling Application. J. of Const Engineering and Mgmt. Nov/Dec 2004. 835-843.

Crawford, R.L. and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. Journal Field Ornithology 72(3): 380-388.

Crooks, Kevin R. 2002. Relative Sensitivities of Mammalian Carnivores to Habitat Fragmentation. Conservation Biology. 16(2): 488-502.

Dawson, B. L. 1991. South African Road Reserves: Valuable Conservation Areas? In Nature Conservation 2: The Role of Corridors. D. A. Saunders and R. J. Hobbs (eds.) Surrey Beatty & Sons. Chipping Norton, Australia.

Dumas, Brett C., Gary L. Holmstead, Marie J. J. Kerr, and Leslie B. Carpenter. Revised July 2003. Effects of Road and Transmission-Line Rights-of-Way on Botanical Resources. Idaho Power Company Technical Report Appendix E.3.3-4.

Electric Power Research Institute (EPRI). 1975. EPRI RP7826 Final Report. Study of Environmental Impact of Underground Electric Transmission Systems. May 1975.

_____. 1992. Underground Transmission Systems Reference Book, 1992 Edition.

_____. 2002. Wildlife and Integrated Vegetation Management on Electric Transmission Line Rights-of-Way. EPRI, Palo Alto, CA: 2002. 1005366.

_____. 2003. Landscape Fragmentation and Electric Transmission Corridor Siting and Management Technical Report. EPRI, Palo Alto, CA: 2003. 1005371.

Florida Electric Utilities. 2007. Undergrounding Assessment Phase 1 Final Report: Literature Review and Analysis of Electric Distribution Overhead to Underground Conversion. By InfraSource Technology. Raleigh, North Carolina.

Forman, R. T. T., D. S. Friedman, D. Fitzhenry, J. D. Martin, A. S. Chen, and L. E. Alexander. 1997. Ecological effects of roads: toward three summary indices and an overview for North America. *In* Habitat Fragmentation, Infrastructure and the Role of Ecological Engineering. K. Canters, A. Piepers, and D. Hendriks-Heersma (eds.) Proceedings of the International Conference. Ministry of Transport, Public Works and Water Management: 40-54. Maastricht – The Hague. Delft, the Netherlands. September 17-21.

Fort Pierce Utilities Authority. 2005. Draft report of qualitative advantages and disadvantages of converting overhead distribution facilities to underground facilities within the service territory of the Fort Pierce Utilities Authority. Hi-Line Engineering LLC. Fort Pierce, Florida.

French, S. G. Houston, C. Johnson, J. Glasgow. 2008. EPRI-GTC tailored collaboration project: a standardized methodology for siting overhead electric transmission lines. p. 221-235 *In* J.W. Goodrich-Mahoney, L. P. Abrahamson, J. L. Ballard and S. M. Tikalsky (eds.) Proceedings of the 8th International Symposium on Environmental Concerns in Rights-of-Way Management, September 12-16, 2004, Saratoga Springs, New York. Elsevier, Oxford, UK.

Geist, V.A. 1978. Behavior. Pages 283-296 in J.L. Schmidt and D.L. Gilbert, eds. Big Game of North America: Ecology and Management. Stackpole Books, Harrisburg, PA.

Global Invasive Species Team. 2005. The Nature Conservancy. http://tncweeds.ucdavis.edu.

Greathead, D.J. 1995. Benefits and risks of classical biocontrol. Pp 53-63 In H.M. Hokkanen and J.M. Lynch (eds.) Biological control: benefits and risks. Cambridge University Press, Cambridge, U.K.

Graul, W.D. 1980. Grassland Management and Bird Communities. In: Workshop proceedings, management of western forests and grasslands for nongame birds. M. DeGraff and N. G. Tilighman, compilers.U.S. Department of Agriculture, Forest Service General Technical Report INT-86, Ogden, Utah. Pp. 38-47.

Hayden-Wing Associates. 1991. Review and evaluation of the effects of Triton Oil and Gas Corporation's proposed coalbed methane field development on elk and other big game species. Unpublished report. Hayden-Wing Associates, Laramie, WY.

Helling, C. S., P. C. Kearney, and M. Alexander. 1971. Behavior of pesticides in soil. Adv. Agron. 23:147-240.

Integrated Vegetation Management on Gas Pipeline Rights-of-Way. 2002. Gas Research Institute, Des Plains, IL: 2002. GRI-01/0096.

Johnson, Bradley W. 2006. Out of Mind? A study on the Costs and Benefits of Undergrounding Overhead Power Lines. Edison Electric Institute. Washington, D. C.

Johnson, B. K., J. W. Kern, M. J. Wisdom, S. L. Findholt, and J. G. Kie. 2000. "Resource Selection and Spatial Partitioning of Mule Deer and Elk During Spring." Journal of Wildlife Management. Volume 64: 685-697. The Wildlife Society. Bethesda, MD.

Kiessling, R., P. Nefzger, J. F. Nolasco and U. Kaintzyk. 2003. Overhead Power Lines: Planning, Design, Construction. Springer. New York, NY.

Knight, R. L., F. W. Smith, S. W. Buskirk, W. H. Romme, and W. L. Baker (eds.). 2000. Forest Fragmentation in the Southern Rocky Mountains. University Press of Colorado. Boulder, CO.

Knock, S.T., D.S. Dobkin, J.T. Rotenberry, M.A. Schroeder, W.M.V. Haegen, and C. Van Riper III. 2003. Teetering on the Edge or Too Late? Conservation and Research Issues for Avifauna of Sagebrush Habitats. Condor 105: 611-634.

Kramer, S.R., McDonald, W.J., Thomson, J.C. 1992. An Introduction to Trenchless Technology. Van Nostrand Reinhold. New York, NY.

Lathrop, Earl W. and Edwin F. Archbold. 1980. Plant response to utility right-of-way construction in the Mojave Desert. Environmental Management Vol. 4(3): 215-226.

Liguori, S. and Burruss, J. 2008. PacifiCorp's bird management program: integrating reactive, proactive, and preventative measures to reduce avian mortality on power lines. p. 325–329 *In* J. W. Goodrich-Mahoney, D. F. Mutrie and C. A. Guild (eds.) Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-Way Management, September 9-13, 2000, Calgary, Alberta, Canada.

Lockwood, J.A. 1993. Environmental issues involved in biological control of rangeland grasshoppers (*Orthoptera: Acrididae*) with exotic agents. Environmental Entomology 22:503-518.

_____. 2000. Nontarget effects of biological control: what are we trying to miss? Pp. 15-30 *In* P.A. Follett and J.J. Duan (eds.) Nontarget Effects of Biological Control. Kluwer Academic Publishers. Boston, Massachusetts.

Luken, James O., Andrew C. Hinton, and Douglas G. Baker. 1991. Forest edges associated with power-line corridors and implications for corridor siting. Landscape and Urban Planning 20: 315-324.

Lyon, L.J. 1983. Road density models describing habitat effectiveness for elk. Journal of Forestry. Volume 81, Number 9.

Mader, H.J. 1984. Animal Isolation by Roads and Agricultural Fields. Biological Conservation. Volume 29.

Manville, A.M., II. 2001. Avian mortality at communication towers: steps to alleviate a growing problem. Pp. 75-86 in B.B. Levitt (editor). Cell towers B wireless convenience? or environmental hazard? Proceedings of the ACell Towers Forum,@ state of the science/state of the law, December 2, 2000, Litchfield, CT. New Century Publishing 2000, Markham, Ontario.

Marcot, B., M. J. Wisdom, H. W. Li, and G. C. Castillo. 1994. Managing for Featured, Threatened, Endangered, and Sensitive Species and Unique Habitats for Ecosystem Sustainability. General Technical Report PNW-GTR-329. USDA Forest Service, Pacific Northwest Research Station. Portland, OR.

Martin, Pamela. 1999. Undergrounding Public Utility Lines. Honolulu, HI: Legislative Reference Bureau.

McCall, P. J., S. A. Vrona, and S. S. Kelley. 1981. Fate of uniformly carbon-14 ring labeled 2,4,5-Trichlorophenoxyacetic acid and 2,4-Dichlorophenoxyacetic acid. J. Agric. Food Chem. 29:100-107.

McEvoy, P.B. and E.M. Coombs. 2000. Why things bite back: unintended consequences of biological weed control. Pp. 167-194 In P.A. Follett and J.J. Duan (eds.) Nontarget effects of biological control. Kluwer Academic Publishers. Boston, Massachusetts.

Miller, R. H. Best Management Practices – Integrated Vegetation Management. International Society of Arboriculture. 2007. Champaign, IL.

Murphy, M.L. and W.R. Meehan. 1991. Stream Ecosystems. American Fisheries Society Special Publication. 19:17-46.

Nesmith, J.C.B., J.P. Shatford, and D.E. Hibbs. 2008. Stable plant communities in the Pacific Northwest. p. 37-41 *In* J.W. Goodrich-Mahoney, L. P. Abrahamson, J. L. Ballard and S. M. Tikalsky (eds.) Proceedings of the 8th International Symposium on Environmental Concerns in Rights-of-Way Management, September12-16, 2004, Saratoga Springs, New York. Elsevier, Oxford, UK.

Nickerson, Norton H., Ross A. Dobberteen, and Nancy M. Jarman. 1989. Effects of Power-Line Construction on Wetland Vegetation in Massachusetts, USA. Environmental Management Vol. 13, No. 4, pp. 477-483.

North Carolina Natural Disaster Preparedness Task Force. 2003. The Feasibility of Placing Electric Distribution Facilities Underground. By the North Carolina Public Staff Utilities Commission. Raleigh, North Carolina.

Noss, R.F. and A.Y. Copperrider. 1994. Saving Nature's Legacy. Island Press. Washington, DC: Island Press.

Olson, B.E. 1999. Impacts of Noxious Weeds on Ecologic and Economic Systems, p. 4-18 *In* R.L. Sheley and J.K. Petroff (eds.) Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis, OR.

Parker, L. W., and K. G. Doxtader. 1983. Kinetics of the microbial degradation of 2, 4-D in soil: effects of temperature and moisture. J. Environ. Qual. 12(4):553-558.

Parker, P.L., King, T.F., Revised 1998. Guidelines for Evaluating and Documenting Traditional Cultural Properties, National Register Bulletin, National Register of Historic Places, National Park Service, U.S. Department of the Interior, Washington D.C.

Pemberton, R.W. 1985. Native weeds as candidates for biological control research. pp. 869-877. In E.S. Delfosse (ed.) Proceedings of the VI International Symposium on the Biological Control of Weeds. August 19-25, 1984, Vancouver, Canada. Agriculture Canada.

Peterson, A.M. 1993. The effects of electric transmission rights-of-way on trout in forested headwater streams in New York. P.315-318 *In* G. J. Doucet, C. Séguin and M Giguère (eds.) Proceedings of the 5th International Symposium on Environmental Concerns in Rights-of-Way Management, September 19-22, 1993, Montreal, Quebec, Canada.

Reed, R. A., J. Johnson-Barnard, and W. L. Baker. 1996. Contribution of Roads to Forest Fragmentation in the Rocky Mountains. Conservation Biology. Volume 10, Number 4.

Roig-Soles, J. and Navazo-Lopez, V. 1997. A five-year Spanish research project on bird electrocution and collision with electric lines. p. 317-325 *In* J.R. Williams, J. W. Goodrich-Mahoney, J. R. Wisniewski, and J. Wisniewski (eds.) Proceeding of the VI International Symposium on Environmental Concerns in Rights-of-Way Management, February 24-26, 1997, New Orleans, Louisiana, Elsevier Science Ltd, New York.

Rowland, M. M., M. J. Wisdom, B. K. Johnson and J. G. Kie. 2000. Elk Distribution and Modeling in Relation to Roads. Journal of Wildlife Management. Volume 64, Number 3.

Rudis, V.A. 1995. Regional Forest Fragmentation Effects on Bottomland Hardwood Community Types and Resource Values. Landscape Ecology. Volume 10, Number 5.

Segelbacher, G., J. Hoglund, and I. Storch. 2003. From connectivity to isolation: genetic consequences of population fragmentation in Capercaillie across Europe. Molecular Ecology. 12: 1773–1780.

Soulé, M.E., ed. 1986. Conservation Biology: The science of scarcity and diversity. Sunderland, MA: Sinauer Associates. Sunderland, MA.

Stahlecker, D.W. 1978. Effects of a new transmission line on wintering prairie raptors. Condor 80(4):444-446. Internet Website: http://elibrary.unm.edu/sora/Condor/files/issues/v080n04/p0444-p0446.pdf.

Steenhof, K., M. N. Kochert, and J. A. Roppe. 1993. Nesting by raptors and common ravens on electrical transmission line towers. Journal of Wildlife Management 57(2):271-281. Internet Website: http://www.energy.ca.gov/research/environmental/avian_bibliography/one_rec.php?InNum=3701.

Stylinski, Cathlyn D. and Edith B. Allen. 1999. Lack of native species recovery following severe exotic disturbance in southern Californian shrublands. Journal of Applied Ecology 36: 544-554.

Taylor, A. W., and D. E. Glotfelty. 1988. Evaporation from soils and crops. Chapter 4 in Environmental chemistry of herbicides, Vol I. R. Grover (ed.) CRC Press, Boca Raton, Fla.

Thibodeau, Francis R. and Norton H. Nickerson. 1986. Impact of power utility rights-of-way on wooded wetlands. Environmental Management. Vol. 10, No. 6, pp. 809-814.

Tilman, D., R. M. May, C.L. Lehman, and M. A. Nowak. 1994. Habitat destruction and the extinction debt. Nature. 371: 65–66.

U.S. Department of Energy and U.S. Department of the Interior, Bureau of Land Management. 2007. Programmatic Environmental Impact Statement, Designation of Energy Corridors on Federal Land in the 11 Western States (DOE/EIS-0386). Draft October 2007. Internet Website: http://corridoreis.anl.gov/eis/guide/index.cfm.

U.S. Forest Service (USFS). 1995. Agriculture Handbook Number 701 – Landscape Aesthetics, a Handbook for Scenery Management. USFS.

van der Zande, A. N., W. J. Ter Keurs, W. J. and van der Weijden. 1980. The Impact of Roads on the Densities of Four Bird Species in an Open Field Habitat: Evidence of a Long Distance Effect. Biological Conservation 18: 299-321.

Ware, G. W. 1991. Fundamentals of Pesticides: A Self-instruction Guide. Thomson Publications. Fresno, California. 307 pgs.

Waters, T. F. 1995. Sediment in Streams. American Fisheries Society Monograph 7. Bethesda, Maryland.

Watters, M.E., T.E. McLash, C.L. Aldridge, and R.M. Brigham. 2002. The effects of vegetation structure on predation of artificial Greater Sage Grouse nest predation. Ecoscience. 9:314-319.

Weller, C., J. Thomson, P. Morton, and G. Aplet. 2002. Fragmenting our lands: the ecological footprint from oil and gas development – a spatial analysis of a Wyoming gas field. The Wilderness Society. Washington, DC.

Willyard, Cassandra J., Susan M. Tikalsky, and Patricia A. Mullins. 2004. Ecological effects of fragmentation related to transmission line rights-of-way: a review of the state of the science. Wisconsin Focus on Energy Environmental Research Program.

Willyard, C. J. and S. M. Tikalsky. 2008. Research gaps regarding the ecological effects of fragmentation related to transmission –line rights-of-way. p. 521-527 *In* J.W. Goodrich-Mahoney, L. P. Abrahamson, J. L. Ballard and S. M. Tikalsky (eds.) Proceedings of the 8th

International Symposium of Environmental Concerns in Rights-of-Way Management, September 12-16, 2004, Saratoga Springs, New York. Elsevier, Oxford, UK.

Wisconsin Public Service Commission. 2004. Underground Electric Transmission Lines.

Wisdom, M. J., R. S. Holthausen, and B. K. Wales. 2000. Source Habitats for Terrestrial Vertebrates of Focus in the Interior Columbia Basin: Broad-Scale Trends and Management Implications. General Technical Report, PNW GTR-485. USDA Forest Service, Pacific Northwest Research Station. Portland, OR.

Working Group on Southwest Connecticut and the Task Force on Long Island Sound. 2003. Comprehensive Assessment and Report Part I. Energy Resources and Infrastructure of Southwest Connecticut. Institute for Sustainable Energy, Eastern Connecticut State University.

Yahner, Richard H., Russel J. Hutnik, Stephen A. Liscinsky. 2002. Bird populations associated with an electric transmission right-of-way. Journal of Arboriculture 28(3): 123-130.

Appendix B – Discussion of Available Underground Cable Systems

I. EXTRUDED DIELECTRIC CABLE SYSTEMS

HVED cable installations in the US are commonly in concrete encased duct banks because direct burial and tunnel installations have not proven reliable or economically feasible. Therefore, this report will look solely at HVED cable systems from a duct bank installation standpoint.

HVED cables have been used extensively in North America at voltages 138 kV and higher since the mid-1980s, and have seen extensive use overseas since the 1970's. XLPE-insulated cables have been used at 500 kV and higher throughout the world since the late 1990's. Two long, over 25 miles, 500kV installations have been in service in Japan since 2001. Installation of several major 345kV XLPE cable systems, totaling more than 100 circuit miles, have been installed in the US in the last 10 years.

A. Cable

The components of a typical dielectric cable are shown in Figure B1-1. The typical cable consists of a stranded copper or aluminum conductor, inner semi-conducting conductor shield, extruded solid dielectric insulation, outer semi-conducting shield, a metallic moisture barrier, and a protective jacket.

Insulation materials used for solid dielectric cables include:

- Thermoplastic Polyethylene Compounds

  Typical thermoplastic polyethylene insulation materials are low density polyethylene (LDPE), high molecular weight polyethylene (HMWPE) and high density polyethylene (HDPE).

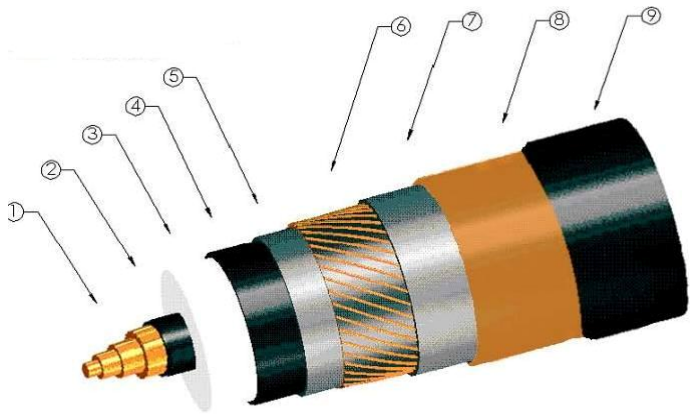
- Thermosetting Compounds

  Ethylene propylene rubber (EPR) and cross-linked polyethylene (XLPE) are typical thermosetting insulation compounds.

For voltages over 69 kV, the preferred insulation in the United States for a HVED cable system is XLPE. This is due to the higher dielectric losses associated with EPR-insulated cables.

Materials used for semi-conducting extruded conductor and insulation shields are semi-conducting PE, XLPE and EPR compounds. PE compounds are used with PE and XLPE insulation, XLPE compounds with XLPE insulation, and EPR compounds with EPR insulation.

Cable Jackets are typically extruded PE and on rare occasions polyvinyl chloride (PVC)



1 - CONDUCTOR
Material: copper

2 - INNER SEMI-CONDUCTIVE SHIELD

3 - EXTRUDED SOLID DIELECTRIC INSULATION
Material: cross-linked polyethylene

4 - OUTER SEMI-CONDUCTIVE SHIELD

5 - SEMI CONDUCTIVE SWELLING/BEDDING TAPES

6 - CONCENTRIC COPPER WIRE METALLIC SHIELD

7 - SEMI CONDUCTIVE SWELLING/BEDDING TAPES

8 - MOISTURE BARRIER/SHEATH
Material: copper, aluminum, lead, or stainless steel

9- PROTECTIVE JACKET
Material: medium density polyethylene

Figure B1-1 Typical Solid Dielectric Cable Cross-Section

The manufacturing process for extruded cables is of critical importance in ensuring a reliable end product. Triple extrusion is the preferred and recommended technique. Most transmission cable manufactures use this “true triple head” extrusion technique today. Microscopic voids and contaminants can lead to cable failures. As such, quality control during manufacture of extruded dielectric cables is critical to minimize moisture contamination, voids, contaminants and protrusions. Manufacturers minimize insulation contamination by using super clean insulation compounds; transporting and storing the compounds in sealed facilities; and screening out contaminants at the extruder head.

B. Cable Accessories

The three basic cable accessories for extruded dielectric cables are splices, terminations and sheath bonding materials.

Splices

Pre-fabricated or pre-molded splices are commonly used to joint extruded dielectric cables. Cable preparation for these types of splices is generally the same. Insulation and shields are removed from the conductor; and the insulation is penciled. The conductor ends are then joined by a compression splice or MIG welding (aluminum conductor only). An advantage of these types of splices is that all parts can be factory tested prior to field installation. Figure B1-2 shows a typical pre-molded splice.

Figure B1-2 Typical Pre-molded 345kV XLPE Splice

Terminations

Terminations are available for extruded dielectric cable to allow transitions to overhead lines or above ground equipment. Termination bodies are typically made of porcelain or polymer and include skirts to minimize the probability of external flashovers due to contamination. Figure B1-3 shows a typical XLPE termination.

Figure B1-3 Typical 345kV XLPE Termination

Sheath Bonding

Another important component of an HVED cable system is the grounding/bonding of the cable shield. A typical underground distribution system grounds the shield at each splice and termination point. However, bonding method, known as multi-point bonding, enables circulating currents to be developed on the cable shield resulting in additional heating in the cable and ultimately resulting in reduced power transfer. The way to maximize the ampacity of an underground cable is to eliminate the circulating currents. This is accomplished by using special bonding methods such as single-point and cross-bonding. These methods eliminate or reduce the amount of current, which would flow on the cable shield resulting in no or limited additional heating and therefore higher ampacity ratings.

II. SELF CONTAINED FLUID FILLED (SCFF) CABLE SYSTEM

A. Introduction

While AC SCFF cable has historically been used extensively outside of the United States, there are very few SCFF currently in operation in the US. As older SCFF lines are retired, they are being replaced with XLPE-insulated cables. SCFF cables have been manufactured for AC system voltages from 69 kV up to 525 kV, and tested up to 1100 kV. There is one relatively short 525-kV SCFF AC cable installation in the US, in Grand Coulee Dam.

B. Cable

A SCFF cable system consists of installing three individual single-core cables in a duct system or direct buried.

The SCFF cable consists of a hollow copper conductor which is filled with dielectric fluid typically pressurized to 3-60 psig, high quality Kraft paper or laminated paper polypropylene insulation, outer shielding, and a sheath which is covered by a plastic jacket. Cable jackets are typically extruded polyethylene (PE). The metallic sheath is typically aluminum or an extruded lead-alloy. In this construction the metallic sheath serves both as a hermetic moisture seal and as a pressure containment vessel. In the case of a lead sheath, bronze tapes are frequently required to strengthen the lead sheath and to keep it from deforming due to the cable pressure.

While cables with Kraft paper had a proven track record at voltages below 345kV, the industry identified in the mid 1980’s that in order to achieve higher voltages a new insulation was needed to reduce the dielectric losses of the insulation. In 1985, a new paper insulation, laminated paper polypropylene (LPP), was introduced to the paper cable industry for use on EHV cables. LPP insulation utilizes a composite construction involving a layer of low-loss, electrical-grade, homocast polypropylene film (unoriented), bonded without adhesive between two layers of high-purity Kraft electrical-insulating paper. This laminate tape looks and handles like a paper-insulating tape of equal thickness. The LPP composite is manufactured by laminating an extruded polypropylene film that is sandwiched, while hot, between two cellulose-paper layers. The three layers are bonded using two pressure rollers. No adhesive or copolymer materials are used in making the LPP laminate.

The major advantages of LPP over conventional paper in EHV cables are due to the polypropylene film and include the following:

- Lower dielectric loss
- Higher ac and impulse strength
- Thinner insulation walls
- Higher ampacity ratings

In a SCFF cable, the central duct is filled with dielectric fluid. This fluid is allowed to flow through the wires of the conductor into the insulation. The volumetric change in the fluid due to the heating effects of load currents is compensated by connecting the duct to fluid reservoirs or tanks at intervals along the route using special “stop” or feed joints or at the ends of the route. When the cable cools, the fluid is driven back into the cable by maintaining the reservoirs at a positive pressure at all temperatures. The pressure is kept as low as possible, consistent with the profile of the route, and the minimum pressure is typically 3 psig. A low-viscosity impregnant is chosen to ensure that the fluid may flow readily through the duct, especially during heating and cooling transients and thus maintain the internal pressure within the design range. As the fluid flows freely throughout the insulation, the cable has some self-healing properties, because there are no voids in the insulation or joints. Figure B1-4 shows a typical cross-section of a SCFF cable.

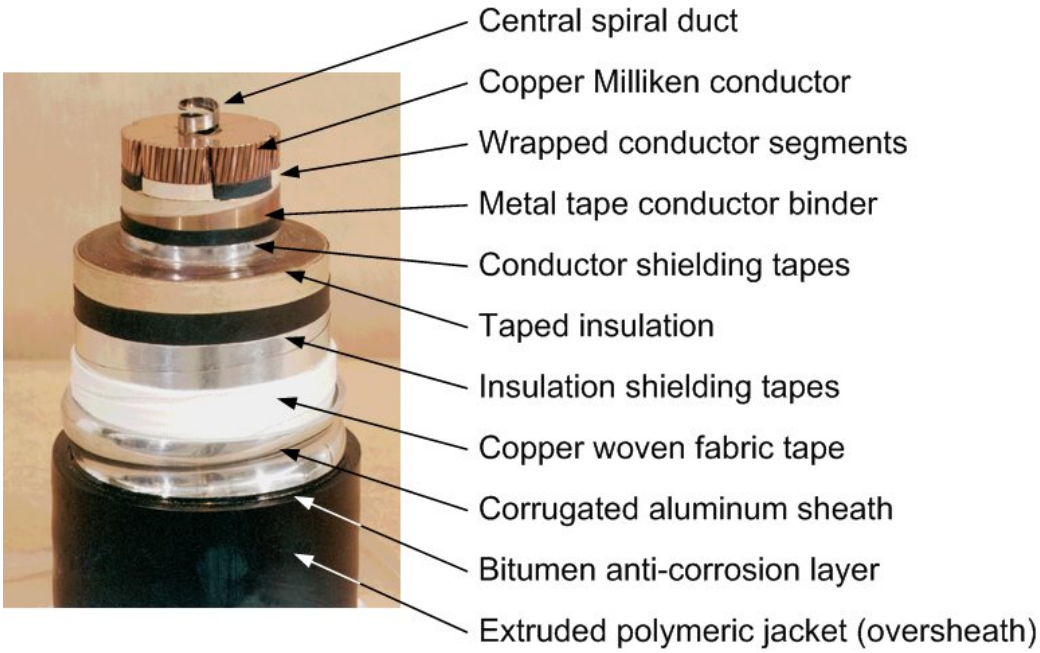


Figure B1-4 Typical SCFF Cable Cross-Section

The manufacturing process is as follows: a conductor core is helically wound with layers of metalized or carbon black paper tape for the conductor; high quality Kraft paper or paper/polypropylene laminate is then helically wound around the conductor in multiple layers for the insulation; additional layers of metalized or carbon black paper tape helically wound around the insulation to form the insulation shield. Prior to the installation of the sheath and jacket, the cable is dried and placed into impregnating tanks. After the cable is impregnated with the appropriate dielectric fluid, fabric tapes are wound around the core to provide a bedding layer to absorb any expansion and contraction of the cable core under the sheath. The outer sheath and jacket is then extruded on to the core.

As well as electrical performance, it is necessary for the cable to have a satisfactory mechanical performance. For large insulation thicknesses, it is usually necessary to have thicker paper tapes on the outside of the cable to achieve this. Thus the density of the papers may be varied in the wall of the insulation.

C. Cable Accessories

The three basic cable accessories for extruded dielectric cables are splices, terminations and sheath bonding materials.

Splicing of each SCFF cable begins with removal of the outer sheath and jacket and the insulation is step-penciled. The conductor ends are then joined by compression connector or MIG welding (aluminum conductor only). Insulation paper tape is wound around the spliced conductor, filling the step-penciled area of the insulation. Metalized tapes or carbon black tapes are used to re-establish the conductor and insulation shields. An outer joint casing is placed around the jointed cable to provide a continuation of the outer sheath and contain the fluid in the cable.

Terminations are available for SCFF cable to allow transitions to overhead lines or above ground equipment. Termination bodies are typically made of porcelain and include skirts to minimize the probability of external flashovers due to contamination.

Once the cable installation is completed the cable is filled with filtered synthetic dielectric fluid and pressurized to a nominal 2-60 psig depending on the cable system design. To maintain these pressures during the operation of the cable system, pressure reservoirs are placed at one end, at intermediate locations or at both ends depending on the cable system design. If significant elevation changes exist along the route, reservoirs may be required at these locations as well. If higher pressures are needed, a special pressurization plant is needed. Regardless of the type of pressurization system, a monitoring system is required at each pressurization point. The monitoring equipment controls the operation of the system and communicates the system status to the utility. This is the biggest disadvantage of the SCFF system.

Another important component of a SCFF cable system is the grounding/bonding of the cable shield. Unlike an underground distribution system, which grounds the shield at each splice and termination, an underground transmission line requires alternative grounding/bonding methods. Grounding at each splice and terminations causes circulating currents to be developed on the cable shield resulting in additional heating in the cable and lower ampacity. The way to maximize the ampacity of an underground cable is to eliminate the circulating currents. This is accomplished with underground transmission cables by using special bonding methods such as single-point and cross-bonding. These methods eliminate or reduce the amount of current, which would flow on the cable shield resulting in no or limited additional heating and ultimately a higher ampacity.

When connecting a SCFF cable system directly to an overhead line, a small fenced transition station consisting of an A-frame structure and termination stand. The pressure reservoirs would be mounted near each termination. A larger transition station would be required if a larger pressurization plant would be required.

III. GAS INSULATED TRANSMISSION LINE (GITL)

A. Introduction

Gas Insulated Transmission Lines (GITL) have been in commercial use in the US since the 1970's. These lines consist of an aluminum pipe containing a single-phase conductor with a pressurized, insulating gas. The technology is similar to gas insulated bus bars used to connect gas insulated switchgear (GIS). GITLs are well suited for high power applications and are most commonly used in tunnel, underground, and substation installations.

B. GITL Conductor

GITL systems are typically manufactured in pre-assembled 60 foot lengths of single core aluminum pipe. The aluminum pipe enclosure is similar to those used for bus conductors at substations. These sections are typically connected by automated welds, though they can be connected through flanges as an alternative. Above ground installations must take into account the thermal expansion and stress that the pipe will encounter through the installation of metallic bellows. The aluminum conductor and aluminum casing are both electrically and mechanically isolated through the use of epoxy insulators. The epoxy insulators are enclosed entirely within the casing, so they are immune to degradation from water, sunlight, or any other environmental factors. They are designed to have an approximate service life of 50 years. The aluminum conductor and enclosure will be exposed to different temperature changes based on peak load requirements and ambient temperatures, so the spacers mechanically isolate the two by being able to slide or roll along the interior of the enclosure pipe allowing the two to expand independently. Epoxy spacers are required approximately every 20 feet to properly support the conductor. Figure B1-5 shows a typical construction of GITL.

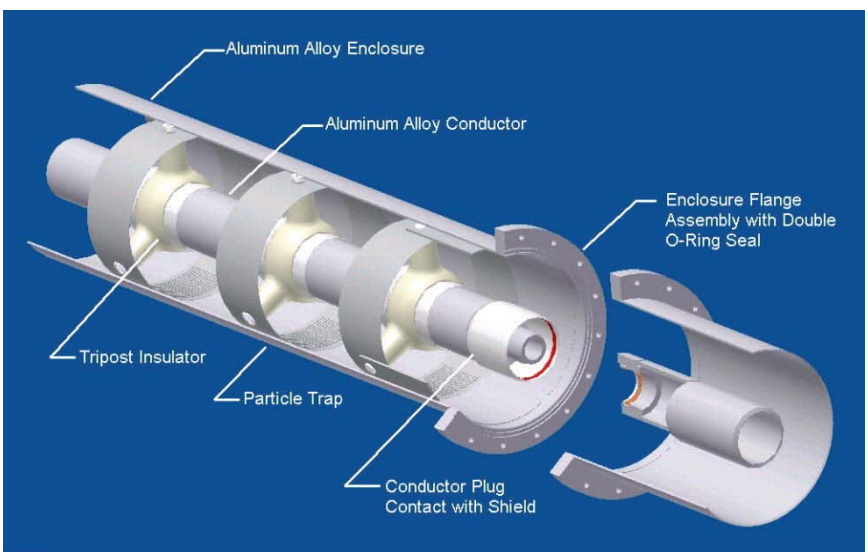


Figure B1-5 Typical GITL (Image Courtesy of AZZ)

Because the pipe is fairly rigid, direction changes with a radius of less than approximately 1300 feet must be made through prefabricated elbows designed to a specific angle; changes in direction that allow for a larger radius can be made by simply flexing the enclosure pipe during installation. Prefabricated elbows

are made in shorter sections, are designed for the specific route, and are not as easy to ship as the typical GITL sections, so they tend to increase the average per length cost of the overall installation.

The aluminum enclosure pipe effectively isolates the electrical system from external environmental factors. In above ground installations, no added corrosion protection is required; however the exterior of the pipe should be visually inspected annually to check for corrosion or damage. High-current circuits may require the use of specialized paint that reflects sunlight while still emits infrared radiation depending on the thermal environment of the installation. In underground and tunnel installations, cathodic protection systems should be used to mitigate any corrosive activity from deteriorating the system. In all applications, the enclosure pipe must be grounded at either end of the route and intermittently along an installation. This allows circulating currents to flow, which does cause heating and losses in the circuit. However, this is necessary for personnel safety and has the additional effect of reducing the external magnetic fields produced by the system to negligible levels.

GITL systems use SF_6 and N_2 gas for insulation, which is widely used in high-voltage substation equipment. SF_6 will break into its fundamental components and recombine when exposed to an electric discharge or arc with minimal contamination. Also, the insulating properties of SF_6 do not weaken over time, so it will outlast the insulation of a typical underground cable. However, SF_6 is a strong greenhouse gas that raises major environmental concerns. To help alleviate some concerns most GITL systems use a mixture of SF_6 and N_2 to reduce the overall amount of SF_6 in the system. The only maintenance required for the system is the use of a gas density monitor to ensure there are no leaks and trigger an alarm if there is a 5% drop relative to the original charge of gas.

A GITL installation is a specialized line that historically has not been used as a part of a standard transmission line system. The lines are normally installed in utility controlled environments and require specialized installation practices when compared to overhead and underground cable systems. The additional overall cost and increased exposure of a GITL system makes it a less desirable option for a standard transmission line installation.

IV. HIGH TEMPERATURE SUPERCONDUCTING (HTS)

A. Introduction

Research is currently underway in the advancement of high temperature superconductors (HTS). Utilizing a unique cable design where all three phases are centered concentrically on a single core, the cables are capable of displaying low electric losses with the same power transfer capabilities as compared with a standard non-superconducting cable. The core, filled with a cryogenic fluid, super cools the conducting material resulting in extremely low losses and high electrical power transfer capacities. Most HTS systems are located adjacent to large metro areas, where they are capable of transferring large quantities of power a few thousand feet, at the distribution level. However, technological advances in the last few years have seen the first 138 kV AC system installed in Long Island, New York in early 2008. Because HTS systems have not been established at the 500kV voltage levels, nor over long distances, superconducting cable would not be a technology option to consider for BPA'S Project. Figure B1-6 shows a typical superconductor cable design.

Figure B1-6 Typical Cable Design (Photo Courtesy of Southwire)

Appendix E

Visual Assessment

Visual Resource Report in Support of the I-5 Corridor Reinforcement Project Environmental Impact Statement

Prepared for:

Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208-3621

Prepared by:

Golder Associates Inc.

March 2012

Table of Contents

1.0 Introduction 1
1.1 Data Sources 1
1.2 Analytical Methods 1
1.2.1 Visual Resource Inventory 4
1.2.2 Visual Simulations 6
1.2.3 Visual Contrast Rating 7
1.3 Definition of the Study Area 8
2.0 Affected Environment 9
2.1 Willapa Hills 9
2.2 Cowlitz/Chehalis Foothills 9
2.3 Western Cascades Lowlands and Valleys 10
2.4 Valley Foothills 10
2.5 Portland/Vancouver Basin 11
2.6 Substations 11
2.6.1 Sundial Substation 11
2.6.2 Casey Road Substation 11
2.6.3 Baxter Road Substation 12
2.6.4 Monahan Creek Substation 12
2.7 West Alternative 12
2.7.1 Scenic Quality Ratings 13
2.7.2 Sensitivity Ratings and Overall Landscape Ratings 14
2.8 Central Alternative 15
2.8.1 Scenic Quality Ratings 16
2.8.2 Sensitivity Ratings and Overall Landscape Ratings 17
2.9 East Alternative 18
2.9.1 Scenic Quality Ratings 19
2.9.2 Sensitivity Ratings and Overall Landscape Ratings 20
2.10 Crossover Alternative 21
2.10.1 Scenic Quality Ratings 22
2.10.2 Sensitivity Ratings and Overall Landscape Ratings 23
3.0 Environmental Consequences 24
3.1 Visual Impact 24
3.1.1 Impact Levels 24
3.2 Impacts Common to Action Alternatives 25
3.3 Substations 25
3.3.1 Sundial Substation 25

3.3.2 Casey Road Substation 25
3.3.3 Baxter Road Substation 25
3.3.4 Monahan Creek Substation 25
3.4 West Alternative 26
3.4.1 West Option 1 37
3.4.2 West Option 2 39
3.4.3 West Option 3 43
3.5 Central Alternative 44
3.5.1 Central Option 1 47
3.5.2 Central Option 2 47
3.5.3 Central Option 3 48
3.6 East Alternative 51
3.6.1 East Option 1 54
3.6.2 East Option 2 55
3.6.3 East Option 3 55
3.7 Crossover Alternative 55
3.7.1 Crossover Option 1 57
3.7.2 Crossover Option 2 58
3.7.3 Crossover Option 3 58
3.8 No Action Alternative 59
4.0 Mitigation Measures 60
5.0 Unavoidable Impacts 61
6.0 Cumulative Effects of the Project 62
7.0 Federal, State, Local, and Permit Requirements Review 63
8.0 List of Preparers 64
9.0 References 65
10.0 Acronyms and Glossary 66

List of Tables

Table 1-1 Viewpoints
Table 1-2 Scenic Quality Evaluation Criteria Ranking
Table 1-3 Visual Resource Landscape Rating
Table 1-4 Degree of Contrast Criteria
Table 2-1 West Alternative Scenic Quality Ratings
Table 2-2 West Alternative Sensitivity and Overall Landscape Ratings
Table 2-3 Central Alternative Scenic Quality Ratings
Table 2-4 Central Alternative Sensitivity and Overall Landscape Ratings
Table 2-5 East Alternative Scenic Quality Ratings
Table 2-6 East Alternative Sensitivity and Overall Landscape Ratings
Table 2-7 Crossover Alternative Scenic Quality Ratings
Table 2-8 Crossover Alternative Sensitivity and Overall Landscape Ratings
Table 3-1 Visual Impact Rating
Table 3-2 West Alternative Contrast Ratings and Visual Impact
Table 3-3 Central Alternative Contrast Ratings and Visual Impact
Table 3-4 East Alternative Contrast Ratings and Visual Impact
Table 3-5 Crossover Alternative Contrast Ratings and Visual Impact

List of Figures

Figure 1-1 Viewpoint Locations
Figure 3-1 Viewpoint 25-1
Figure 3-2 Viewpoint 25-2
Figure 3-3 Viewpoint 25-3
Figure 3-4 Viewpoint 41-1
Figure 3-5 Viewpoint 50-1
Figure 3-6 Viewpoint 52-1
Figure 3-7 Viewpoint 40-1
Figure 3-8 Viewpoint 48-1
Figure 3-9 Viewpoint 51-1
Figure 3-10 Viewpoint M-1
Figure 3-11 Viewpoint K-1

1.0 Introduction

This resource report describes the existing conditions and potential impacts on visual resources from construction and operation of a proposed electrical transmission line route for the I-5 Corridor Reinforcement Project (project). The Bonneville Power Administration (BPA) proposes to construct a new 500-kV transmission line in a north/south alignment between a new substation near Castle Rock, Washington and a new substation near BPA's existing Troutdale Substation in Multnomah County, Oregon. The transmission line towers would carry conductors for the electricity, overhead ground wires for lightning protection, and fiber for communication needs. BPA would construct new and improved existing access roads to accommodate construction and maintenance of the new transmission line. The route alternatives consist of segments, some of which are sited parallel to existing transmission lines, either within or adjacent to the existing right-of-way, and some would be located in new right-of-way. The information provided in this report may be used in part to select a preferred route and to support a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS) for the project.

Four alternatives (West, Central, East, and Crossover) are described and evaluated. Each alternative is comprised of segments. Each alternative also includes options which consider one or more other segments in lieu of one or more of the alternative segments. Three alternative sites for the new north substation are under consideration near Castle Rock. These substations are each assigned to specific alternatives. One substation site is proposed at the south end of the project in Oregon.

Section 1 of this report identifies data sources, analytical methods, and defines the study area used in the evaluation. Section 2 provides an overview of the affected environment, including descriptions of the alternatives, their options, and potential substation sites. Section 3 describes the potential impacts of implementing the project. Impact levels are defined and impacts common to all alternatives are included. Section 4 presents mitigation measures to minimize impacts on visual quality. Unavoidable impacts that may remain after all mitigation measures have been implemented are included in Section 5. Cumulative impacts are discussed in Section 6 and include an evaluation of the project in conjunction with other future development. Section 7 provides a description of the review and permit requirements of applicable laws, regulations, and plans.

1.1 Data Sources

No previous investigations or studies are relevant to or were used for this study. Tower designs were selected from tower design data provided by BPA on February 10, 2011. Photos used for this effort were taken by Golder Associates Inc. (Golder).

1.2 Analytical Methods

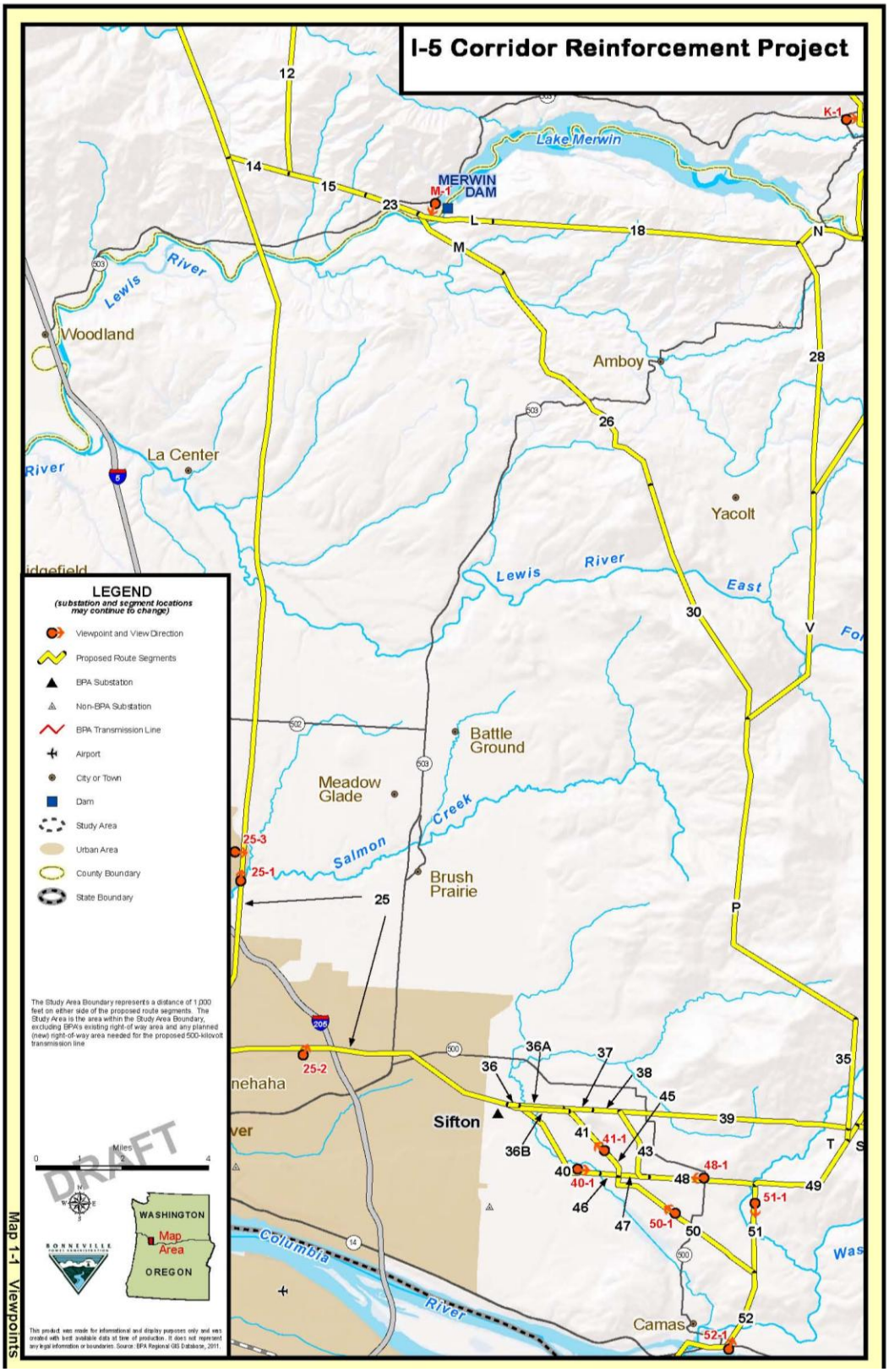
The method of assessment used for this analysis is based on the Bureau of Land Management's (BLM) Visual Resource Management (VRM) system. This method is effective for a variety of different development types, including transmission line projects. Other methods such as those designed specifically for forestry are effective for categorizing the landscape and rating the visual effects of forestry operations, clear cut logging cutblocks, or selective logging. These methods are less suitable for assessing transmission projects and the visual changes introduced by them, including construction of transmission towers, circuits/lines, roads, and substations.

Golder visited the route segments at locations where potentially important visual changes could occur. Due to the size of the project and remoteness of certain segments, only selected key areas were visited. Much of the Central and East alternatives is only accessible by logging roads and is not considered to contain key viewing areas. Golder took photos from 11 viewpoints to aid in the visual resource assessment. We identified areas of likely importance on maps of the area. In the field, specific locations were identified that offered a view of the project. The viewpoints are listed in Table 1-1 and their locations are depicted in Figure 1-1.

Table 1-1 Viewpoints

Viewpoint	Segment	New Towers Visible	Existing Line	Existing Towers Visible	Easting	Northing	Direction of View (Bearing)	Location
25-1	25	25/77 to 25/80	Ross-Lexington No 1	6/1 to 6/4	528696	5063610	N	NE Salmon Creek Avenue
25-2	25	25/124	McNary-Ross No 1 / Bonneville PH1-Alcoa No 1&2	6/3	531509	5057281	NNE	NE 76th Avenue – Walnut Grove
25-3	25	25/78	Ross-Lexington No 1	6/3	528398	5064676	E	WSU Vancouver Campus
40-1	40	40/12 to 40/14	North Bonneville-Ross No 1 / North Bonneville-Ross No 2	26/3 to 26/5	542086	5053784	EES	NW Underwood Street
41-1	41	41/4 to 41/7	Bonneville PH1-Alcoa No 1&2	N/A	543041	5054564	NW	NE 28th Street
48-1	48	48/1 to 48/7	North Bonneville-Ross No 1 / North Bonneville-Ross No 2	24/2 to 24/4	546833	5053813	WWS	NE 267th Avenue
50-1	50	50/5 to 50/10	Bonneville PH1-Alcoa No 1&2	3/5, 3/6, 4/1 to 4/4	545856	5052407	NW	NE 3rd Street
51-1	51	51/4 to 51/11	North Bonneville-Troutdale No 1 / North Bonneville-Troutdale No 2	N/A	548814	5053008	S	NE Zeek Road
52-1	52	52/3-52/10	North Bonneville-Troutdale No 1 / North Bonneville-Troutdale No 2 / North Camas-Oak Park No 1	1/1 to 1/12, 2/1 to 2/8	548234	5047480	NNE	Parking Lot Lewis and Clark Highway - Camas
M-1	M	M/2 to M/4	N/A	N/A	534066	5089450	S	Swimming Beach – Ariel – Lake Merwin
K-1	K	K/79	N/A	N/A	549193	5093744	EES	Yale Bridge Road

Figure 1-1 Viewpoint Locations



Golder collected photos with a Nikon D50 digital camera using a focal length of approximately 50mm (35mm film equivalent), considered consistent with the view perceived by the human eye (Horenstein et al. 2001). This is the standard focal length used in the development of photo simulations for visual resource assessment. Where potentially affected landforms were too large to fit into a single frame, multiple overlapping photos were taken.

The affected environment is discussed below in Section 2.0. This assessment is based on field observations, photos, maps, and visualization software (Google Earth). The project is divided into segments, comprising the alternatives, which traverse the landscape. Because the landscape often changes both in its scenic quality and its sensitivity across a particular segment area, a viewpoint that is representative of the most altered view does not reflect the overall visual impact for the entire segment. Other factors that are taken into account are the relative number of viewers, viewing conditions, length of view, and viewer sensitivity.

The general methods of the BLM VRM system are to inventory the visual resources of an area using the BLM Visual Resource Inventory methods and to perform analysis on a proposed alteration using the Visual Resource Contrast Rating (USDI 1986a, 1986b).

1.2.1 Visual Resource Inventory

The visual resource inventory process involves rating an area of land, in this case the area underlying and surrounding the proposed transmission line segments, measuring its visual appeal, determining the sensitivity or public concern for the scenic quality, and determining the visibility of the land to sensitive viewing locations (USDI 1986a). Ratings are performed with the understanding that all land has scenic value and that certain landscapes have more broadly appealing features than others. The value placed on the visual landscape is in the context of how and by whom it is viewed.

1.2.1.1 Scenic Quality

Scenic quality is a measure of the overall appeal of a view. The first step in the visual resource inventory process is to rate the scenic quality. The resulting ranking is High, Medium, or Low, which is determined based on several key factors (USDI 1986a). The key factors and the criteria used to rate them in this visual resource assessment are listed in Table 1-2.

With a maximum possible score of 32, values are totaled with results of 19 or more ranked High, 12 to 18 ranked Medium, and 11 or less ranked Low (these values are represented by A, B, and C respectively in the BLM VRM system).

1.2.1.2 Sensitivity

The second step in the visual resources inventory is ranking sensitivity levels. Sensitivity is a way of ranking public concern for visual resources. Factors considered in ranking sensitivity are the type of users, amount of use, public interest, adjacent land uses, special areas, and other factors that may be identified in other studies or research. Each of the sensitivity factors is assigned a ranking of High, Medium, or Low. Based on the ranking result, an overall sensitivity level is then assigned. The overall ranking is not necessarily an average of the individual factor rankings, since it is possible for certain factors to outweigh others. For example, public interest may be very high, despite other factors being low, indicating a generally high level of concern.

Table 1-2 Scenic Quality Evaluation Criteria Ranking

Key Factor	Rating Criteria and Score		
Landform	High vertical relief as expressed in prominent cliffs, spires, or massive rock outcrops, or severe surface variation or highly eroded formations including major badlands or dune systems; or detail features dominant and exceptionally striking and intriguing such as glaciers.	Steep canyons, mesas, buttes, cinder cones, and drumlins; or interesting erosional patterns or variety in size and shape of landforms; or detail features which are interesting though not dominant or exceptional.	Low rolling hills, foothills, or flat valley bottoms; or few or no interesting landscape features.
	5	3	1
Vegetation	A variety of vegetative types as expressed in interesting forms, textures, and patterns.	Some variety of vegetation, but only one or two major types.	Little or no variety or contrast in vegetation.
	5	3	1
Water	Clear and clean appearing, still, or cascading white water, any of which are a dominant factor in the landscape.	Flowing, or still, but not dominant in the landscape.	Absent, or present, but not noticeable.
	5	3	0
Color	Rich color combinations, variety or vivid color; or pleasing contrasts in the soil, rock, vegetation, water or snow fields.	Some intensity or variety in colors and contrast of the soil, rock and vegetation, but not a dominant scenic element.	Subtle color variations, contrast, or interest; generally mute tones.
	5	3	1
Influence of Adjacent Scenery (Beyond the landform being evaluated)	Adjacent scenery greatly enhances visual quality.	Adjacent scenery moderately enhances overall visual quality.	Adjacent scenery has little or no influence on overall visual quality.
	5	3	0
Scarcity	One of a kind; or unusually memorable, or very rare within region. Consistent chance for exceptional wildlife or wildflower viewing, etc.	Distinctive, though somewhat similar to others within the region.	Interesting within its setting, but fairly common within the region.
	5	3	1
Cultural Modifications (changes to the visual landscape discernable as artifical, such as buildings or roads)	Modifications add favorably to visual variety while promoting visual harmony.	Modifications add little or no visual variety to the area, and introduce no discordant elements.	Modifications add variety but are very discordant and promote strong disharmony.
	2	0	-4
Source: Illustration 2 – Scenic Quality Inventory and Evaluation Chart. Manual 8410a. (USDI 1986a)			

The type of user has an influence on visual sensitivity, as perceptions of the landscape tend to vary based on the intended use of the land. Recreational sightseers tend to be highly sensitive to changes in scenic quality. Industrial workers travelling through the area regularly, such as forestry workers, tend to be less sensitive. Residents tend to have high sensitivity due to their attachment to the landscape and the duration of their views.

The amount of use influences sensitivity; as with a greater number of viewers, sensitivity generally increases. Public interest is generally expressed in public meetings, newspaper articles, websites, signs, and letters. A high public response and level of concern over a project indicate a higher sensitivity. The adjacent land use can influence sensitivity, as it can influence the type and expectations of the viewers. For example, adjacent commercial or industrial land use would be less sensitive than adjacent residential or recreational use. Special areas such as parks, natural areas, designated scenic areas, etc., can be indicative of a potentially higher level of sensitivity, but may depend on management objectives set out for the area.

1.2.1.3 Visual Landscape Rating

The scenic quality and sensitivity rankings are combined into a visual landscape rating based on the following table (see Table 1-3).

Table 1-3 Visual Resource Landscape Rating

Visual Resource		User Sensitivity		
		High	**Medium**	**Low**
Scenic Quality	**High**	High	High	High
	Medium	High	Medium	Low
	Low	Medium	Low	Low
Source: Illustration 11 – Determining Visual Resource Inventory Classes. Manual 8410a. (USDI 1986a)				

1.2.2 Visual Simulations

To assess the visual contrast of the project with the existing conditions, a 3-D computer landscape model of the study area was created using Visual Nature Studio (VNS) software (2010). VNS allows GIS and other spatial data to be incorporated into a 3-D landscape model. With a Digital Elevation Model used as the ground surface, vegetation is added to the model based on National Land Cover Data classified satellite imagery. Key existing views and project features are added to the model, including vegetation clearing, transmission towers, conductors, and substations. Transmission tower objects are the approximate size and design of the planned towers, based on descriptions provided by BPA.

At key viewpoints, visual simulations were created that simulate the appearance of the project facilities that correspond to the photographs taken in the field. The rendered images from the modeled views were then used for evaluating contrast.

1.2.3 Visual Contrast Rating

The project was rated at key viewpoints to determine the degree of visual contrast between the project and the existing landscape. Contrast is determined using the basic visual elements of form, line, color, texture. Factors such as scale (the proportional size of the object in relation to the field of view of the viewer) are also considered. The BLM Visual Contrast Rating Manual (USDI 1986b) describes the following elements:

- *form*, which includes the sub-elements of structures and movement, relates to the shape of disturbances in contrast to the existing landscape shapes
- *line*, which relates to the path the eye naturally follows when perceiving differences in landscape shape, color or texture
- *color*, which relates to the degree that the sub-elements of hue (e.g., red, blue, green), value (e.g., brightness), and chroma (e.g., saturation) contrast with existing landscape colors
- *texture*, which relates to the patterns that exist within the larger landscape elements
- *scale*, which relates to the proportional size of the object in relation to the field of view of the viewer

The elements are then combined into an overall contrast rating which, like the visual landscape inventory ratings, does not necessarily represent a mathematical average, since one element may dominate over the others. Each element and the overall contrast rating are then rated according to the descriptions provided in Table 1-4.

Section 3.0, Environmental Consequences discusses how the visual contrast rating is further combined with the visual landscape rating to determine the overall visual impact level for the segment.

Table 1-4 Degree of Contrast Criteria

Degree of Contrast	Criteria
None	The element is not visible or perceived.
Weak	The element contrast can be seen but does not attract attention.
Moderate	The element contrast begins to attract attention and begins to dominate the characteristic landscape.
Strong	The element contrast demands attention, will not be overlooked, and is dominant in the landscape.
Source: BLM Visual Resource Contrast Rating. Manual 8431. (USDI 1986b)	

1.3 Definition of the Study Area

The study area for a Visual Resources Assessment is defined as the area within 5 miles of the project. A distance of 5 miles was used because it represents locations with a potential foreground or middle-ground view (USDI 1986a) and the maximum distance at which a transmission line would create a dominant or intrusive presence to the viewer.

2.0 Affected Environment

The U.S. Environmental Protection Agency (EPA) Ecoregions provide a description of the physiography and general land use of the affected environment. The affected environment traverses several ecoregions as described by the United States Geological Survey (EPA 2007). Ecoregions are areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources; they are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components (see http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm#Level III). This hierarchical system has subdivisions from Level I to Level IV, with Level I being the coarsest level (dividing North America into 15 ecological regions) and Level IV being the finest level. The Level III Ecoregions that dominate the study area's landscape include the Coast Range, Puget Lowland, Cascades, and Willamette Valley. These are further divided into Level IV Ecoregions. Level IV regions crossed by the study area include the Willapa Hills within the Coast Range; the Cowlitz/Chehalis Foothills within the Puget Lowland; the Western Cascades Lowlands and Valleys within the Cascades; and the Valley Foothills and Portland/Vancouver Basin within the Willamette Valley.

The affected environment consists of valley basins and foothills between the Coast Range on the west and the West Cascades to the east of the study area. The ecoregions traversed by the project are described in general in the following paragraphs. A more detailed rating of scenic quality and sensitivity is also provided in Sections 2.1 through 2.4.

2.1 Willapa Hills

At the north end of the project, all action alternatives originate in the Willapa Hills Level IV ecoregion. Segments A, B and E are contained in this region; segments C and D as well as the northern portions of segments 1, 2, 3 and F intersect it. This ecoregion consists of low, rolling hills and gently sloping mountains and fewer drainages than surrounding areas (EPA 2007). Visually, the region's landforms are uninteresting and the vegetation patterns do not form interesting or unique textures or patterns. Water features are not prominent. With fairly uniform vegetation, there are few interesting color differences, so it does not form a strong scenic element. The consistent vegetation and low rolling hills result in few long-range views. the hills and vegetation limit visual effects and result in adjacent scenery having little influence. The region is relatively sparsely populated, with the neighborhood of Longview Heights in the south and scattered residential acreages throughout other areas.

2.2 Cowlitz/Chehalis Foothills

All action alternatives also pass through a narrow section of the Cowlitz/Chehalis Foothills Level IV ecoregion. Segments 4, 5, 7 and 8 are contained in this region, the northern portions of segments 9, 11 and F as well as the southern portion of Segment 3 intersect it. This region in the study area consists of rolling to steeply sloping hills and the relatively flat Cowlitz River Valley. This region also forms the corridor for the Interstate (I-5) and contains the urban areas of Longview/Kelso and Castle Rock.

The landforms are non-dramatic and of little visual interest. The vegetation does not tend to vary to form interesting patterns or textures, but rather acts to visually contain the views so that long-range viewing opportunities are rare. There is water present, predominantly the Cowlitz River; however, it is not cascading or pristine, so only contributes to somewhat enhance scenic quality.

There are some color variations in the vegetation; however, they do not dominate or create a strong scenic element. The influence of adjacent scenery is limited due to the few long-range viewing opportunities. The visual characteristics of this region are common in much of south-western Washington and northwest Oregon.

2.3 Western Cascades Lowlands and Valleys

Covering a large part of the study area, the Western Cascades Lowlands and Valleys Level IV ecoregion includes the many valleys and ridges that stretch out west from the Cascade Range. Segments 10, 12, 14, 15, 18, 23, 26, 28, 30, 35, G to J, and L to W are contained in this region. The southern portions of segments 9, 11 and F, the northern portion of Segment 25, and the eastern portions of segments 39 and 49 intersect it. These segments include most of the East and Central alternatives.

The region has moderate to steeply sloping hills with western hemlock (*Tsuga heterophylla*) and Douglas-fir (*Pseudotsuga menziesii*) forests. The area has intensive forestry activity throughout. Although in general it is sparsely populated, it includes the communities of Ariel, Amboy, and Yacolt in the North; Venersborg and Hockinson in the Southwest; and the rural residential areas of Camas and Washougal in the South. The Kalama River, Lewis River, Lake Merwin, Yale Lake, portions of the Gifford Pinchot National Forest, Moulton Falls Park, and other small recreation sites are within this region of the study area.

The landforms of this region, while having more geographic relief than others in the study area, are not dominant or exceptional. The vegetation is fairly consistent and does not form interesting patterns or textures in most places. It tends to be most varied and interesting around the rivers and lakes mentioned above. Although not dominant through most of the area, water contributes to scenic quality around Merwin and Yale Lake and along the banks of watercourses. For the most part, water is not striking, cascading, or pristine. Color contributes to scenic quality, primarily in the fall. Otherwise, the landscape is dominated by similar shades of green throughout most of the area during the majority of the year.

2.4 Valley Foothills

West of the Western Cascades Lowlands and Valleys, the Valley Foothills Level IV ecoregion contains or is intersected by many of the smaller segments of the project in the Camas area. Segments 38, 41, 43, 45 and 47 fall completely within this region, segments 36B, 37, 39, 46, 48, 49, 50 and 51 intersect it. It is also intersected by a small northern portion of Segment 25.

This ecoregion is a transition zone between the Portland/Vancouver Basin to the west and the Western Cascades Lowlands and Valleys to the east. It is dryer than the neighboring mountainous ecosystems and has vegetation reflective of that, with Oregon oak (*Quercus garryana*) and Douglas-fir as the native vegetation. The non-native land use, which is more common than native vegetation, is made up of rural residential developments, woodlands, pastures, tree farms, vineyards, and orchards.

The landforms of this region consist of low rolling foothills with few dramatic features. There is some variety in the vegetation; however, it is rarely expressed in interesting forms, textures, or patterns. Visible water is rare throughout the ecoregion and for the most part does not contribute to scenic quality. There are some variations in color, which contribute slightly to the scenic quality; however, they are mostly shades of green and are not a dominant scenic element. Adjacent scenery has little effect on scenic quality, as most adjacent scenery is either blocked by

the topography and vegetation or is not a strong positive influence. The scarcity of the scenery is considered low, as the scenic elements found in the Valley Foothills are common throughout much of southwestern Washington and Oregon.

2.5 Portland/Vancouver Basin

The Portland/Vancouver Basin Level IV ecoregion is composed of floodplains and undulating terraces. Segments 36, 36A, 40 and 52 are contained in the region; segments 36B, 37, 46, 48, 50 and 51 as well as the southern portions of Segment 25 intersect it. All action alternatives move through this ecoregion before terminating at Sundial Substation.

The landforms of the region are dominated by low relief floodplains with small rolling hills on the eastern edge. These non-dramatic landforms do little to contribute to scenic quality. Vegetation is moderately varied in the ecoregion, as the change from rolling hills to floodplains results in more interesting forms, patterns, and textures. The vegetation patterns in the ecoregion moderately enhance scenic quality. Water moderately enhances the scenic quality from select locations surrounding the Columbia and Lewis Rivers, and other small creeks. As a scenic element, the water is limited in its influence because it is only visible in select locations and because it is not generally cascading or pristine. Color variations due to the diverse vegetation moderately enhance the scenic quality, but do not tend to be a dominant landscape element. Adjacent scenery is generally not highly visible or has little influence on scenic quality. This type of landscape is similar to other valley and basin ecoregions in southwestern Washington and northwestern Oregon.

2.6 Substations

2.6.1 Sundial Substation

The Sundial Substation is located in an area of Low scenic quality, owing to the flat relief floodplains; only somewhat varied vegetation consisting of smaller patches of forest, shrubs and open pastures; some influence of water, but that is not cascading or pristine; some color variations that are not a dominant scenic feature; no influence from adjacent scenery (due to limited visibility); somewhat distinctive scenery, but still common to floodplain landscape; and many negative cultural modifications due to proximity to an existing industrial park. The area has Medium sensitivity, given its location next to the Columbia River; high amount of use; low public interest; little influence of adjacent land use; no special areas; or other considerations. The combined Low scenic quality rating and Medium sensitivity rating result in a Low visual landscape rating.

2.6.2 Casey Road Substation

The proposed site of the Casey Road Substation is located in a remote area. . of Low scenic quality, in consideration of the low rolling foothills lacking dominant vertical relief or specific interesting landforms; a dense, uniform mixed-wood vegetation that is currently partly logged; very little visible water; few color variations; and no influence of adjacent scenery due to limited visibility. The site has a visual landscape common to the region, and includes negative cultural modifications such as the right-of-way of an existing transmission line and logging activity. The area has Low sensitivity, given the following factors: the type of use does not include residential use, parks, or other sensitive recreational uses; the amount of use is low; there is low public interest; the adjacent land uses do not increase the sensitivity; and there are not any special areas.

The Low scenic quality rating and Medium sensitivity rating result in a Low visual landscape rating.

2.6.3 Baxter Road Substation

The site is located approximately 2.5 miles from the Casey Road site, in an area of Low scenic quality, with low rolling foothills with few interesting features, little variety of vegetation, very little visible water, few color variations, and no influence of adjacent scenery. The site has a visual landscape common to the region, and there are no enhancing cultural modifications. The area has Low sensitivity, given the following factors: the type of use does not include residential use, parks, or other sensitive recreational uses; the amount of use is low; there is low public interest; the adjacent land uses do not increase the sensitivity; and there are not any special areas. The Low scenic quality rating and Medium sensitivity rating result in a Low visual landscape rating.

2.6.4 Monahan Creek Substation

The Monahan Creek Substation is located in an area of Low scenic quality, in consideration of the low foothills lacking dominant vertical relief or specific interesting landforms; largely uniform vegetation consisting primarily of mixed-wood forest and small open pastures; very little visible influence of water on the landscape; few color variations in the vegetation; no influence of adjacent scenery (due to limited visibility); a commonly occurring landscape throughout the region; and negatively influencing cultural modifications (buildings and other structures). The area is Medium sensitivity, given the rural residential usage, amount of use, and public interest. The combined Low scenic quality rating and Medium sensitivity rating result in a Low visual landscape rating.

2.7 West Alternative

The West Alternative originates in the Willapa Hills ecoregion, where it passes through rolling vegetated hills and rural residential areas before entering the West Side Highway and Kelso in the Puget Lowland ecoregion. Through the Puget Lowland ecoregion it passes through many residential and rural-residential areas. The hills become larger and the population less dense as it passes into the Western Cascades Lowlands and Valleys. After crossing the Lewis River, the alternative enters the Portland/Vancouver Basin ecoregion. The physiographic characteristics of the study area are consistent with the descriptions provided for the ecoregions through which the alternative passes.

The landscape along this alternative is consistent with the description of ecoregions, but the sensitivity varies locally with land use. Proximity to residential areas is the primary determinant for sensitivity along the alternative. The West Alternative portion of the study area is relatively close to residential areas for most of its length. At the north end it passes through rural residential areas northwest of West Side Highway. Rural residential areas have fewer users of the land, so the amount of use is lower than in more densely populated residential areas. However, public concern for the visual landscape in these areas may be higher due to the expectation of rural residents to have a more natural or open landscape. As the alternative crosses through West Side Highway and Kelso it runs through or close to residential areas.

The segment then crosses the Coweeman River and again crosses rural residential areas, which elevate the sensitivity. As the alternative continues south, across the Lewis River, it passes through agricultural land, which tends to be less sensitive than rural residential. The density of

residences increases south towards Hazel Dell. As the alternative shifts to a predominantly east-west direction it passes through urban residential, commercial, and industrial land. Crossing NE 4th Plain Road and heading SE towards Mill Plain and Camas, the alternative again passes through open space and rural residential areas. Public interest is high along the alternative, with signs on many yards expressing opposition to the project running through populated areas.

2.7.1 Scenic Quality Ratings

The scenic quality ratings for each segment of the West Alternative are provided in Table 2-1.

Table 2-1 West Alternative Scenic Quality Ratings

Route	Segment	Segment Length (miles)	Existing Conditions – Scenic Quality Ratings								
			Landform	Vegetation	Water	Color	Adjacent Scenery	Scarcity	Cultural Modifications	Scenic Quality Total	Scenic Quality Rating
West Alternative	2	6.04	2	2	1	2	0	1	-1	**7**	**Low**
	4	0.77	2	2	3	3	0	1	-2	**9**	**Low**
	9	18.72	2	2	3	3	0	1	-1	**10**	**Low**
	25	29.87	1	3	3	3	1	1	-2	**10**	**Low**
	36B	1.41	1	2	0	2	0	1	-1	**5**	**Low**
	41	1.27	1	3	1	3	0	1	-1	**8**	**Low**
	45	0.67	1	2	0	2	0	1	-1	**5**	**Low**
	50	4.09	1	3	1	3	0	1	-1	**8**	**Low**
	52	4.65	2	3	3	3	0	2	-2	**11**	**Low**
	Totals	**67.49**									
West Option 1	36	0.22	1	2	0	2	0	1	-1	**5**	**Low**
	40	2.69	1	4	2	4	0	1	-1	**11**	**Low**
	46	0.46	1	2	2	2	0	1	-1	**7**	**Low**
	Totals	**3.37**									
West Option 2	36	0.22	1	2	0	2	0	1	-1	**5**	**Low**
	36A	1.03	1	2	0	2	0	1	-1	**5**	**Low**
	37	0.67	1	2	0	2	0	1	-1	**5**	**Low**
	38	0.66	1	2	0	2	0	1	-1	**5**	**Low**
	43	1.86	1	3	0	2	0	1	-1	**6**	**Low**
	48	2.49	1	2	0	2	0	1	-1	**5**	**Low**
	51	2.07	2	3	1	3	0	1	-1	**9**	**Low**
	Totals	**9.00**									
West Option 3	36	0.22	1	2	0	2	0	1	-1	**5**	**Low**
	36A	1.03	1	2	0	2	0	1	-1	**5**	**Low**
	37	0.67	1	2	0	2	0	1	-1	**5**	**Low**
	38	0.66	1	2	0	2	0	1	-1	**5**	**Low**
	39	5.35	1	2	1	2	0	1	-1	**6**	**Low**
	T	0.31	1	2	0	2	0	1	-1	**5**	**Low**
	49	2.73	1	2	0	2	1	1	-1	**6**	**Low**
	51	2.07	2	3	1	3	0	1	-1	**9**	**Low**
	Totals	**13.04**									

2.7.2 Sensitivity Ratings and Overall Landscape Ratings

The sensitivity rankings and overall landscape rating based on scenic quality and sensitivity for each West Alternative segment are listed in Table 2-2.

Table 2-2 West Alternative Sensitivity and Overall Landscape Rating

Route	Segment	Segment Length (miles)	Existing Conditions – Sensitivity and Overall Landscape Rating						
			Type of User	Amount of Use	Public Interest	Adjacent Use	Special Areas	Sensitivity Rating	Landscape Rating
West Alternative	2	6.04	H	M	M	L	L	**Medium**	**Low**
	4	0.77	H	H	M	L	L	**High**	**Medium**
	9	18.72	H	H	H	L	L	**High**	**Medium**
	25	29.87	H	H	H	L	L	**High**	**Medium**
	36B	1.41	H	H	H	L	L	**High**	**Medium**
	41	1.27	H	H	H	L	L	**High**	**Medium**
	45	0.67	H	H	H	L	L	**High**	**Medium**
	50	4.09	H	H	H	L	L	**High**	**Medium**
	52	4.65	H	H	H	L	L	**High**	**Medium**
	Totals	**67.49**							
West Option 1	36	0.22	H	H	H	L	L	**High**	**Medium**
	40	2.69	H	H	H	M	L	**High**	**Medium**
	46	0.46	H	H	H	L	L	**High**	**Medium**
	Totals	**3.37**							
West Option 2	36	0.22	H	H	H	L	L	**High**	**Medium**
	36A	1.03	H	H	H	L	L	**High**	**Medium**
	37	0.67	H	H	H	L	L	**High**	**Medium**
	38	0.66	M	L	M	L	L	**Medium**	**Low**
	43	1.86	H	H	H	L	L	**High**	**Medium**
	48	2.49	H	H	H	L	L	**High**	**Medium**
	51	2.07	H	M	H	L	L	**High**	**Medium**
	Totals	**9.00**							
West Option 3	36	0.22	H	H	H	L	L	**High**	**Medium**
	36A	1.03	H	H	H	L	L	**High**	**Medium**
	37	0.67	H	H	H	L	L	**High**	**Medium**
	38	0.66	M	L	M	L	L	**Medium**	**Low**
	39	5.35	H	H	H	L	L	**High**	**Medium**
	T	0.31	M	L	M	M	L	**Medium**	**Low**
	49	2.73	H	M	M	H	L	**Medium**	**Low**
	51	2.07	H	M	H	L	L	**High**	**Medium**
	Totals	**13.04**							

Notes:
H = high rating for sensitivity conditions, M = medium rating, L = low rating

2.8 Central Alternative

The Central Alternative shares many characteristics with the West and Crossover alternatives. Northwest of the Cowlitz River the alternatives are very similar with only slight localized differences. East of the Cowlitz River, the Central Alternative crosses the Cowlitz/Chehalis Foothills ecoregion described in Section 2.0. The alternative then enters the Western Cascades Lowlands and Valleys ecoregion, which is also described in Section 2.0.

Through the portion of the Central Alternative located southeast of the Cowlitz River and north of the Lewis River, the alternative has generally Low sensitivity. This area is sparsely populated and has limited use. Sensitivity and scenic quality are higher near the Lewis River just west of Lake Merwin through Ariel. Near Amboy and Yacolt, and east of Lewisville and Battle Ground, the alternative is located amongst rural residential homes and has Medium sensitivity. Midway south along Segment P, the route turns east and away from rural residential areas until Segment 35, where the route passes near the rural residential homes of Camas.

2.8.1 Scenic Quality Ratings

The scenic quality ratings for each segment of the Central Alternative are provided in Table 2-3.

Table 2-3 Central Alternative Scenic Quality Ratings

Route	Segment	Segment Length (miles)	Existing Conditions - Scenic Quality Ratings								
			Landform	Vegetation	Water	Color	Adjacent Scenery	Scarcity	Cultural Modifications	Scenic Quality Total	Scenic Quality Ratings
Central Alternative	B	0.78	2	2	1	2	0	1	0	**8**	**Low**
	F	15.86	2	3	3	3	0	2	-2	**11**	**Low**
	G	1.39	2	2	1	2	0	1	-1	**7**	**Low**
	H	1.53	2	2	2	2	0	1	0	**9**	**Low**
	10	7.93	2	2	2	2	0	1	-1	**8**	**Low**
	12	4.96	2	2	2	2	0	1	0	**9**	**Low**
	15	1.86	2	2	2	3	0	1	-1	**9**	**Low**
	23	1.29	2	3	3	3	0	2	-1	**12**	**Medium**
	L	1.71	2	3	3	3	0	2	-1	**12**	**Medium**
	18	7.17	2	2	0	2	0	1	-1	**6**	**Low**
	28	5.94	2	2	1	2	2	1	-2	**8**	**Low**
	V	5.96	2	2	2	2	0	1	-2	**7**	**Low**
	P	8.62	1	2	0	2	0	1	-1	**5**	**Low**
	35	2.52	1	2	1	2	0	1	-1	**6**	**Low**
	T	0.31	1	2	0	2	0	1	-1	**5**	**Low**
	49	2.73	1	2	0	2	1	1	-1	**6**	**Low**
	51	2.07	2	3	1	3	0	1	-1	**9**	**Low**
	52	4.70	2	3	3	3	0	2	-2	**11**	**Low**
	Totals	**77.33**									
Central Option 1	A	2.50	2	2	1	2	0	1	0	**8**	**Low**
	Totals	**2.50**									
Central Option 2	1	6.42	2	2	1	2	0	1	-1	**7**	**Low**
	4	0.77	2	2	3	3	0	1	-2	**9**	**Low**
	5	1.93	2	2	3	3	0	1	-1	**10**	**Low**
	8	1.61	2	2	1	2	1	1	-1	**8**	**Low**
	11	5	2	2	2	2	0	1	-1	**8**	**Low**
	Totals	**15.73**									
Central Option 3	M	2.39	2	3	3	3	0	2	-1	**12**	**Medium**
	26	6.54	2	2	1	2	1	1	-1	**8**	**Low**
	30	6.01	2	3	3	3	1	1	-1	**12**	**Medium**
	Totals	**14.94**									

2.8.2 Sensitivity Ratings and Overall Landscape Ratings

The sensitivity rankings and overall landscape rating based on scenic quality and sensitivity for each Central Alternative segment is presented in Table 2-4.

Table 2-4 Central Alternative Sensitivity and Overall Landscape Rating

Route	Segment	Segment Length (miles)	Existing Conditions -Sensitivity and Overall Landscape Rating						
			Type of User	Amount of Use	Public Interest	Adjacent Use	Special Areas	Sensitivity Rating	Landscape Rating
Central Alternative	B	0.78	L	M	M	L	L	**Low**	**Low**
	F	15.86	M	H	M	L	L	**Medium**	**Low**
	G	1.39	L	L	L	L	L	**Low**	**Low**
	H	1.53	L	L	L	L	L	**Low**	**Low**
	10	7.93	L	L	L	L	L	**Low**	**Low**
	12	4.96	L	L	M	L	L	**Low**	**Low**
	15	1.86	L	L	L	L	L	**Low**	**Low**
	23	1.29	M	H	H	L	L	**Medium**	**Medium**
	L	1.71	H	M	H	L	L	**High**	**High**
	18	7.17	M	L	M	H	L	**Medium**	**Low**
	28	5.94	M	M	M	L	L	**Medium**	**Low**
	V	5.96	L	L	M	L	L	**Low**	**Low**
	P	8.62	H	L	M	H	L	**Medium**	**Low**
	35	2.52	L	L	H	H	L	**Medium**	**Low**
	T	0.31	M	L	M	M	L	**Medium**	**Low**
	49	2.73	H	M	M	H	L	**Medium**	**Low**
	51	2.07	H	M	H	L	L	**High**	**Medium**
	52	4.70	H	H	H	L	L	**High**	**Medium**
	Totals	**77.33**							
Central Option 1	A	2.50	L	L	L	L	L	**Low**	**Low**
	Totals	**2.50**							
Central Option 2	1	6.42	M	M	M	L	L	**Medium**	**Low**
	4	0.77	H	H	M	L	L	**High**	**Medium**
	5	1.93	M	H	H	L	L	**Medium**	**Low**
	8	1.61	M	L	M	L	L	**Low**	**Low**
	11	5	L	L	L	L	L	**Low**	**Low**
	Totals	**15.73**							
Central Option 3	M	2.39	H	M	H	L	L	**High**	**High**
	26	6.54	H	M	H	L	L	**High**	**Medium**
	30	6.01	M	M	H	H	L	**Medium**	**Medium**
	Totals	**14.94**							

Notes:
H = high rating for sensitivity conditions, M = medium rating, L = low rating

2.9 East Alternative

The East Alternative originates west of Castle Rock in the Willapa Hills ecoregion, described in Section 2.0. The alternative crosses the Cowlitz River and extends across the Cowlitz/Chehalis Foothills ecoregion for approximately 8 miles before entering the Western Cascades Lowlands and Valleys ecoregion, described in Section 2.0. The East Alternative shares the portion of the route south of Lake Merwin and Yale Lake with the Crossover Alternative.

The sensitivity of the area surrounding the East Alternative is mostly based on land use. At the north end of the alternative, sensitivity is Low as there are not homes, roads or recreation areas. Near the north end of Castle Rock, sensitivity increases due to the increased amount of use and type of users. The number of potential viewers increases in the vicinity of Highway 504 and I-5. Highway 504 is a designated state scenic drive, where the sensitivity of Segment F is considered greater. East of Castle Rock viewer sensitivity is considered Low, as there are few residences, roads, or recreation areas. Segment K, covering most of the northern portion of the alternative, has Low sensitivity for most of its length because there are few homes, few roads, and low levels of use. Sensitivity is increased at the south end of Segment K, where it crosses Lewis River Road, and extends across the rural residential areas northwest of Ariel, and across the east end of Lake Merwin. South of Lake Merwin, the alternative shares segments with those described in Section 2.10 for the Crossover Alternative.

2.9.1 Scenic Quality Ratings

The scenic quality ratings for each segment of the East Alternative are provided in Table 2-5. General descriptions of the ratings are provided in Section 2.0.

Table 2-5 East Alternative Scenic Quality Ratings

Route	Segment	Segment Length (miles)	Existing Conditions - Scenic Quality Ratings								
			Landform	Vegetation	Water	Color	Adjacent Scenery	Scarcity	Cultural Modifications	Scenic Quality Total	Scenic Quality Ratings
East Alternative	B	0.78	2	2	1	2	0	1	0	**8**	**Low**
	F	15.86	2	3	3	3	0	2	-2	**11**	**Low**
	I	2.77	2	3	2	3	0	1	0	**11**	**Low**
	K	22.8	2	3	3	3	2	2	-1	**14**	**Medium**
	W	1.31	2	3	3	3	1	2	-1	**13**	**Medium**
	O	19.47	3	2	2	2	2	1	-1	**11**	**Low**
	Q	2.63	2	2	2	2	0	1	0	**9**	**Low**
	S	0.41	1	2	0	2	0	1	-1	**5**	**Low**
	49	2.73	1	2	0	2	1	1	-1	**6**	**Low**
	51	2.07	2	3	1	3	0	1	-1	**9**	**Low**
	52	4.70	2	3	3	3	0	2	-2	**11**	**Low**
	Totals	**75.53**									
East Option 1	3	7.82	2	2	3	3	0	2	-1	**11**	**Low**
	7	2.05	2	2	1	2	1	1	-1	**8**	**Low**
	11	5	2	2	2	2	0	1	-1	**8**	**Low**
	J	2.72	2	2	1	2	0	1	0	**8**	**Low**
	Totals	**17.59**									
East Option 2	U	6.11	2	3	1	2	2	1	-1	**10**	**Low**
	V	5.96	2	2	2	2	0	1	-2	**7**	**Low**
	P	8.62	1	2	0	2	0	1	-1	**5**	**Low**
	35	2.52	1	2	1	2	0	1	-1	**6**	**Low**
	T	0.31	1	2	0	2	0	1	-1	**5**	**Low**
	Totals	**23.52**									
East Option 3	R	3.68	2	2	1	2	1	1	-1	**8**	**Low**
	Totals	**3.68**									

2.9.2 Sensitivity Ratings and Overall Landscape Ratings

The sensitivity rankings and overall landscape rating based on scenic quality and sensitivity for each segment of the East Alternative are provided in Table 2-6.

Table 2-6 East Alternative Sensitivity and Overall Landscape Rating

Route	Segment	Segment Length (miles)	Existing Conditions -Sensitivity and Overall Landscape Rating						
			Type of User	Amount of Use	Public Interest	Adjacent Use	Special Areas	Sensitivity Rating	Landscape Rating
East Alternative	B	0.78	L	M	M	L	L	**Low**	**Low**
	F	15.86	M	H	M	M	M	**Medium**	**Low**
	I	2.77	M	L	M	L	L	**Medium**	**Low**
	K	22.8	H	H	M	L	L	**Medium**	**Medium**
	W	1.31	H	M	M	L	L	**Medium**	**Medium**
	O	19.47	L	L	M	L	L	**Low**	**Low**
	Q	2.63	M	L	L	L	L	**Low**	**Low**
	S	0.41	M	L	M	M	L	**Medium**	**Low**
	49	2.73	H	M	M	H	L	**Medium**	**Low**
	51	2.07	H	M	H	L	L	**High**	**Medium**
	52	4.70	H	H	H	L	L	**High**	**Medium**
	Totals	**75.53**							
East Option 1	3	7.82	M	H	M	L	L	**Medium**	**Low**
	7	2.05	H	M	M	L	L	**Medium**	**Low**
	11	5	L	L	L	L	L	**Low**	**Low**
	J	2.72	L	L	L	L	L	**Low**	**Low**
	Totals	**17.59**							
East Option 2	U	6.11	L	L	L	M	L	**Low**	**Low**
	V	5.96	L	L	M	L	L	**Low**	**Low**
	P	8.62	H	L	M	H	L	**Medium**	**Low**
	35	2.52	L	L	H	H	L	**Medium**	**Low**
	T	0.31	M	L	M	M	L	**Medium**	**Low**
	Totals	**23.52**							
East Option 3	R	3.68	L	L	L	L	L	**Low**	**Low**
	Totals	**3.68**							

Notes:
H = high rating for sensitivity conditions, M = medium rating, L = low rating

2.10 Crossover Alternative

The Crossover Alternative shares the northern half of the route with the West Alternative. The Crossover Alternative passes through the Western Cascades Lowlands and Valleys ecoregion and does not enter the Valley Foothills and Portland/Vancouver Basin until near its southern limit. The physiographic characteristics and scenic quality of the area surrounding the alternative are consistent with the ecoregion descriptions provided in Section 2.0.

The sensitivity varies along the alternative, with land use influencing the sensitivity. Near Amboy and Ariel, there are residential users, motorists, and recreational users of the landscape. South of Lake Merwin, sensitivity is lower, as there are fewer residences close to the alternative. Recreational land use becomes more influential on sensitivity; however, there is not a high amount of use, so sensitivity is Low to Medium. Entering the rural residential areas of Camas, the sensitivity becomes Medium to High, depending on the number and proximity of residences.

2.10.1 Scenic Quality Ratings

The scenic quality ratings for each segment of the Crossover Alternative are provided in Table 2-7.

Table 2-7 Crossover Alternative Scenic Quality Ratings

Route	Segment	Segment Length (miles)	Existing Conditions - Scenic Quality Ratings								
			Landform	Vegetation	Water	Color	Adjacent Scenery	Scarcity	Cultural Modifications	Scenic Quality Total	Scenic Quality Rating
Crossover Alternative	2	6.04	2	2	1	2	0	1	-1	7	**Low**
	4	0.77	2	2	3	3	0	1	-2	9	**Low**
	9	18.72	2	2	3	3	0	1	-1	10	**Low**
	14	1.50	2	2	2	3	0	1	-1	9	**Low**
	15	1.86	2	2	2	3	0	1	-1	9	**Low**
	23	1.29	2	3	3	3	0	2	-1	12	**Medium**
	L	1.72	2	3	3	3	0	2	-1	12	**Medium**
	18	7.17	2	2	0	2	0	1	-1	6	**Low**
	N	1.64	2	2	3	3	2	2	-1	13	**Medium**
	W	1.31	2	3	3	3	1	2	-1	13	**Medium**
	O	19.47	3	2	2	2	2	1	-1	11	**Low**
	Q	2.64	2	2	2	2	0	1	0	9	**Low**
	S	0.41	1	2	0	2	0	1	-1	5	**Low**
	49	2.73	1	2	0	2	1	1	-1	6	**Low**
	51	2.07	2	3	1	3	0	1	-1	9	**Low**
	52	4.70	2	3	3	3	0	2	-2	11	**Low**
	Totals	**74.04**									
Crossover Option 1	47	0.69	1	2	0	2	0	1	-1	5	**Low**
	48	2.50	1	2	0	2	0	1	-1	5	**Low**
	50	4.09	1	3	1	3	0	1	-1	8	**Low**
	Totals	**7.28**									
Crossover Option 2	C	3	2	2	1	2	0	1	0	8	**Low**
	E	1.34	2	2	1	2	0	1	0	8	**Low**
	Totals	**4.34**									
Crossover Option 3	D	2.86	2	2	1	2	0	1	0	8	**Low**
	E	1.34	2	2	1	2	0	1	0	8	**Low**
	Totals	**4.2**									

2.10.2 Sensitivity Ratings and Overall Landscape Ratings

The sensitivity rankings and overall landscape rating based on scenic quality and sensitivity for each segment of the Crossover Alternative are presented in Table 2-8.

Table 2-8 Crossover Alternative Sensitivity and Overall Landscape Rating

Route	Segment	Segment Length (miles)	Existing Conditions -Sensitivity and Overall Landscape Rating						
			Type of User	Amount of Use	Public Interest	Adjacent Use	Special Areas	Sensitivity Rating	Landscape Rating
Crossover Alternative	2	6.04	H	M	M	L	L	**Medium**	**Low**
	4	0.77	H	H	M	L	L	**High**	**Medium**
	9	18.72	H	H	H	L	L	**High**	**Medium**
	14	1.50	L	L	L	L	L	**Low**	**Low**
	15	1.86	L	L	L	L	L	**Low**	**Low**
	23	1.29	M	H	H	L	L	**Medium**	**Medium**
	L	1.72	H	M	H	L	L	**High**	**High**
	18	7.17	M	L	M	H	L	**Medium**	**Low**
	N	1.64	H	M	M	H	L	**Medium**	**Medium**
	W	1.31	H	M	M	L	L	**Medium**	**Medium**
	O	19.47	L	L	M	L	L	**Low**	**Low**
	Q	2.64	M	L	L	L	L	**Low**	**Low**
	S	0.41	M	L	M	M	L	**Medium**	**Low**
	49	2.73	H	M	M	H	L	**Medium**	**Low**
	51	2.07	H	M	H	L	L	**High**	**Medium**
	52	4.70	H	H	H	L	L	**High**	**Medium**
	Totals	**74.04**							
Crossover Option 1	47	0.69	H	H	H	L	L	**High**	**Medium**
	48	2.50	H	H	H	L	L	**High**	**Medium**
	50	4.09	H	H	H	L	L	**High**	**Medium**
	Totals	**7.28**							
Crossover Option 2	C	3	L	L	L	L	L	**Low**	**Low**
	E	1.34	H	M	M	L	L	**Medium**	**Low**
	Totals	**4.34**							
Crossover Option 3	D	2.86	L	L	L	L	L	**Low**	**Low**
	E	1.34	H	M	M	L	L	**Medium**	**Low**
	Totals	**4.2**							

Notes:
H = high rating, M = medium rating, L = low rating

3.0 Environmental Consequences

3.1 Visual Impact

The visual impact of the project is a function of the visual landscape rating (described in Section 1.2.1) and the visual contrast rating. Visual landscape ratings are provided for each segment in Tables 2-2, 2-4, 2-6, and 2-8; visual contrast ratings are provided for each segment in the segment descriptions below. These two ratings can be combined in Table 3-1 to determine the visual impact, which is rated as Negligible, Low, Moderate or High. This table rates the impact of the contrast of the project segments against the overall landscape in which it occurs. See Section 3.1.1 for more detail on how these impacts are determined.

Table 3-1 Visual Impact Rating

Visual Resource		Landscape Rating		
		Low	**Medium**	**High**
Overall Segment Contrast	**None**	Negligible	Negligible	Negligible
	Weak	Low	Low	Moderate
	Moderate	Low	Moderate	High
	Strong	Moderate	High	High
Source: Golder 2010				

3.1.1 Impact Levels

Impacts would be high where project activities would result in the following:

- A High or Medium landscape rating, and project features that dominate the landscape, or
- A High landscape rating, and project features that attract attention to the landscape.

Impacts would be moderate where project activities would result in the following:

- A High landscape rating, and project features that do not attract attention to the landscape, or
- A Medium landscape rating, and project features that attract attention to the landscape, or
- A Low landscape rating, and project features that dominate the landscape.

Impacts would be low where project activities would result in the following:

- A Medium or Low landscape rating, and project features that do not attract attention to the landscape, or
- A Low landscape rating, and project features that attract attention to the landscape.

No impact would occur where project features are visually negligible or not visible at all.

3.2 Impacts Common to Action Alternatives

Every action alternative would result in visual alterations to the landscape. Managing visual quality is a balancing act between placing disturbances in either more remote locations or adjacent to existing disturbances. Remote locations have fewer potential viewers, but are often less disturbed and therefore more sensitive to additional disturbances and viewers present may be more sensitive to potential changes. Sites close or adjacent to existing disturbances tend to be of a lower scenic quality, but often have higher populations and thus more potential viewers. As visual impact is a function of scenic quality, sensitivity, and contrast, the effects of alternatives are often balanced out.

The duration of the impacts is common to all action alternatives. The impacts discussed below are considered permanent for the life of the project. The landscape can be visually restored to existing conditions following the removal of transmission towers and re-growth of vegetation, so the alterations are not permanent, unless these facilities are never removed or are replaced with new facilities at the same location in the future.

3.3 Substations

3.3.1 Sundial Substation

There are no sensitive viewpoints that are expected to have a view of the Sundial Substation. The existing conditions of the area have many industrial operations, which would result in a lower contrast of the substation. The contrast is expected to be Weak, as it is unlikely to draw viewer's attention. With a contrast rating of Weak and a landscape rating of Low, the overall visual impact would likely be Low.

3.3.2 Casey Road Substation

The Casey Road Substation is not expected to be visible from any significant sensitive viewpoints. The visual impact of the Casey Road Substation would likely be Low.

3.3.3 Baxter Road Substation

The Baxter Road substation site sits in a small topographical depression and is surrounded by vegetation. The site is not expected to be visible from any significant sensitive viewpoints. The visual impact of the Baxter Road Substation would likely be Low.

3.3.4 Monahan Creek Substation

Monahan Creek Substation would likely be visible to surrounding residents and to motorists and commuters along Delameter Road and Monahan Road. The location of the substation would likely mean few long-range views; however, the substation would likely dominate the attention of viewers that have a foreground view, including users of Delameter Road. From beyond the immediately adjacent area, foreground vegetation would likely block views of most of the substation. No scenic viewpoints or designated areas are expected to be affected. The substation would likely be visible, attract attention, but not completely dominate the visual character of the landscape and therefore have a contrast rating of Moderate. With a contrast rating of Moderate and a landscape rating of Low, the expected visual impact of the substation is Low.

3.4 West Alternative

The impacts of the West Alternative and its options are summarized in Table 3-2. The contrast and impact of the segments within the options are discussed below.

Table 3-2 West Alternative Contrast Ratings and Visual Impact

Route	Segment	Segment Length (miles)	Contrast Ratings[1] and Visual Impact						
			Form	Line	Color	Texture	Scale	Overall Contrast	Visual Impact
West Alternative	2	6.04	Strong	Strong	Moderate	Moderate	Strong	**Moderate**	**Low**
	4	0.77	n/a	n/a	n/a	n/a	n/a	**Strong**	**High**
	9	18.72	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Moderate**
	25[2]	29.87	Moderate	Moderate	Weak	Weak	Strong	**Moderate**	**Moderate**
	36B	1.41	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Moderate**
	41	1.27	Moderate	Weak	Weak	Weak	Moderate	**Moderate**	**Moderate**
	45	0.67	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Moderate**
	50	4.09	Moderate	Moderate	Weak	Weak	Moderate	**Moderate**	**Moderate**
	52	4.65	Weak	Weak	Weak	Weak	Moderate	**Weak**	**Low**
	Totals	**67.49**							
West Option 1	36	0.22	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	40	2.69	Moderate	Moderate	Weak	Weak	Strong	**Moderate**	**Moderate**
	46	0.46	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Moderate**
	Totals	**3.37**							
West Option 2	36	0.22	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	36A	1.03	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	37	0.67	n/a	n/a	n/a	n/a	n/a	**Strong**	**High**
	38	0.66	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	43	1.86	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	48	2.49	Moderate	Moderate	Weak	Weak	Strong	**Moderate**	**Moderate**
	51	2.07	Moderate	Moderate	Weak	Weak	Weak	**Moderate**	**Moderate**
	Totals	**9.00**							
West Option 3	36	0.22	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	36A	1.03	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	37	0.67	n/a	n/a	n/a	n/a	n/a	**Strong**	**High**
	38	0.66	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	39	5.35	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Moderate**
	T	0.31	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	49	2.73	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Low**
	51	2.07	Moderate	Moderate	Weak	Weak	Weak	**Moderate**	**Moderate**
	Totals	**13.04**							

Notes:
1. Only segments that had a visual simulation produced have individual contrast ratings for form, line, color, texture, and scale.
2. Contrast rating for form, line, color, texture and scale is for Viewpoint 25-1, overall contrast rating and visual impact is for Viewpoints 25-1, 25-2 and 25-3.

Segment 2: Typical views towards Segment 2 would be partially or fully obstructed by vegetation and some residences. The segment would be visible near Delameter road on the north end of the segment and then from a select few rural residences at a few locations along Hazel Dell Road and rural residences in the area of Trout Lake Road. It would also be visible at the southern end of the segment in Longview. With a landscape rating of Low and an overall contrast rating of Moderate, the impact of the segment would likely be Low.

Segment 4: This short segment runs adjacent to a residential area at the south end of the neighborhood of the West Side Highway and across I-5. For the residences along the right-of-way, the contrast would be Strong due to the scale of the towers created by their proximity. With an existing landscape rating of Medium and a contrast rating of Strong, the overall impact of Segment 4 would likely be High.

Segment 9: Segment 9 covers a long distance between Kelso/Longview and just north of the Lewis River, running adjacent to existing circuits. At the north end, the segment crosses over I-5 and through rural residential areas that decrease in density farther south along the segment. The expected contrast along Segment 9 would likely be Moderate or Strong, due to the large scale of the towers relative to their proximity to residences. The overall contrast of the segment is Moderate, as only certain residences would have the view dominated by the segment. The experience of most viewers would be slightly more distant and the line would be visible, but would not totally dominate the view. With a landscape rating of Medium and a contrast rating of Moderate, the overall impact of the segment would likely be Moderate.

Segment 25: Typical views of Segment 25 are from residences adjacent to the right-of-way or from nearby residential areas. The towers would dominate the view of anyone located adjacent to the right-of-way due to the towers' large scale and proximity to the viewer. From slightly farther away, the view of the segment would be partially obscured by trees and other houses. Most views would have many other existing visual alterations in the view, which would dilute the viewer's attention towards the segment. Three visual simulations along Segment 25 were created and are depicted in Figures 3-1 to 3-3.

Viewpoint 25-1 is specifically located on NE Salmon Creek Avenue; it is also representative of views from within or adjacent to the right-of-way through the low density rural residential areas north of Hazel Dell. The segment expands the cleared right-of-way, which disrupts the form of the vegetation. The patchy vegetation patterns of this area, however, mitigate the contrast of the vegetation clearing, resulting in a Moderate contrast rating for form. The line of the horizon is altered by both the vegetation clearing and the towers. Also the transmission lines themselves create a line that the eye naturally follows, which draws the viewer's attention. Since this line contrast element already exists, the contrast of the segment is lessened, resulting in a Moderate line contrast rating. The color of the cleared area is very similar to existing conditions. The towers are a contrasting color, but do not attract attention, resulting in a Weak color contrast rating. The texture of the vegetation clearing is very similar to the existing conditions and surrounding landscape and therefore was given a Weak texture contrast rating. The scale of the clearing has increased, as well as the size of the proposed transmission towers. The size of these towers relative to the existing structures and surrounding vegetation draw the attention of the viewer and were assigned a Strong contrast rating for scale. The overall contrast rating of Segment 25 from this viewpoint is Moderate.

Figure 3-1 Viewpoint 25-1

Looking North from NE Salmon Creek Avenue, Hazel Dell. West Alternative. Shows existing Ross-Lexington No. 1 line and towers 6/1 to 6/4. Simulation shows new towers 25/77 to 25/80.

Existing Conditions

Simulation

Figure 3-2 Viewpoint 25-2

Looking North-Northeast from NE 76th Avenue, Walnut Grove. West Alternative. Shows existing McNary-Ross No. 1 and Bonneville PH1-Alcoa No. 1&2 lines and Tower 6/34. Simulation shows new Tower 25/124.

Existing Conditions

Simulation

Figure 3-3 Viewpoint 25-3

Looking East from WSU Campus, Vancouver. West Alternative. Shows existing Ross-Lexington No. 1 line and Tower 6/3. Simulation shows new Tower 25/78.

Existing Conditions

Simulation

Viewpoint 25-2 is located in a residential neighborhood on the corner of NE 76th Avenue and NE 64th Street. It is representative of the view that would likely be experienced by many potential viewers in the neighborhoods surrounding Segment 25. The segment consists of existing right-of-way through suburban areas, so the main change is the visibility of the proposed towers above houses. The segment has Weak form contrast, as the main body of the view is largely unchanged. The line contrast is Moderate because the line of the horizon above the trees is more prominently disrupted by the taller towers. The color of the segment is very similar to existing conditions, so has Weak contrast. The texture element is also very similar to existing conditions and displays Weak contrast. The scale is a Moderate contrast, as the size of the proposed towers stands out more over the trees and houses and begins to dominate the landscape. The overall contrast of Segment 25 with the existing landscape at this viewpoint is Moderate.

Viewpoint 25-3 is located on the parking lot of Washington State University's Vancouver campus in Mt. Vista. It is representative of the view likely to be experienced by students and staff of the university as well as some residents of Mt. Vista. In this area, Segment 25 follows an existing right-of-way and the main change is the addition of new, taller towers to the right-of-way. The segment has Weak form contrast because the main body of the view is largely unchanged. The segment has Moderate line contrast, as the line of the horizon above the trees is more prominently disrupted by the taller towers. The color of the segment is very similar to existing conditions, so has Weak contrast. The texture element is also very similar to existing conditions and displays Weak contrast. The element of scale moderately contrasts, as the size of the towers now stands out more over the trees and begins to dominate the landscape. The overall contrast of Segment 25 with the existing landscape at this viewpoint is Moderate.

The overall contrast of Segment 25 across its considerable length is Moderate. The effect of vegetation clearing is moderated because it follows an existing right-of-way. The project's towers are larger and taller than existing structures, which would draw the attention of more viewers, but the towers are unlikely to be dominant in the landscape in contrast to existing conditions. With a landscape rating of Medium and an overall contrast of Moderate, the overall impact of Segment 25 on visual resources would likely be Moderate.

Segment 36B: This segment parallels segments 36 and 36A, and would run along the south side of the existing right-of-way. Typical views would have an unobstructed view of the segment. Some clearing of vegetation would be required where the segment crosses NE 199th Avenue and therefore has a Moderate contrast. The segment would be visible from the residences along NE Stoney Meadows Drive that back onto the open space as well as from NE 199th Avenue. With the segment on the south side of the existing right-of-way, the vegetation buffer between the residential area around NE 48th Circle and the towers would be maintained and visibility from 48th Circle is predicted to be limited. With a Moderate overall contrast and Medium landscape rating, the overall visual impact would likely be Moderate.

Segment 41: Typical views of Segment 41 would be from the Great Mountain Golf Course, NE 28th Street, and few residences along NE 28th Street. The typical view from the golf course would be unobstructed, whereas most residents would have a partially obstructed view.

A visual simulation viewpoint along Segment 41 is depicted in Figure 3-4. Viewpoint 41-1 simulates the view from NE 28th Street looking northwest. It is also representative of other unobstructed views that would be typical of those found on the golf course and to residents that are directly adjacent to the right-of-way. The triple-circuit tower replaces the previous double-circuit tower. The proposed tower for this segment is approximately twice the height than the tower it replaces, but requires little new right-of-way clearing. The segment has Moderate form contrast because the substantially larger tower draws more attention to its shape in contrast to its

surroundings. The line contrast is Weak, as the line of the horizon and the line of the circuits is similar to existing conditions. The color contrast is Weak, as the colors are very similar to existing conditions. The contrast in texture is also Weak. The scale is Moderate, as the larger towers stand out from their surroundings and begin to dominate the view. The overall contrast of the segment from this viewpoint is Moderate.

The overall contrast for the segment is Moderate. With a contrast rating of Moderate and a landscape rating of Medium, the overall visual impact of Segment 41 would likely be Moderate.

Segment 45: Typical views of Segment 45 would be direct, close views by residences along the right-of-way or partially obstructed views by nearby residents and motorists along NE 28th Street other smaller residential roads. Segment 45 shares characteristics with Segment 41 and the same contrast ratings apply as the ratings for Viewpoint 41-1 and the segment overall. The overall contrast for the segment is Moderate. With a contrast rating of Moderate and a landscape rating of Medium, the overall visual impact of Segment 45 would likely be Moderate.

Segment 50: Typical views of this segment are along rural roads or from residences adjacent to the segment. For much of its length, the segment passes through agricultural fields with open views but few viewers. At both ends of the segment, it passes through rural residential neighborhoods where the segment is highly visible from homes immediately adjacent to the right-of-way and would also be visible from more distant residences.

A visual simulation viewpoint along Segment 50 is depicted in Figure 3-5. Viewpoint 50-1 shows the view from NE 3rd Street looking northwest through an open rural section of Segment 50. This view is typical of the central section of the segment. The form of the segment has Moderate contrast with existing conditions, as the additional larger tower has a different shape than the existing towers, which promotes further disharmony in the landscape. The line contrast is Moderate, as the eye is drawn in similar ways as with existing conditions but the effect is increased to start to dominate the landscape. There is Weak contrast in the color element because there is little effect on vegetation and the towers and lines resemble existing conditions. There is Weak texture contrast, as the towers and lines are adjacent to existing lines and do not alter the vegetation in this view. The contrast in scale is Moderate, as the larger towers attract the attention of the viewer and begin to dominate their surroundings. Overall the contrast of the segment at this viewpoint is Moderate.

At the southeast end of the segment, the configuration is a triple circuit to minimize the right-of-way requirements. The larger triple-circuit tower would likely have a Moderate contrast with the existing conditions. The overall contrast for the segment is expected to be Moderate. With a landscape rating of Medium and an overall contrast rating of Moderate, the visual impact of Segment 50 would likely be Moderate.

Figure 3-4 Viewpoint 41-1

Looking Northwest from NE 28th Street, North of Camas, South of State Highway 500. West Alternative. Shows existing Bonneville PH1-Alcoa No. 1&2 line. Simulation shows new towers 41/4 to 41/7.

Existing Conditions

Simulation

Figure 3-5 Viewpoint 50-1

Looking Northwest from NE 3rd Street, North of Camas. West Alternative and Crossover Option 1. Shows Bonneville PH1-Alcoa No. 1&2 line and existing towers 3/5, 3/6, and 4/1 to 4/4. Simulation shows new towers 50/5 to 50/10.

Existing Conditions

Simulation

Segment 52: Views of Segment 52 range from unobstructed, distant views in open rural areas, close up views from roads and residences along the right-of-way in Camas, and views from Highway 14. North of the Columbia River Valley, the view and configuration would be similar to Viewpoint 51-1, as the landscape and line configuration are similar. The rebuilt 230-kV lines and proposed towers are larger than existing circuits and are no longer matching, so have more contrast than the existing towers. The contrast is Weak, however, because the size of the cleared right-of-way and number of towers remains relatively unchanged and is unlikely to dominate the characteristic landscape any more than existing conditions.

A visual simulation viewpoint along Segment 52 is depicted in Figure 3-6. Viewpoint 52-1 simulates the view of the segment from the Lewis and Clark Camp National Historic Site, located along Highway 14 (the Lewis and Clark Highway). It represents a middle-distance view of the segment as it descends into the Columbia River Valley. The contrast in form is Weak, as from this distance the greater size and shape of the towers do not begin to dominate the view. The line contrast is Weak because the line the eye follows changes very little from existing conditions. The color contrast is Weak, because colors are maintained from existing conditions. Texture contrast is also Weak, as there are not noticeable texture changes. The contrast in scale is Moderate, as the larger towers are noticeably larger than existing conditions and their surroundings. The overall contrast at this viewpoint is Weak, as the changes are noticeable, but are not dominant when compared to existing conditions.

The overall contrast of Segment 52 is Weak: the new towers, though noticeably larger and less harmonious, replace existing towers and therefore do not dominate the landscape in comparison to the existing landscape. With an overall Weak contrast and a landscape rating of Medium, the overall visual impact of the segment would likely be Low.

Overall Impact: The West Alternative has Moderate impact extending for most of the length of the alternative. There are “hot spots” of High impact localized to a fairly limited number of residences on segments 4 and 36. This alternative does not impact any recognized scenic areas or viewpoints, but has localized impacts on a large number of residents along the proposed route. The overall impact of the West Alternative would likely be Moderate to High.

Figure 3-6 Viewpoint 52-1

Looking North-Northeast from Lewis and Clark Highway, Camas. All action alternatives. Shows existing lines North Bonneville-Troutdale No. 1, North Bonneville-Troutdale No. 2, and North Camas-Oak Park No. 1, and existing towers 1/1 to 1/12, and 2/1 to 2/8. Simulation shows new towers 52/3 to 52/10.

Existing Conditions

Simulation

3.4.1 West Option 1

West Option 1 replaces segments 36b, 41 and 45 with segments 36, 40 and 46.

Segment 36: Through most of its short length, Segment 36 passes through rural fields where typical views would have a clear view of the segment, since it passes over flat ground with little vegetation. The contrast would be Weak because little vegetation clearing would be required and only the towers would be visible. The segment would be visible from the residences along NE Stoney Meadows Drive that back onto the open space. With a Weak overall contrast and Medium landscape rating, the overall impact would likely be Low.

Segment 40: For much of its length, views of Segment 40 are from several hundred feet away, across relatively open rural terrain. There are unobstructed or partially obstructed views from several residential roads and homes southwest of the segment. At the south end of the segment, it passes over NE Goodwin Road and through Camas Meadows Golf Course.

A visual simulation along Segment 40 is depicted in Figure 3-7. Viewpoint 40-1 depicts the view from the Lacamas Heritage Trail parking area off NE Goodwin Road. This portion of the segment includes the rebuilding of the existing 230-kV lines onto a new double-circuit 500-kV tower with the new line. This results in a tower height 2-3 times higher than the existing tower but minimizes the need for additional right-of-way or clearing. The form of the segment contrasts moderately with existing conditions as the shape of the new towers has changed and is more visible in the distance. The segment has Moderate line contrast with existing conditions as the towers now project much higher above the line of the horizon and above the ground, which draws the path of the eye to the alteration. The contrast in color is Weak, as the larger towers result in more metallic grey in the view; however, the color element alone does not attract attention. The texture contrast is also Weak, as it does not attract the viewer's attention. The contrast in scale is Strong, as the proposed towers dominate the view from close up and are visible from greater distances since they are taller than the surrounding trees. The overall contrast at Viewpoint 40-1 is Moderate.

The overall contrast of Segment 40 is Moderate, due to the taller towers that would be visible from a greater distance and would begin dominating the view from closer viewpoints. With an overall contrast of Moderate and a landscape rating of Medium, the overall visual impact of the segment would likely be Moderate.

Segment 46: This short segment passes through green space, the Lacamas Heritage Trail, and near residences. Views from the trail would be from directly in the right-of-way and would be similar to Viewpoint 40-1. It has the same contrast rating as Viewpoint 40-1 (Moderate). From residences set back from the right-of-way, the view would likely be partially obstructed by vegetation and other houses. The contrast from these locations would likely also be Moderate, as the towers would not be as prominent as closer up; however, the larger proposed double-circuit towers would be more visible above foreground obstructions such as houses or trees. With an overall contrast rating of Moderate and a landscape rating of Medium, the overall visual impact of Segment 46 would likely be Moderate.

***Overall Impact*:** West Option 1 removes three segments with Moderate impacts and adds three segments with impacts similar to those they replace. West Option 1 is considered to have the same overall impact as the West Alternative.

Figure 3-7 Viewpoint 40-1

Looking East-Southeast from Lacamas Heritage Trail Parking Area. West Option 1. Shows existing lines North Bonneville-Ross No. 1 and North Bonneville-Ross No. 2, and towers 26/3 to 26/5. Simulation shows new towers 40/12 to 40/14.

Existing Conditions

Simulation

3.4.2 West Option 2

West Option 2 replaces segments 36B, 41, 45and 50 with segments 36, 36A, 37, 38, 43, 48 and 51.

Segment 36: See West Option 1, Segment 36.

Segment 36A: This segment would be very similar to Segment 36. Typical views would have a clear view of the segment. As little vegetation clearing would be required and only the towers would be visible, the contrast would be Weak. The segment would be visible from the residences along NE Stoney Meadows Drive that back onto the open space as well as from NE 199th Avenue. With a Weak overall contrast and Medium landscape rating, the overall impact would likely be Low.

Segment 37: Segment 37 would be visible from the residences along the north edge of the right-of-way, specifically from the residential area around NE 48th Circle and from NE 199th Ave. The segment would remove much of the treed visual barrier between the residences and the right-of-way. This would cause the segment to be very prominent, as well as cause the previously obstructed existing segments to be visible. From these residences, the contrast would be Strong. From the road, the expected contrast is Weak: to motorists, the segment would only be visible momentarily where it runs perpendicular to the road and would not likely attract the attention of viewers.

The impact of Segment 37 is localized to specific residences and would have little impact beyond the residential area around NE 48th Circle. The overall contrast is Strong. With a Strong overall contrast and a Medium landscape rating, the overall visual impact of the segment would likely be High.

Segment 38: Views of Segment 38 would be largely obscured by vegetation. The top of the towers may be visible to some residents. The expected contrast of any potential views is Weak, as they are unlikely to attract the viewer's attention. With a Weak contrast and Low landscape rating, the overall visual impact of Segment 38 would likely be Low.

Segment 43: Views of Segment 43 would be mostly obstructed in the northern half of the segment. It would be visible to nearby residents and roadways. Because Segment 43 would be new right-of-way, it would attract the viewer's attention from the existing landscape; however, because the landscape consists of patches of trees, the discontinuous patterns would reduce the attention drawn to the segment. The overall anticipated contrast of Segment 43 is Weak. With a Weak contrast rating and Medium landscape rating, the overall visual impact of the segment would likely be Low.

Segment 48: Segment 48 would be seen by rural residences adjacent to the right-of-way and more distant residences with a partially obscured view. It would also be visible to motorists along NE 267th Avenue, which is crossed by the segment.

A visual simulation viewpoint along Segment 48 is depicted in Figure 3-8. Viewpoint 48-1 simulates the view from NE 267th Ave looking west-southwest. Right-of-way width is not changed by West Option 2, but larger double-circuit towers are added. These towers have Moderate form contrast, as they have a different, less harmonious shape, and are visible from much farther away. The proposed towers have Moderate line contrast, as they stand out above the line of the horizon well into the distance, whereas only the nearest existing towers are above the horizon. The color contrast color is Weak, as the larger towers result in more metallic grey in

the view; however, the color element alone does not attract attention. The texture contrast is also Weak, as it does not attract the viewer's attention. The contrast in scale is Strong, as the proposed towers dominate the view from close up and would be visible from greater distances than the existing towers since the proposed towers are taller than the surrounding trees. The overall contrast at Viewpoint 48-1 is Moderate.

The overall contrast of the segment is Moderate, as most potential views would be similar to Viewpoint 48-1. With an overall contrast rating of Moderate and a landscape rating of Medium, the overall visual impact of Segment 48 would likely be Moderate.

Segment 51: Views of Segment 51 are typically from rural residences and roads. Along this segment, the existing 230-kV towers would be replaced with one taller 230-kV double-circuit tower and a similarly sized single circuit 500-kV tower. The proposed towers are approximately twice the height of the existing towers and would no longer match, which is less harmonious than the existing matching towers. This is visually preferable, however, to a third set of towers and a wider right-of-way.

A visual simulation viewpoint along Segment 51 is depicted in Figure 3-9. Viewpoint 51-1 simulates the view from NE Zeek Road, looking south. The towers have Moderate form contrast, as they are larger than existing towers, have a different, less harmonious shape, and are visible farther into the distance. The taller towers also have Moderate line contrast, as they stand out above the line of the horizon well into the distance. The contrast of the project's color is Weak: the larger towers result in more metallic grey in the view, but the color element alone does not attract attention. The texture contrast is also Weak, because it does not attract the viewer's attention. The contrast in scale is Moderate, as the proposed towers are more prominent than the existing towers, but do not dominate the view and the characteristic landscape. The overall contrast at Viewpoint 51-1 is Moderate.

The overall contrast of Segment 51 is Moderate, as most viewing conditions would be similar to Viewpoint 51-1.

With an overall contrast rating of Moderate and a landscape rating of Medium, the overall visual impact of Segment 51 would likely be Moderate.

Overall Impact: West Option 2 removes three segments with Moderate impact and adds two segments with Low impact, four segments with Moderate and one segment with High impact. This option shares the impact of the West Alternative; however, the impact to residents along NE 48th Circle is increased from Moderate (Segment 36B) to High (Segment 37), the visual impact to the golf course is removed and the impact on residents along NE 28th Street is transferred to farther east to a new right-of-way. This option is less preferable to West Option 1 and the West Alternative, since it would result in High impacts to several residents, would require new right-of-way and would add more and longer segments with Low and Moderate impact.

The most preferable (lowest impact) options for the West Alternative are West Option 1 and the main alternative, followed by West Option 2 and West Option 3.

Figure 3-8 Viewpoint 48-1

Looking West-Southwest from NE 267th Avenue, North of Camas. West Option 2, Crossover Option 2. Shows existing lines North Bonneville-Ross No. 1 and North Bonneville-Ross No. 2, and towers 24/2 to 24/4. Simulation shows new towers 48/1 to 48/7.

Existing Conditions

Simulation

Figure 3-9 Viewpoint 51-1

Looking South from NE Zeek Road, Washougal. Central, East, and Crossover Alternatives, and West Options 2 and 3. Shows existing lines North Bonneville-Troutdale No. 1 and North Bonneville-Troutdale No. 2. Simulation shows new towers 51/4 to 51/11.

Existing Conditions

Simulation

3.4.3 West Option 3

West Option 3 replaces segments 36B, 41, 45 and 50 with segments 36, 36A, 37, 38, 39, T, 49 and 51.

Segment 36: See West Option 1, Segment 36.

Segment 36A: See West Option 2, Segment 36A.

Segment 37: See West Option 2, Segment 37.

Segment 38: See West Option 2, Segment 38.

Segment 39: Views of Segment 39 would typically be from rural residences and glimpse views along roadways. The widened right-of-way and addition of the single-circuit 500-kV tower would, from locations along the right-of-way, resemble Viewpoint 25-1 (see Figure 3-1). It would likely have Moderate contrast from existing conditions. The overall contrast of Segment 39 is expected to be Moderate, since there are residences scattered along the length of the segment that would be exposed to both the proposed segment and existing towers due to the right-of-way widening and removal of vegetation that is currently acting as a visual barrier. With a contrast of Moderate and a landscape rating of Medium, the overall visual impact of Segment 39 would likely be Moderate.

Segment T: There are no major public views of this segment as it is located amongst mature vegetation and is not on exposed terrain, and the views of the segment from the closest residences would likely be blocked by vegetation. The overall visual impact of Segment T would likely be Low.

Segment 49: Views of Segment 49 would likely be limited through the northern two thirds of the segment, as it is not exposed to roads, residences, or other viewpoints of consideration. Near the southern end of the segment, there are rural residences located immediately adjacent to the right-of-way. At the southern section, the existing right-of-way would be maintained and a double circuit installed. This would allow existing visual buffers to be maintained. The taller towers would likely be visible above the trees to a handful of residents. The anticipated overall contrast of the segment is Moderate, as the scale of the double-circuit towers attracts the viewer's attention. With an overall contrast of Moderate and a landscape rating of Low, the overall visual impact of the segment would likely be Low.

Segment 51: See West Option 2, Segment 51.

Overall Impact: West Option 3 removes four segments with a Moderate impact but adds two segments with Low impact, four segments with Moderate impact, and one segment (Segment 37) with High impact. This option is less preferable than West Option 1, West Option 2, and the West Alternative, since it would result in High impacts to several residents, and would add more and longer segments with Low impacts and similar or longer segments with Moderate impacts compared to all other options.

3.5 Central Alternative

The impacts of the Central Alternative and its options are summarized in Table 3-3. The contrast and impact of the segments within the options are discussed below.

Table 3-3 Central Alternative Contrast Ratings and Visual Impact

Route	Segment	Segment Length (miles)	Contrast Ratings[1] and Visual Impact						
			Form	Line	Color	Texture	Scale	Overall Contrast	Visual Impact
Central Alternative	B	0.78	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	F	15.86	Weak	Moderate	Weak	Weak	Weak	**Weak**	**Low**
	G	1.39	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	H	1.53	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	10	7.93	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	12	4.96	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	15	1.86	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	23	1.29	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	L	1.71	Weak	Moderate	Weak	Weak	Weak	**Weak**	**Moderate**
	18	7.17	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	28	5.94	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	V	5.96	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	P	8.62	None	Weak	None	None	None	**Weak**	**Low**
	35	2.52	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	T	0.31	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	49	2.73	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Low**
	51	2.07	Moderate	Moderate	Weak	Weak	Weak	**Moderate**	**Moderate**
	52	4.70	Weak	Weak	Weak	Weak	Moderate	**Weak**	**Low**
	Totals	**77.33**							
Central Option 1	A	2.50	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	Totals	**2.50**							
Central Option 2	1	6.42	0	0	0	0	0	**Weak**	**Low**
	4	0.77	n/a	n/a	n/a	n/a	n/a	**Strong**	**High**
	5	1.93	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	8	1.61	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	11	5	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	Totals	**15.73**							
Central Option 3	M	2.39	Moderate	Weak	Weak	Weak	Low	**Weak**	**Moderate**
	26	6.54	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Moderate**
	30	6.01	Weak	Weak	Weak	Weak	Weak	**Weak**	**Low**
	Totals	**14.94**							

Notes:
1. Only segments that had a visual simulation produced have individual contrast ratings for form, line, color, texture, and scale.

Segment B: Segment B is not expected to be visible from any significant viewpoints. The overall impact of this segment would likely be Negligible.

Segment F: Views of Segment F are typically obstructed by surrounding vegetation. The segment is most visible as it crosses the Cowlitz River valley. As it crosses the valley and travels south along the slopes on the east side of the valley, locations with potential views of the segment include views from the Cowlitz River, I-5, Highway 504, and roads and residences surrounding Bond Road on the east side of I-5. In general, there are few viewing opportunities of the segment along this route. The view from the river, I-5 and highways would likely be a glimpse view of the lines overhead and would likely have Weak contrast, as the segment is not likely to attract the attention of the viewer. There is one residence that would be directly adjacent to the right-of-way. To this resident, the contrast is likely to be Moderate to Strong. The overall contrast of Segment F is Weak, as it is unlikely to significantly attract the attention of viewers. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment G: Segment G is not expected to be visible from any significant viewpoints. The overall impact of this segment would likely be Negligible.

Segment H: Segment H would not likely have any considerable viewing locations. It may be visible from a few rural residences located at the end of Mahaffey Road, although the views would be oblique and likely partially obstructed. As such, the expected contrast for the segment is Weak. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment is Low.

Segment 10: Segment 10 would not likely have any considerable viewing locations, as it passes mainly through uninhabited forest without long range exposure to potential viewers. At the very south end of the segment, it passes over Kalama River Road and the Kalama River. At these locations the lines would be visible overhead; however, the towers would not likely be visible due to foreground vegetation. The contrast of just the lines passing over the river and road is likely to be Weak. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment 12: For most of its length Segment 12 would not likely have any considerable viewing locations, as it passes through mainly forest. At the very south end of the segment it would likely have slight exposure to the roads and residences in the Lewis River Valley. The small portion of the segment that could be visible passes through existing cutblocks, which would limit the contrast of the right-of-way clearing. The closest potential views would be approximately 1 mile away, so the towers are likely to have Weak contrast with the landscape. The overall contrast expected for the segment is Weak. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment 15: Views of Segment 15 would likely be limited to a few rural residences located on Tangen Road. Views to the Lewis River Valley and Ariel would likely be obstructed by topography and vegetation. Where views exist, the contrast would be mitigated by the existing transmission line right-of-way that runs parallel to the segment. For the few residences on the hill on Tangen Road, the contrast would likely be Moderate, as the segment would likely attract attention, but would not dominate the landscape. The overall contrast of the segment is expected to be Weak. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment 23: Segment 23 would be visible from the Lewis River Road and limited locations along the Lewis River, and select residences in Ariel and across the Lewis River would have partially obstructed views of the segment. The new right-of-way follows and widens the right-of-way of an existing transmission line, so the contrast with existing conditions is lessened. The expected contrast is Weak, as there are few unobstructed views and more distant views would be mitigated by the existing cleared vegetation. With a contrast of Weak and a landscape rating of Medium, the overall visual impact of Segment 23 would likely be Low.

Segment L: Segment L would likely be visible from Ariel, Lake Merwin, and occasional rural residences south of Lake Merwin. With a contrast rating of Weak and a landscape rating of High, the overall visual impact of the segment would likely be Moderate.

Segment 18: Views of Segment 18 are likely to be very limited, as it passes through forest that does not have any revealing landforms, such as exposed hillsides. At the east end of the segment there are rural residences adjacent to the right-of-way. Depending on the right-of-way vegetation clearing requirements, certain homes may not have vegetation obstructing the view to the right-of-way. Based on initial tower placement, however, there are not likely to be any direct unobstructed views of the towers. Since most of the segment would not be noticeable or would be heavily obstructed by vegetation, the contrast is likely Weak. With an overall contrast of Weak and a landscape rating of Low, the visual impact would likely be Low.

Segment 28: At the north end of the segment, it passes over NE Yale Bridge Road/Highway 503 and through Chelatchie Prairie. Here the segment would be visible to motorists and the few residences on the small prairie. The segment would likely have a Moderate contrast, as the towers would attract attention on the flat prairie and the right-of-way clearing would attract attention, particularly as it ascends the steep slope on the south side of the prairie. Neither would likely dominate the view. Farther south, the segment would also likely be visible to residents located off Healy Road. There would likely be a Moderate contrast to those few residents with an unobstructed view. The segment south of Healy Road would not likely be visible from any considerable viewpoints. The overall contrast of the segment is Weak, as it is only visible in limited locations and would largely go unnoticed. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment V: Views of the segment are mostly obstructed by foreground vegetation and topography. The subtle relief and topography make views of the landscape rare and usually partly obstructed. At the south end of Segment V, it passes over the East Fork of the Lewis River, over NE Sunset Falls Road, and near (approximately 600 feet from) a few rural residences. Views from the river are likely to be just of the lines passing overhead, as the foreground vegetation would likely block the views of the rest of the towers. The contrast at the river is likely to be Weak, as the lines are not likely to draw the attention of viewers. The segment would not likely draw the attention of motorists, as it would pass perpendicularly over the road and would only be visible as a brief glimpse; therefore, it would likely have a Weak contrast. From nearby rural residences, views are likely to be obstructed by vegetation and topography. The overall contrast of the segment is Weak. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment is Low.

Segment P: Segment P passes along the western edge of the foothills and the eastern edge of the rural residences of Hockinson and Venersborg. There are no major public viewpoints close to this segment. Most views from nearby residences are likely to be obstructed by vegetation; however, there would likely be a few residences with a direct view of the segment. To these residents, the contrast would likely be Moderate to Strong, as the proximity of the towers would begin to dominate the view.

The overall contrast of the segment is Weak, as there are no public viewing areas that are affected and localized views are likely to be isolated and limited to only a few locations. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment 35: Views of Segment 35 are likely to be obstructed by foreground vegetation. The segment crosses NE Lessard Road and within a few hundred feet of a few residences, but is not likely to be visible through the vegetation. The contrast of the segment is likely to be Weak. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment T: Segment T is not expected to be visible from any significant viewpoints. The overall impact of this segment would likely be Negligible.

Segment 49: See West Option 3, Segment 49.

Segment 51: See West Option 2, Segment 51.

Segment 52: See West Alternative, Segment 52.

Overall Impact: Most of the Central Alternative runs through sparsely populated land with few sensitive viewers. Most impacts are Low, with a few Moderate impacts around Lake Merwin and Camas. The High impact reported for Segment 4 is localized and affects a relatively few number of residents. The overall impact of the Central Alternative is Low to Moderate.

3.5.1 Central Option 1

Central Option 1 adds Segment A to extend the transmission line from the site of the proposed Baxter Road Substation to the proposed Casey Road Substation.

Segment A: Segment A is not expected to be visible from any significant viewpoints. The overall impact of this segment would likely be Negligible.

Overall Impact: Central Option 1 adds one segment of Negligible impact. Central Option 1 is considered to have a visual impact similar to the Central Alternative.

3.5.2 Central Option 2

Central Option 2 replaces segments B, F and G and the proposed Baxter Road Substation with segments 1, 4, 5, 8 and 11 and the proposed Monahan Creek Substation.

Segment 1: Typical views of Segment 1 would be at least partially blocked by the surrounding vegetation. The segment would be visible from Delameter Road and select residences in that area, although it is unlikely to be dominant in the landscape, due to the subtle relief and trees that block the view. South along the segment there is little expected visibility of the segment, as there are few residences or roads nearby and the route does not follow highly exposed terrain. Near the south end of Segment 1, as it passes down the hillside into Longview, it would likely be visible from a few residences on the north edge of Beacon Hill.

The contrast from Segment 1 is expected to range from None to Weak, as it is not likely to be visible along much of its length. It would be visible from certain locations, but is unlikely to

draw the attention of the viewer. With a landscape rating of Low and a contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment 4: This short segment runs adjacent to a residential area at the south end of the neighborhood of West Side Highway and across the Cowlitz River. For the residences along the right-of-way, the contrast would be Strong due to the scale of the towers created by their proximity. With an existing landscape rating of Medium and a contrast rating of Strong, the overall impact of Segment 4 would likely be High.

Segment 5: Segment 5 is largely obscured by the surrounding vegetation. The segment would be visible to motorists as it passes over I-5 and would have an expected contrast rating of Weak. The duration of the view would very brief as it crosses perpendicular to the road and the right-of-way clearing and towers are not likely to be noticeable farther away. The segment would also have partially obscured views from residences along Kitchen Drive and Holcomb Road. For most locations, the contrast would likely be Weak. For isolated residences adjacent to the segment, however, the contrast could be Moderate. The overall contrast for the segment is Weak, as it is unlikely to draw the attention of most viewers. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment 8: There are no potential viewpoints that are expected to have considerable views of Segment 8, as they are likely to be screened by terrain and vegetation. The overall visual impact of Segment 8 would likely be Negligible.

Segment 11: Segment 11 passes largely through forest with no considerable viewing opportunities. The segment does, however, pass through a rural area where it would likely be visible along parts of Rose Valley Road and to some residents of Clearwater Road. Views from the valley would likely be mostly obstructed by vegetation. The linear nature of the disturbance would draw more attention when visible than existing non-linear disturbances. The angle of viewing and the trees would likely mask the disturbance so the contrast would likely be Weak. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment is Low.

Overall Impact: Central Option 2 replaces two segments with a Negligible impact and one segment with a Low impact. These are replaced with one segment with a Negligible impact, three segments with a Low impact, and one segment with a High impact. Central Option 2 also replaces the Baxter Road Substation, rated at a Low impact with the Monahan Creek Substation, rated at a Moderate impact. Central Option 2 has a higher overall visual impact than the Central Alternative and Central Option 1.

3.5.3 Central Option 3

Central Option 3 replaces segments L, 18, 28 and V with segments M, 26 and 30.

Segment M: The main view of interest for Segment M is at the north end where it crosses the Lewis River, south of Ariel. Both the river and nearby Merwin Lake attract recreational users who are likely to be more sensitive to potential changes to the visual landscape. From Ariel the view across the river to the south side of the valley would likely be partially obstructed by foreground vegetation. Where views are possible the tower would likely be visible on the far side, and the right-of-way clearing may be noticeable but not dominant up the hill on the south side. The level of contrast would largely depend on whether the vegetation can maintained on the river valley slope. Assuming that the vegetation can be kept in the right-of-way through the

lower part of the valley on the steeper slopes, the contrast would likely be Weak. Farther south along the segment, the surrounding vegetation and topography would result in few or obstructed views of the segment and Weak contrast.

A visual simulation viewpoint along Segment M is depicted in Figure 3-10. Viewpoint M-1 simulates the view from the swimming beach on Lake Merwin in Ariel, looking south. The location has Moderate form contrast, as the larger towers have a different, less harmonious shape, and are visible into the distance. The location has Weak line contrast, as the towers do not stand out above the line of the horizon. The contrast of the segment's color is Weak, as the towers result in more metallic grey in the view; however, the color element alone does not attract attention. The texture contrast is also Weak, as it does not attract the viewer's attention. The contrast in scale is Weak, as the proposed towers are only somewhat prominent, and do not dominate the view and the characteristic landscape. The overall contrast at Viewpoint M-1 is Low.

The overall contrast of the Segment M would likely be Weak, since the segment would generally be less visible than at Viewpoint M-1. With an overall contrast of Weak and a landscape rating of High, the overall visual impact would likely be Moderate.

Segment 26: Potential viewing locations of Segment 26 include rural residential homes and Highway 503. There are no key public viewpoints that are likely to be affected. Rural residential homes immediately adjacent to the right-of-way would likely have a Moderate to Strong contrast. From Highway 503 and other public roads, the contrast of the segment is likely going to be Weak, as the segment would pass over the road and would only offer a glimpse view to motorists. Overall, the contrast of the segment would likely be Moderate. With an overall contrast of Moderate and a landscape rating of Medium, the overall visual impact of Segment 26 would likely be Moderate.

Segment 30: Typical views of Segment 30 are obstructed by vegetation and topography. Potential public viewing locations include Yacolt, 2 miles to the East, and where the segment crosses the East Fork of the Lewis River west of Lucia Falls and Moulton Falls Park. There are also a few rural residences close to the segment. From the Lewis River, the contrast of the segment is expected to be Weak, as foreground vegetation would block the view of the towers. The lines would be visible crossing the river, but are unlikely to draw the attention of the viewer. From residences, the contrast would likely be moderate, as the towers may be visible above the trees. With an overall contrast of Weak and a landscape rating of Medium, the overall visual impact of the segment would likely be Low.

Overall Impact: Central Option 3 adds one segment with a Low and two segments with a Moderate impact and removes three segments with a Low impact and one segment with a Moderate impact. The most noticeable visual impact resulting from Central Option 3 would occur where it crosses the Lewis River near Ariel. The difference between the two crossings does not affect the visual impact rating. However, the option does add Segment 26, which has a higher visual impact (Moderate) than the segments it replaces. Central Option 3 is considered to have a higher visual impact than the Central Alternative and Central Option 1 and a lower impact than Central Option 2.

The most preferable (lowest impact) options for the Central Alternative are Central Option 1 and the main alternative, followed by Central Option 3 and Central Option 2.

Figure 3-10 Viewpoint M-1

Looking South near Swimming Beach on Lake Merwin, Ariel. Central and Crossover Alternatives. Simulation shows new towers M/2 to M/4.

Existing Conditions

Simulation

3.6 East Alternative

The impacts of the East Alternative and its options are summarized in Table 3-4. The contrast and impact of the segments within the options are discussed below.

Table 3-4 East Alternative Contrast Ratings and Visual Impact

Route	Segment	Segment Length (miles)	Contrast Ratings[1] and Visual Impact						
			Form	Line	Color	Texture	Scale	Overall Contrast	Visual Impact
East Alternative	B	0.78	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	F	15.86	Weak	Moderate	Weak	Weak	Weak	**Weak**	**Low**
	I	2.77	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	K	22.8	Moderate	Weak	Weak	Weak	Moderate	**Weak**	**Low**
	W	1.31	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	O	19.47	Weak	Weak	Weak	Weak	Weak	**Weak**	**Low**
	Q	2.63	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	S	0.41	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	49	2.73	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Low**
	51	2.07	Moderate	Moderate	Weak	Weak	Weak	**Moderate**	**Moderate**
	52	4.70	Weak	Weak	Weak	Weak	Moderate	**Weak**	**Low**
	Totals	**75.53**							
East Option 1	3	7.82	0	0	0	0	0	**Moderate**	**Low**
	7	2.05	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	11	5	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	J	2.72	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	Totals	**17.59**							
East Option 2	U	6.11	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	V	5.96	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	P	8.62	None	Weak	None	None	None	**Weak**	**Low**
	35	2.52	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	T	0.31	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	Totals	**23.52**							
East Option 3	R	3.68	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	Totals	**3.68**							

Notes:
1. Only segments that had a visual simulation produced have individual contrast ratings for form, line, color, texture, and scale.

Segment B: See Central Alternative, Segment B.

Segment F: See Central Alternative, Segment F.

Segment I: Views of this segment are largely obstructed by vegetation and topography. No significant viewpoints are likely to have views of the segment. Some locations along Rose Valley

Road may have views toward the segment. These views are likely to be partially obstructed and portions of the segment that are visible are likely not to attract attention. The overall contrast of Segment I is likely Weak. With a contrast rating of Weak and a landscape rating of Medium, the overall visual impact of the segment would likely be Low.

Segment K: The majority of Segment K is obstructed by vegetation. At the south end of the segment, it descends between Lake Merwin and Yale Lake. The segment would be briefly visible as it crosses Lewis River Road and would be visible from Yale Road as it passes through an open area east of the road. At both these locations it is likely to have Weak contrast, as it would not likely attract the attention of viewers. Views to residences are likely to be at least partially obscured by vegetation, so the expected contrast is Weak. The segment crosses Lake Merwin, east of the Yale Bridge. From Lake Merwin the lines would be visible, and potentially the tops of the towers as well.

A visual simulation viewpoint along Segment K is depicted at Viewpoint K-1 (see Figure 3-11). Viewpoint K-1 simulates the view from Yale Bridge Road just south of the intersection with Lewis River Road, looking east. The segment has Moderate form contrast at this location, as the larger towers have a different, less harmonious shape, and are visible farther into the distance. The segment has Weak line contrast, as the taller towers now stand out above the vegetation but not above the line of the horizon. The contrast of the segment's color is Weak, as the larger towers result in more metallic grey in the view; however, the color element alone does not attract attention. The texture contrast is also Weak, as it does not attract the viewer's attention. The contrast of the scale is Moderate, as the proposed towers are more prominent, but do not dominate the view and the characteristic landscape.

The overall contrast at Viewpoint K-1, and Segment K, is Weak. . With an overall contrast of Weak and a landscape rating of Medium, the overall visual impact would likely be Low.

Segment W: Views to Segment W are expected to be largely obstructed by vegetation. The most significant view would be as the segment crosses over a small arm of Lake Merwin. The towers are likely going to be set back from the top of the escarpment with the underlying vegetation retained, so as not to be visible from the water. With only the lines visible, the anticipated contrast is Weak. With an overall contrast of Weak and a landscape rating of Medium, the visual impact would likely be Low.

Segment O: There are few potential views of Segment O, as there are no major roads in this area. Longer range views could be possible due to the greater relief; however, the landforms do not appear to expose the segment to longer range views. With an overall contrast of Weak and a landscape rating of Low, the visual impact would likely be Low.

Segment Q: Views to Segment Q would likely be restricted to motorists traveling along NE Boulder Creek Road. Rural residents nearby would likely not have a direct view of the segment due to vegetation. The overall contrast of the view would likely be Weak. With an overall contrast of Weak and a landscape rating of Low, the visual impact would likely be Low.

Segment S: There are no potential viewpoints that are expected to have meaningful views of Segment S, as they are likely to be screened by terrain and vegetation. The overall visual impact of Segment S would likely be Negligible.

Segment 49: See West Option 3, Segment 49.

Segment 51: See West Option 2, Segment 51.

Figure 3-11 Viewpoint K-1

Looking East-Southeast from Yale Bridge Road, Ariel. East Alternative. Simulation shows new Tower K/79.

Existing Conditions

Simulation

Segment 52: See West Alternative, Segment 52.

Overall Impact: Most of the impacts of the East Alternative are found in the south end, as it passes through Camas. Most of the segments have Negligible to Low Impact, as there are few potential sensitive viewpoints and the segments have little contrast with the landscape. The overall impact of the East Alternative is Low to Moderate.

3.6.1 East Option 1

East Option 1 replaces segments B, F and I and the proposed Baxter Substation with segments 3, 7, 11 and J and the proposed Monahan Substation.

Segment 3: Typical views of Segment 3 are partially or fully obstructed by foreground vegetation. There are, however, locations along Delameter Road, Hazel Dell Road, Highway 411, the rural residences located between Kelso and Castle Rock, I-5, and the residences near Ostrander Road that would have a view of the segment.

At Delameter Road, the segment would likely be visible as it leaves the substation, but would not likely be dominant on the landscape due to the subtle relief and vegetation. Where the segment crosses Hazel Dell Road, the towers and lines would likely be visible above the trees from the adjacent residences and briefly visible to motorists as they pass underneath the lines. There are also about five residences at the top of the hill along Pilgrim Road that would have a view of the segment, if their properties have a view to the south and beyond the trees. In these areas, the contrast would likely be Weak to Moderate. Along Hazel Dell Road, the segment would likely be visible to motorists and some residences along the road. The top of the transmission towers would likely just be visible at the top of the hill on the east side of the road. The contrast would likely be Weak, as it would not draw the viewer's attention due to its angle of viewing and being largely obscured. The view from Highway 411 would likely be a very brief view of the lines where they pass over the road. The contrast here would likely be Weak, as this type of view does not tend to draw the attention of motorists.

Along the flat floodplain, the segment would be visible from several residences, where the segment would likely have a Weak to Moderate contrast. Where Segment 3 crosses the Interstate, the contrast would likely be Weak, as the lines would pass over the highway and would only be momentarily visible since they cross perpendicularly. The neighborhood at the south end of Segment 3 would likely have view of the segment with a Moderate contrast.

The overall contrast rating for Segment 3 is Moderate, as some residences would have a view in which the segment could dominate the viewer's attention. With a landscape rating of Low and a contrast rating of Moderate, the overall impact of Segment 3 would likely be Moderate.

Segment 7: Most of Segment 7 would be obstructed by foreground vegetation and topography. Residents on the hill off Ostrander Road may have a view of the segment as it crosses the hillside at the west end of the segment. These views are likely to be partially obstructed and roughly half a mile from the segment. From these locations, the contrast of the segment with the existing landscape would likely be Weak. The overall contrast for the segment would likely be Weak. With a landscape rating of Low and an overall contrast rating of Weak, the overall impact of the segment would likely be Low.

Segment 11: See Central Option 2, Segment 11.

Segment J: Segment J is not expected to be visible from any significant viewpoints. The overall impact of this segment would likely be Negligible.

Overall Impact: East Option 1 replaces one segment with a Negligible impact and two segments with a Low impact with one segment with a Negligible impact and four segments with a Low impact. The option also replaces the Baxter Road Substation, rated at a Low impact, with the Monahan Creek Substation, rated at a Moderate impact. East Option 1 has a slightly higher impact than the East Alternative.

3.6.2 East Option 2

East Option 2 replaces segments O, Q and S with segments U, V, P, 35 and T.

Segment U: Segment U is not expected to be visible from any significant viewpoints. The overall impact of this segment would likely be Negligible.

Segment V: See Central Alternative, Segment V.

Segment P: See Central Alternative, Segment P.

Segment 35: See Central Alternative, Segment 35.

Segment T: See Central Alternative, Segment T.

Overall Impact: East Option 2 replaces one segment with a Negligible impact and two segments with a Low impact with one segment with a Negligible impact and four segments with a Low impact. The choice between East Option 2 and the East Alternative is mainly a balance between Low impacts to outdoor and recreational users of the landscape in East Option 2, and Low impacts to residences in the East Alternative. East Option 2 is considered to have visual impacts similar to the East Alternative.

3.6.3 East Option 3

East Option 3 replaces Segment Q with Segment R.

Segment R: Segment R is not expected to be visible from any significant viewpoints. The overall impact of this segment would likely be Negligible.

Overall Impact: East Option 3 replaces one segment with Low impact with a segment with Negligible impact. East Option 3 is considered to have visual impacts similar to the East Alternative.

The most preferable (lowest impact) options for the East Alternative are East Option 2, East Option 3, and the East Alternative.

3.7 Crossover Alternative

The impacts of the Crossover Alternative and its options are summarized in Table 3-5. The contrast and impact of the segments within the options are discussed below.

Segment 2: See West Alternative, Segment 2.

Segment 4: See West Alternative, Segment 4.

Segment 9: See West Alternative, Segment 9.

Segment 14: There are no potential viewpoints that are expected to have meaningful views of Segment 14, as they are likely to be screened by terrain and/or vegetation. The overall visual impact of Segment 14 would likely be Negligible.

Table 3-5 Crossover Alternative Contrast Ratings and Visual Impact

Route	Segment	Segment Length (miles)	Contrast Ratings[1] and Visual Impact						
			Form	Line	Color	Texture	Scale	Overall Contrast	Visual Impact
Crossover Alternative	2	6.04	Strong	Strong	Moderate	Moderate	Strong	**Moderate**	**Moderate**
	4	0.77	n/a	n/a	n/a	n/a	n/a	**Strong**	**High**
	9	18.72	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Moderate**
	14	1.50	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	15	1.86	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	23	1.29	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	L	1.72	Weak	Moderate	Weak	Weak	Weak	**Weak**	**Moderate**
	18	7.17	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	N	1.64	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	W	1.31	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	O	19.47	Weak	Weak	Weak	Weak	Weak	**Weak**	**Low**
	Q	2.64	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	S	0.41	n/a	n/a	n/a	n/a	n/a	**None**	**Negligible**
	49	2.73	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Low**
	51	2.07	Moderate	Moderate	Weak	Weak	Weak	**Moderate**	**Moderate**
	52	4.65	Weak	Weak	Weak	Weak	Moderate	**Weak**	**Low**
	Totals	**74.04**							
Crossover Option 1	47	0.69	n/a	n/a	n/a	n/a	n/a	**Moderate**	**Moderate**
	48	2.50	Moderate	Moderate	Weak	Weak	Strong	**Moderate**	**Moderate**
	50	4.09	Moderate	Moderate	Weak	Weak	Moderate	**Moderate**	**Moderate**
	Totals	**7.28**							
Crossover Option 2	C	3	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	E	1.34	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	Totals	**4.34**							
Crossover Option 3	D	2.86	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	E	1.34	n/a	n/a	n/a	n/a	n/a	**Weak**	**Low**
	Totals	**4.2**							

Notes:
1. Only segments that had a visual simulation produced have individual contrast ratings for form, line, color, texture, and scale.

Segment 15: Typical views to Segment 15 would likely be obscured by vegetation and terrain. The sparse rural residences south of the segment could have obstructed partial views; however, it

is unlikely that the segment would contrast with the existing landscape and draw the attention of potential viewers. There is one rural residence that appears to have a line of sight to the segment. The overall contrast of the segment is Weak. With an overall contrast of Weak and a landscape rating of Low, the overall visual impact of Segment 15 would likely be Low.

Segment 23: See Central Alternative, Segment 23.

Segment L: See Central Alternative, Segment L.

Segment 18: See Central Alternative, Section 18.

Segment N: Views of Segment N are likely to be largely obstructed by vegetation. The segment would be visible as it crosses NE Yale Bridge Road. At the road crossing, the segment is unlikely to attract the attention of motorists, as it crosses perpendicular to the road and due to the vegetation, would only be visible briefly as motorists pass under the lines. The new right-of-way partly follows and widens the right-of-way of an existing transmission line, so the contrast with existing conditions is lessened. The expected contrast is Weak at the crossing. The overall expected contrast is Weak. With an overall contrast of Weak and a landscape rating of Medium, the visual impact would likely be Low.

Segment W: See East Alternative, Segment W.

Segment O: See East Alternative, Segment O.

Segment Q: See East Alternative, Segment Q.

Segment S: See East Alternative, Segment S.

Segment 49: See West Option 3, Segment 49.

Segment 51: See West Option 2, Segment 51.

Segment 52: See West Alternative, Segment 52.

Overall Impact: The Crossover Alternative is mostly Low to Moderate impact for most of its length. Segment 4 has localized High impact to a limited number of residences. The cross-over avoids the more populated western routes and results in fewer affected residents. This alternative does not impact any recognized scenic areas or viewpoints. The overall impact of this alternative is Low to Moderate.

3.7.1 Crossover Option 1

Crossover Option 1 replaces Segment 51 with segments 47, 48 and 50.

Segment 47 would be seen by rural residences adjacent to the right-of-way, and more distant residences with a partially obscured view. The overall contrast of the segment is Moderate. With an overall contrast rating of Moderate and a landscape rating of Medium, the overall visual impact of Segment 47 would likely be Moderate.

Segment 48: See West Option 2, Segment 48.

Segment 50: See West Alternative, Segment 50.

Overall Impact: Crossover Option 1 adds three segments with a Moderate impact through a rural residential area and eliminates one with a similar impact. Crossover Option 1 offers few visual benefits to offset the added length and exposure to a greater number of sensitive viewers, since it only eliminates one segment of Moderate impact. This option has a higher impact than the Crossover Alternative and is therefore less preferable.

3.7.2 Crossover Option 2

Crossover Option 2 adds segments C and E to extend the transmission line from the site of the proposed Monahan Creek Substation to the proposed Baxter Road Substation.

Segment C: Views of Segment C are expected to be screened by vegetation and topography. The segment would likely be visible at the south end to the rural residents near Melton Road. The segment would run on existing right-of-way with reconfigured towers. As such, the expected contrast of the segment is Weak. With an overall contrast of Weak and a landscape rating of Low, the visual impact would likely be Low.

Segment E: Segment E would likely be visible from Monahan Road, Delameter Road, and the rural residents located along the right-of-way. The segment would run on existing right-of-way with reconfigured towers. As such, the expected contrast of the segment is Weak. The segment would run on existing right-of-way with reconfigured towers. As such, the expected contrast of the segment is Weak. With an overall contrast of Weak and a landscape rating of Low, the visual impact would likely be Low.

Overall Impact: Crossover Option 2 adds two segments of Low impact to the Crossover Alternative. It does not change the overall rating of the alternative, but it does have a higher overall impact because it adds segments to the main alternative without replace any segments. However, the option includes the replacement of the Monahan Creek Substation with the Baxter Road Substation, which has lower visual impacts. Crossover Option 2 is therefore preferred over the Crossover Alternative and Crossover Option 1.

3.7.3 Crossover Option 3

Crossover Option 2 adds segments D and E to extend the transmission line from the site of the proposed Monahan Creek Substation to the proposed Baxter Road Substation.

Segment D: Views of Segment D are expected to be screened by vegetation and topography. The segment would likely be visible at the south end to the rural residents near Melton Road. The segment would require new right-of-way, which would add to the contrast compared to existing conditions; however, it is unlikely that the contrast would attract attention. The expected contrast of the segment is Weak. With an overall contrast of Weak and a landscape rating of Low, the visual impact would likely be Low.

Segment E: See Crossover Option 2, Segment E.

Overall Impact: Crossover Option 3 is similar to Crossover Option 2, except that Segment D requires new right-of-way. Although the segment remains a Low impact, it would be slightly higher impact than Crossover Option 2. However, it would be preferred over Crossover Option 1 and the Crossover Alternative due to the relocation of the substation.

The most preferable (lowest impact) option for the Crossover Alternative is Crossover Option 2, followed by Crossover Option 3, the Crossover Alternative, and Crossover Option 1.

3.8 No Action Alternative

Under the No Action Alternative, visual conditions would continue as described in Section 2, Affected Environment. Transmission lines in existing right-of-way would continue to be visible by surrounding viewers. In areas without existing transmission lines, other visual alterations would continue to occur, such as forestry, urban development, and transportation.

4.0 Mitigation Measures

Standard mitigation measures to minimize impacts to visual quality include the following:

- Use dulled towers to reduce light reflectivity and overall tower visibility.
- Use non-reflective conductors and non-luminous, non-reflective insulators.
- Place towers so that they would not be visible from nearby communities when possible.
- Site new towers near existing towers and use a similar tower type, where possible. This would lessen visual clutter that can result when different types of towers are visible in a vast open landscape.
- Where feasible, site new towers to take advantage of existing screening offered by topography and/or vegetation.
- Set towers back from road crossings to minimize intrusion on views along road corridors. Preserve existing vegetation along the roadway if possible to screen the transmission lines and towers. Allow the growth of dense masses of medium shrubs parallel to the roadway where the transmission line right-of-way crosses.
- Minimize ground-disturbing activities and dispose of all waste soil off-site.
- If wetlands would be disturbed, preserve the existing topsoil in wetland areas near disturbed tower sites by stockpiling it during construction and spreading it after construction so native plant communities would regenerate and blend with the surroundings. Phase and integrate these activities with the project construction schedule to ensure the quickest rehabilitation of sites.
- Leave low-growing vegetation where possible.
- Use techniques to re-vegetate cut and fill slopes on access roads and near tower locations.
- Minimize access road placement in highly sensitive areas.

5.0 Unavoidable Impacts

If all mitigation measures are employed, the transmission towers, vegetation clearing, access roads and substations would still be visible from some locations. Towers of this size are unavoidably visible from some locations, exposing certain viewers to changes in the visual landscape. The visual impact of the West Alternative is considered Moderate to High, while the impacts of the remaining alternatives are considered Low to Moderate. The higher impact rating for the West Alternative is primarily due to the higher number of potential viewers.

Depending on the option selected, potential High visual impacts for the West, Crossover, and Central alternatives could occur where the transmission lines run in close proximity to residential neighborhoods, specifically in the area of the West Side Highway (Segment 4) and around NE 48th Circle (Segment 37).

6.0 Cumulative Effects of the Project

Cumulative effects refer to environmental impacts that are additive or interactive (synergistic) in nature and result from multiple activities over time, including the action alternatives. The U.S. Council on Environmental Quality defines cumulative effects as "the impacts on the environment that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions."

The potential for cumulative effects on the visual resources that may result from this project would be largely dependent on the extent of current and future urban and rural residential development consistent with county development plans, and on current and proposed forest harvesting operations.

Ongoing residential development will likely further encroach into what are now open spaces that are generally considered to have intrinsic scenic value. Developments also introduce more sensitive viewers to an area, which then can have the effect of increasing the perceived sensitivity to changes in the landscape resulting in changes to the landscape rating. This may cause existing and new developments to be received more negatively.

Forestry operations in the study area will continue into the future and are expected to continue to have a similar effect on the visual resources as they do under the current conditions. Forest management practices have generally improved in recent years in the area of visual impact and aesthetics, and as such, this trend would likely result in a reduction of visual impacts from future forest harvesting activities. The cumulative impact of the project with other existing and approved developments would likely be low, as the character of the affected ecoregions is not likely to change. The area encompassing the West Alternative would likely be subject to the most potential impacts in terms of viewers, as residential developments increase in the Portland/Vancouver Basin and open space is replaced by housing developments. With no major reasonably foreseeable developments known for the ecoregions of the East, Central, and Crossover alternatives, the cumulative impact for these alternatives would likely be low.

7.0 Federal, State, Local, and Permit Requirements Review

Federal Regulations

The National Environmental Policy Act (NEPA) requires in 42 USC Section 4321 that all actions sponsored, funded, permitted, or approved by federal agencies undergo planning to ensure that environmental considerations such as those related to visual resources are given due weight in decision-making. NEPA Section 101(b)(2) states that it is the "continuing responsibility of the Federal Government to use all practicable means, consistent with other essential considerations" to " assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings".

State Regulations

There are no state visual resources regulations in Oregon or Washington that apply to this project. The Washington State Environmental Policy Act (SEPA) considers visual resources as an element of the environment in its EIS requirements. Agencies with review authority under SEPA can prepare their own EIS or adopt a NEPA EIS for those projects that they feel require an EIS under SEPA.

Local Regulations

There are no specific local regulations specific to visual resources that apply to this project. See discussion on SEPA under State Regulations above.

Permit Requirements

There are no permits required with respect to visual resources.

8.0 List of Preparers

Kevin Graham. GIS and Visualization Specialist. Visual Resources Task Lead and Author.

Peter Thiede. GIS and Visualization Specialist.

9.0 References

References

Horenstein, H., Hart, R., Gearty, T, Goldberg, V. 2001. Photography. Prentice Hall, Upper Saddle River, NJ. Page 75

United States Department of the Interior (USDI). 1986a. Visual Resource Inventory. BLM Manual Handbook H-8410-1. Bureau of Land Management, Washington, D.C. 7 pages.

United States Department of the Interior (USDI). 1986b. Visual Resource Contrast Rating. BLM Manual Handbook H-8431. Bureau of Land Management, Washington, D.C.

United States Environmental Protection Agency (EPA). 2007. Level III Ecoregions of the Conterminous United States. Western Ecology Division. Corvalis, OR.

10.0 Acronyms and Glossary

Acronyms

BLM	Bureau of Land Management
BPA	Bonneville Power Administration
GIS	Geographic Information System
I	Interstate
kV	kilovolt
NEPA	National Environmental Policy Act
SEPA	State Environmental Policy Act
USDI	U.S. Department of the Interior
VNS	Visual Nature Studio
VRM	Visual Resource Management
WSU	Washington State University

Glossary

cultural modifications – Any human-caused changes in the land form, water form, vegetation, or the addition of a structure that create a visual contrast in the basic elements (form, line, color, texture) of the naturalistic character of a landscape.

cumulative impacts – Impacts created by the incremental effect of an action when added to other past, present, and reasonably foreseeable future actions.

double-circuit – Two separate electrical circuits (for alternating current, each circuit consists of three separate conductors or bundles of conductors) on the same transmission towers.

foreground and middle-ground view – The area visible from a travel route, use area, or other observation point to a distance of 3 to 5 miles. The outer boundary of this zone is defined as the point where the texture and form of individual plants are no longer apparent in the landscape.

long-range view – The area visible from a travel route, use area, or other observation point to a distance of greater than 5 miles. Also called the background distance zone.

right-of-way – An easement for a certain purpose over the land of another, such as a strip of land used for a road, electric transmission line, pipeline, etc.

scenic quality– A rating of the overall appeal of a view that is categorized as High, Medium, or Low, which is determined based on several key factors (BLM 1986). The key factors include landform, vegetation, water, color, influence of adjacent scenery, scarcity, and cultural

modifications. With a maximum possible score of 32, values are totaled with results of 19 or more ranked “High”, 12 to 18 ranked “Medium”, and 11 or less ranked “Low”.

sensitivity levels – In reference to visual resources, sensitivity is an evaluation of the viewer and as a way of ranking public concern.

single-circuit – One electrical circuit that consists of three separate conductors or bundles of conductors on one tower.

single-circuit tower – A tower that can support only one transmission line.

Page intentionally left blank

Appendix F

Electrical Effects

Electrical Effects
for the I-5 Corridor Reinforcement Project

October 2011

Prepared by

T. Dan Bracken, Inc.

for

Bonneville Power Administration

Table of Contents

1.0 Introduction **1**

2.0 Physical Description **3**
2.1 Proposed Line 3
2.2 Existing Lines 4
2.3 Action Alternatives 4
2.4 No Action Alternative 5

3.0 Electric Field **5**
3.1 Basic Concepts 5
3.2 Transmission Line Electric Fields 6
3.3 Calculated Values of Electric Fields 7
3.4 Environmental Electric Fields 8

4.0 Magnetic Field **10**
4.1 Basic Concepts 10
4.2 Transmission-line Magnetic Fields 10
4.3 Calculated Values for Magnetic Fields 11
4.4 Environmental Magnetic Fields 13

5.0 Electric and Magnetic Field (EMF) Effects **15**
5.1 Electric Fields: Short-term Effects 15
5.2 Magnetic Field: Short-term Effects 18

6.0 Regulations **19**

7.0 Audible Noise **21**
7.1 Basic Concepts 21
7.2 Transmission Line Audible Noise 22
7.3 Predicted Audible Noise Levels 23
7.4 Discussion 24

8.0 Electromagnetic Interference **24**
8.1 Basic Concepts 24
8.2 Radio Interference (RI) 25
8.2.1 Predicted RI Levels 26
8.3 Television Interference (TVI) 26
8.3.1 Predicted TVI Levels 26
8.4 Interference with Other Devices 27
8.5 Conclusion 27

9.0 Other Corona Effects **27**

10.0 Summary **27**

List of Preparers **34**

Appendix - Electrical Effects Summaries by Route Segments for the I-5 Corridor Reinforcement Project ..... **follows page 55**

List of Tables

Table 1: Physical Dimensions and Electrical Characteristics of the Proposed Single-circuit 500 kV transmission line for the I-5 Corridor Reinforcement Project 35

Table 2: Mileage and Segments of the Action Alternatives of the I-5 Corridor Reinforcement Project 36

Table 3: Electric and Magnetic Fields from the Proposed 500-kV Transmission Line When Operated on New Right-of-way 37

Table 4: Distance-weighted Average Electric and Magnetic Field Levels for the West Alternative and Options 38

Table 5: Distance-weighted Average Electric and Magnetic Field Levels for the Central Alternative and Options 40

Table 6: Distance-weighted Average Electric and Magnetic Field Levels for the Crossover Alternative and Options 41

Table 7: Distance-weighted Average Electric and Magnetic Field Levels for the East Alternative and Options 42

Table 8: Electric- and Magnetic-field Exposure Guidelines 45

Table 9: States with Transmission Line Field Limits 45

Table 10: Common Noise Levels 46

Table 11: Distance-weighted L_{50} Foul Weather Audible Noise Levels and Radio and Television Interference Levels for the West Alternative and Options 47

Table 12: Distance-weighted L_{50} Foul Weather Audible Noise Levels and Radio and Television Interference Levels for the Central Alternative and Options 48

Table 13: Distance-weighted L_{50} Foul Weather Audible Noise Levels and Radio and Television Interference Levels for the Crossover Alternative and Options 49

Table 14: Distance-weighted L_{50} Foul Weather Audible Noise Levels and Radio and Television Interference Levels for the East Alternative and Options 50

Table 15: Average Electric Fields, Magnetic Fields and Audible Noise at the Edge of the Right-of-Way by Alternative.[1] 51

List of Figures

Figure 1: Single-circuit Tower for I-5 Corridor Reinforcement Project 52
Figure 2: Plot of Electric Fields from Proposed Line on New ROW (Calculation 1.1.0) 52
Figure 3: Example Plot of Electric Field from Proposed Line on Existing ROW 53
Figure 4: Plot of Magnetic Fields from Proposed Line on New ROW (Calculation 1.1.0) 53
Figure 5: Example Plot of Magnetic Fields from Proposed Line on Existing ROW (Calculation 25.2.0) 54
Figure 6: Plot of Audible Noise from Proposed Line on New ROW (Calculation 1.1.0) 54
Figure 7: Example Plot of AN from Proposed Line on Existing ROW (Calculation 25.2.0) 55

List of Maps

Map 1: I-5 Corridor Reinforcement Project West Alternative and Options .....follows page 2
Map 2: I-5 Corridor Reinforcement Project Central Alternative and Options.....follows page 2
Map 3: I-5 Corridor Reinforcement Project East Alternative and Options.....follows page 2
Map 4: I-5 Corridor Reinforcement Project Crossover Alternative and Options .....follows page 2

This page intentionally left blank.

1.0 Introduction

The Bonneville Power Administration (BPA) is proposing to build an approximately 70-mile 500-kilovolt (kV) transmission line from a new BPA substation near Castle Rock in Cowlitz County, Washington, to a new BPA substation near Troutdale in Multnomah County, Oregon. The proposed line is designated the I-5 Corridor Reinforcement Project transmission line. Depending on the route selected, the proposed transmission line will traverse areas with a variety of land uses, including forest, agricultural, urban/suburban, and rural. Four alternatives – West, Central, East and Crossover – are under consideration for the proposed transmission line as shown in Maps 1-4. In addition, there are three additional routing options for portions of each alternative.

The purpose of this report is to describe and quantify the electrical effects of the proposed I-5 Corridor Reinforcement Project 500-kV transmission line along the alternatives and options. These effects include the following:

- the levels of 60-hertz (Hz; cycles per second) electric and magnetic fields (EMF) at 3.28 feet (ft.) or 1 meter (m) above the ground,
- the effects associated with those fields,
- the levels of audible noise produced by the line, and
- electromagnetic interference to radio and television reception associated with the line.

Electrical effects occur near all transmission lines, including those 500-kV lines already present in the area of the proposed route for the I-5 Corridor Reinforcement Project. Therefore, the levels of these quantities for the proposed line are computed and compared with those from the existing lines in Oregon, Washington and elsewhere.

The proposed line would be built on new and existing right-of-way, paralleling existing lines along portions of the route. Each of the four alternatives and options is described by a series of fixed, linear route segments between geographic locations. There are 60 segments total in the four alternatives and options. Although a route segment is unique geographically, it is not necessarily unique in the physical and electrical configurations that produce electrical effects. Therefore in some cases a route segment is broken up into two or more geographical line sections each with a constant configuration for calculation of electrical effects.

Electrical effects were analyzed for all line sections, with or without parallel lines, that had constant physical and electrical characteristics for at least one span between towers. There were 109 separate line sections identified for the four alternatives and their options. Identical configurations are present in different sections. Therefore calculations of electrical effects were required for only 36 different electrical configurations. In eight short sections where the line would change direction, cross other lines, change conductor location on the towers, and/or enter a substation, physical characteristics would not be constant and calculations of effects were not performed. However, the electrical effects associated with these short line sections would be very similar to those for the analyzed segments.

The results of electrical effects calculations for all the individual sections are described in the appendix to this report. These calculations are cross-referenced to alternative routes and segments to facilitate determination of electrical effects levels at specific locations along the proposed routes.

The voltage on the conductors of transmission lines generates an electric field in the space between the conductors and the ground. The electric field is calculated or measured in units of volts-per-meter (V/m) or kilovolts-per-meter (kV/m) at a height of 3.28 feet (ft.) (1 meter [m]) above the ground. The

current flowing in the conductors of the transmission line generates a magnetic field in the air and earth near the transmission line; current is expressed in units of amperes (A). The magnetic field is expressed in milligauss (mG), and is usually measured or calculated at a height of 3.28 ft. (1 m) above the ground. The electric field at the surface of the conductors causes the phenomenon of corona. Corona is the electrical breakdown or ionization of air in very strong electric fields, and is the source of audible noise, electromagnetic radiation, and visible light.

To quantify EMF levels along the route, the electric and magnetic fields from the proposed and existing lines were calculated using the BPA Corona and Field Effects Program (USDOE, undated). In this program, the calculation of 60-Hz fields uses standard superposition techniques for vector fields from several line sources: in this case, the line sources are transmission-line conductors. (Vector fields have both magnitude and direction: these must be taken into account when combining fields from different sources.) Important input parameters to the computer program are voltage, current, and geometric configuration of the line. The transmission-line conductors are assumed to be straight, parallel to each other, and located above and parallel to an infinite flat ground plane. Although such conditions do not occur under real lines because of conductor sag and variable terrain, the validity and limitations of calculations using these assumptions have been well verified by comparisons with measurements. This calculation approach was used to estimate fields for the line segments in the proposed I-5 Corridor Reinforcement Project. Minimum clearances were assumed to provide worst-case (highest) estimates for the electric and magnetic fields.

Electric fields are calculated using an imaging method. Fields from the conductors and their images in the ground plane are superimposed with the proper magnitude and phase to produce the total field at a selected location.

The total magnetic field is calculated from the vector summation of the fields from currents in all the transmission-line conductors. Balanced currents are assumed for each three-phase circuit and the contribution of induced image currents in the conductive earth is not included. Peak and average current and power flow direction for the proposed and existing lines in each segment were provided by BPA. These currents were estimated for the four action alternatives (a term used to discuss the alternatives and options together) that include the addition of the proposed line and the No-action Alternative that assumes the proposed line is not constructed. The currents in these cases were based on the projected system normal annual peak power loads in 2019, the selected year for modeling. A modeling year five to 10 years in the future provides meaningful estimates of loads for the proposed 500-kV transmission line during its initial years of operation. Projections beyond this timeframe may not be reliable.

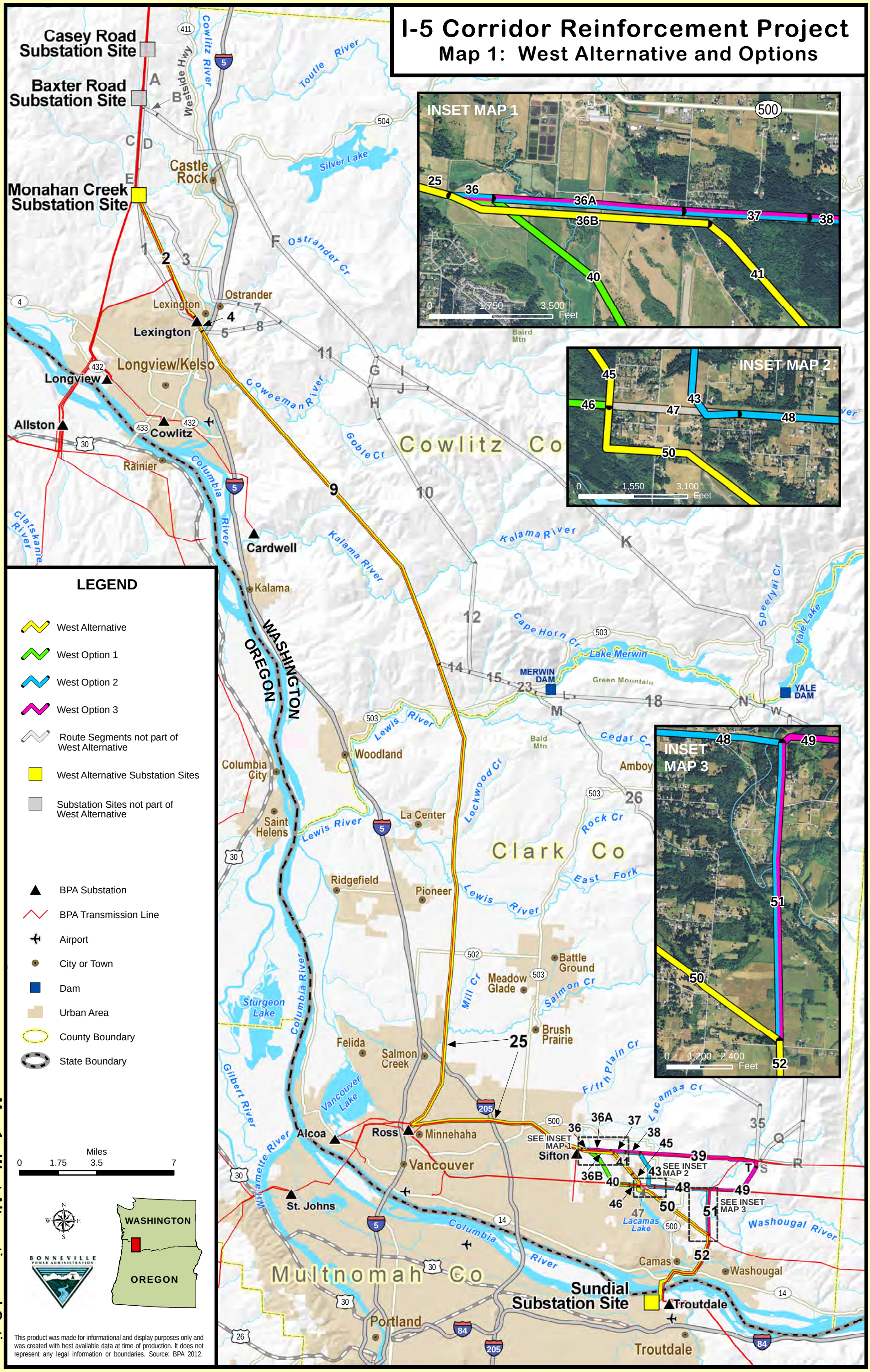
Maximum and average electric and magnetic fields for the proposed transmission line were calculated at the standard height (3.28 ft. or 1 m) above the ground (IEEE, 1987). Calculations were performed out to 1000 ft. (305 m) from the centerline of the proposed line in each segment. The validity and limitations of such calculations have been well verified by measurements.

Because maximum voltage, maximum current, and minimum conductor height above-ground are used, ***the calculated maximum values given here represent worst-case conditions:*** i.e., the calculated fields are higher than they would be in practice. Such worst-case conditions would seldom occur. The average calculated values represent the average fields expected along the entire length of a route segment or line section within a segment.

The corona performance of the proposed line was also predicted using the BPA Corona and Field Effects Program (USDOE, undated). Corona performance is calculated using empirical equations that have been developed over several years from the results of measurements on numerous high-voltage lines

I-5 Corridor Reinforcement Project

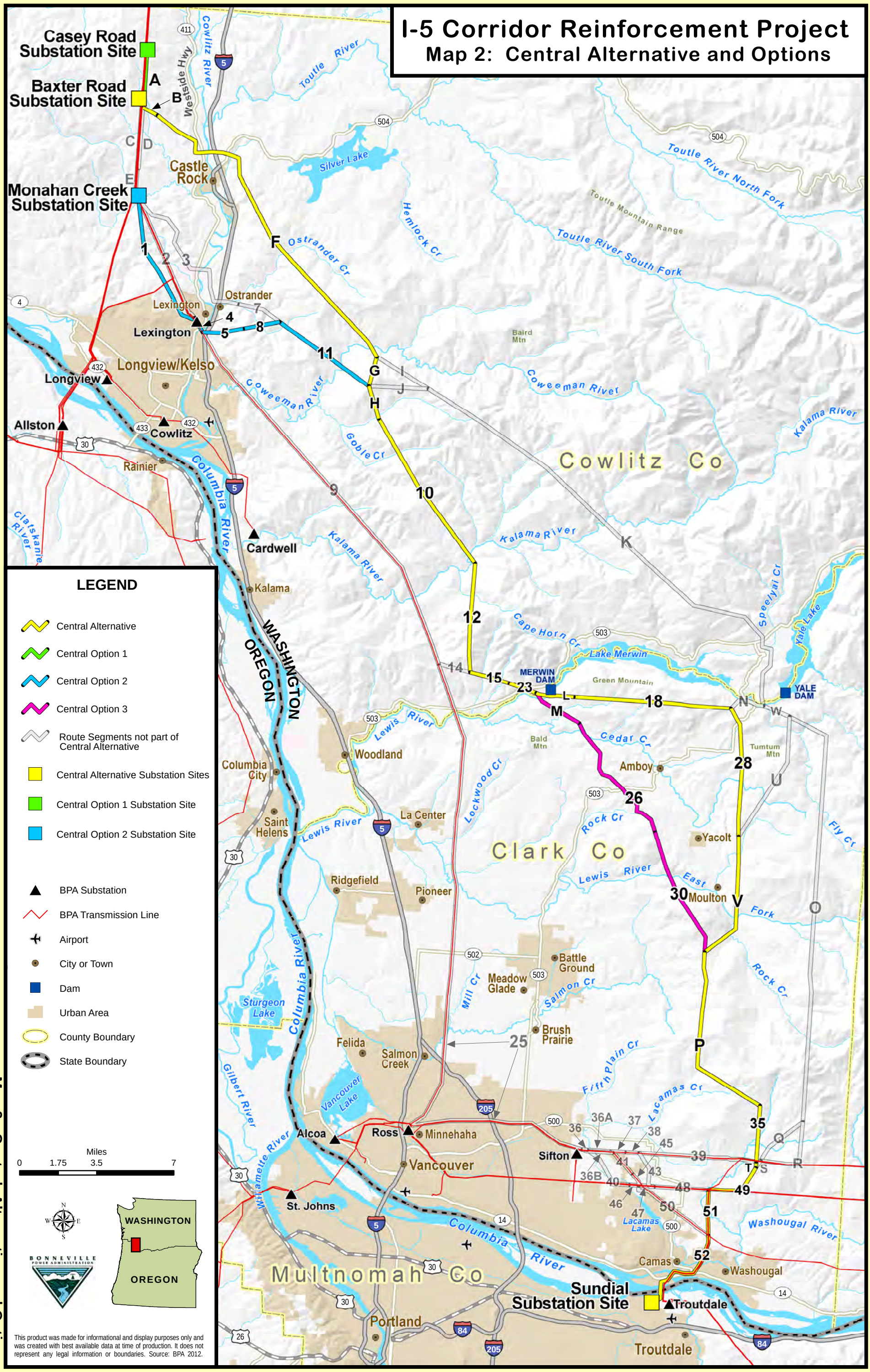
Map 1: West Alternative and Options



Map 1: West Alternative and Options

I-5 Corridor Reinforcement Project

Map 2: Central Alternative and Options

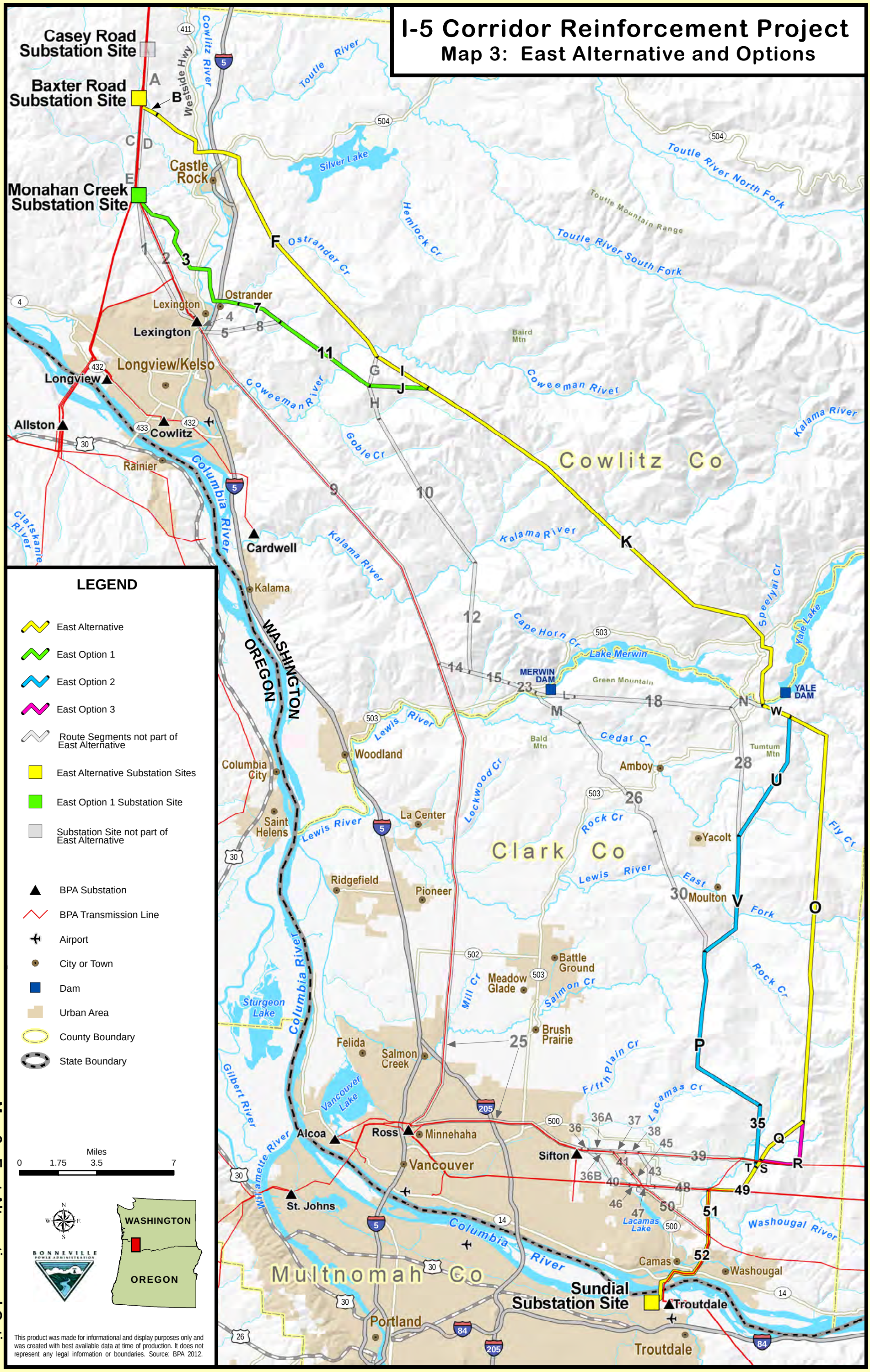


This product was made for informational and display purposes only and was created with best available data at time of production. It does not represent any legal information or boundaries. Source: BPA 2012.

Map 2: Central Alternative and Options

I-5 Corridor Reinforcement Project

Map 3: East Alternative and Options



This product was made for informational and display purposes only and was created with best available data at time of production. It does not represent any legal information or boundaries. Source: BPA 2012.

Map 3: East Alternative and Options

I-5 Corridor Reinforcement Project

Map 4: Crossover Alternative and Options

Casey Road Substation Site

Baxter Road Substation Site

Monahan Creek Substation Site

SEE INSET MAP

INSET MAP

Monahan Creek Substation Site

Sundial Substation Site

Castle Rock

Lexington

Ostrander

Longview/Kelso

Longview

Allston

Cowlitz

Rainier

Cardwell

Kalama

Woodland

Columbia City

Saint Helens

La Center

Ridgefield

Pioneer

Amboy

Yacolt

Moulton

Battle Ground

Meadow Glade

Brush Prairie

Felida

Salmon Creek

Alcoa

Ross

Minnehaha

Vancouver

Sifton

St. Johns

Camas

Washougal

Troutdale

Portland

Clark Co

Multnomah Co

WASHINGTON

OREGON

Columbia River

Lewis River

Kalama River

Coweeman River

Toutle River

Cowlitz River

Lake Merwin

Silver Lake

Yale Lake

Lacamas Lake

Sturgeon Lake

Vancouver Lake

MERWIN DAM

YALE DAM

Green Mountain

Baird Mtn

Bald Mtn

Tumtum Mtn

Cape Horn Cr

Ostrander Cr

Hemlock Cr

Cedar Cr

Lockwood Cr

Rock Cr

Salmon Cr

Mill Cr

Fifth Plain Cr

Lacamas Cr

Washougal River

Fly Cr

Speelyai Cr

Goble Cr

Clatskanie River

Gilbert River

Willamette River

East Fork

LEGEND

- Crossover Alternative
- Crossover Option 1
- Crossover Option 2
- Crossover Option 3
- Route Segments not part of Crossover Alternative
- Crossover Alternative Substation Sites
- Crossover Options Substation Site
- Substation Site not part of Crossover Alternative
- BPA Substation
- BPA Transmission Line
- Airport
- City or Town
- Dam
- Urban Area
- County Boundary
- State Boundary

Miles

0 1.75 3.5 7

WASHINGTON

OREGON

BONNEVILLE POWER ADMINISTRATION

This product was made for informational and display purposes only and was created with best available data at time of production. It does not represent any legal information or boundaries. Source: BPA 2012.

Map 4: Crossover Alternative and Options

(Chartier and Stearns, 1981; Chartier, 1983). The validity of this approach for corona-generated audible noise has been demonstrated through comparisons with measurements on other lines all over the United States (IEEE Committee Report, 1982). The accuracy of this method for predicting corona-generated radio and television interference from transmission lines has also been established (Olsen et al., 1992). Important input parameters to the computer program are voltage, current, conductor size, and geometric configuration of the line.

Corona is a highly variable phenomenon that depends on conditions along a length of line. Predictions of the levels of corona effects are reported in statistical terms to account for this variability. Calculations of audible noise and electromagnetic interference levels were made under conditions of estimated average operating voltage (539 kV for the proposed line) and with the average line height over a span.

Levels of audible noise, radio interference, and television interference are predicted for both fair and foul weather; however, corona is basically a foul-weather phenomenon. Wet conductors can occur during periods of rain, fog, snow, or icing. Along the route of the proposed I-5 Corridor Reinforcement Project transmission line, such conditions are expected to occur about 21 percent of the time during a year, based on hourly precipitation records during years with complete records for the Portland International Airport (2005-2009). Corona activity also increases with altitude. For purposes of evaluating corona effects from the proposed line, an altitude of 0 to 1000 feet (305 m) was assumed. Sixty-two percent of spans were below an elevation of 1000 feet and 94 percent were below 2000 feet. Most of the population along the line is at the lower elevations.

2.0 Physical Description

2.1 Proposed Line

BPA provided the physical and operating characteristics of the proposed and existing lines that were used in the calculations. In almost all segments the proposed 500-kV transmission line would be a three-phase, single-circuit line. Each phase is carried on a separate set of conductors (wires). The voltage and current waves on each phase are displaced by 120° in time (one-third of a cycle) from the waves on the other phases. For the proposed single-circuit configuration the phases would be arranged in a delta (triangular) configuration (Figure 1). In this configuration, the horizontal spacing between phases in the lower conductor positions would be 46 ft. (14 m). The vertical spacing between the conductor positions would be 31.5 ft. (9.6 m). The physical dimensions and electrical characteristics of the proposed single circuit line are shown in Table 1.

In a few segments where there is limited right-of-way available, it would be necessary to place the proposed line on a new tower with one or two existing lines in a double- or triple-circuit configuration. In these cases, the three phases of each line would be arranged vertically. The approximate conductor locations for all sections with calculations are shown in the appendix to this report.

For the 500-kV line, each phase is carried on a bundle of three conductors (wires) and there are three bundles per circuit as shown in Figure 1. Each bundle of the proposed 500-kV line will have three 1.300-inch diameter conductors arranged in an inverted triangle bundle configuration with approximately 17-in. (43.3 cm) spacing between conductors.

The height of the conductor above ground – the ground clearance – depends on conductor temperature: higher temperature produces smaller clearance because the conductors sag. The minimum conductor-to-ground clearance used in the calculations of electric and magnetic fields is 35 ft.

(10.7 m) at a conductor temperature of 122°F (50°C). This conductor temperature is specified by the National Electric Safety Code (NESC) (IEEE, 2002) for calculation of electric fields and is used by BPA to characterize the maximum electric and magnetic fields from transmission lines; it represents heavy operating conditions and high ambient air temperatures. Clearances above ground under normal operating temperatures are greater than the clearance used for calculations. Under very infrequent extreme conditions, conductor temperatures could exceed 122°F (50°C), resulting in smaller clearances and somewhat higher fields, but the line would still be in compliance with the NESC.

In some line sections, larger clearances would be employed to ensure that the BPA criterion for maximum electric field at ground level of 9 kV/m is met along the entire route. The increases in conductor height usually range from 1 to 4 ft. (0.3 to 1.2 m) depending on the voltage, relative phases and location of the adjacent line(s). At road crossings, the ground clearance would be at least 50 ft. (15.2 m). The average height above ground along a span at a conductor temperature of 122°F (50°C) is approximately 12 ft. (3.7 m) greater than the minimum clearance. The average line height was used to calculate average electric and magnetic fields and corona noise levels along the line.

The maximum phase-to-phase voltage for the proposed line would be 550 kV and the average voltage would be 539 kV. The maximum electrical current on the line would be 1080 amperes (A) per phase, based on the BPA projected system annual peak load in 2019 as the base year. The load factor for this line will be about 0.30 (average load = peak load x load factor), resulting in an average current of 324 A.

New right-of-way for the proposed line will be 150 ft. (46 m) wide. When placed on existing right-of-way the centerline of the proposed line will be at least 75 ft. (23 m) from the edge of the existing or newly acquired right-of-way.

2.2 Existing Lines

The proposed I-5 Corridor Reinforcement Project 500-kV line would parallel existing transmission lines along parts of all four action alternatives. The existing lines that will be parallel to the proposed line and the lengths of the parallel sections are dependent on the route. These lines are included in calculations for the four action alternatives and for the No Action Alternative.

2.3 Action Alternatives

Four action alternatives are under consideration for the proposed line. Each action alternative is comprised of many route segments. Some route segments are divided into line sections to account for changes in line configuration within the segment. (Detailed information about each route segment and line section can be found in tables in the appendix to this report.)

Comparison of the fields and corona effects for the alternatives and options requires more than examination or comparison of calculated results for individual route segments or line sections. To produce a general summary of levels for an action alternative, the distance-weighted means of the average and maximum values for all sections in an alternative or option were computed. These summary measures do not necessarily represent any particular location along a route. However they do provide a means of comparing overall levels between alternatives and options.

The proposed line would be located on two types of right-of-way: “new” right-of-way without adjacent transmission lines and “existing” right-of-way with existing adjacent lines. In some cases, an existing right-of-way may still require purchase of additional right-of-way to be purchased for the proposed line. However, this situation is considered “existing,” because of the presence of adjacent line(s).

The mileage by type of right-of-way (new or existing) for the four alternatives and their options are shown in Table 2. This table also shows the number of route segments in each alternative and option.

The West Alternative is almost entirely on existing right-of-way (98%) while the Central and East alternatives are primarily on new right-of-way (90%). The Crossover Alternative is distributed about equally on new right-of-way (58%) and existing right-of-way (42%).

The composition of right-of-way type in an alternative or option affects the overall field levels and the change in field levels between the action and No Action alternatives. New right-of-way sections have higher edge-of-right-of-way fields than existing right-of-way sections and introduce fields and corona effects where none exist in the No Action Alternative. The electrical effects summary measures were computed separately for the new and existing rights-of-way types within each alternative and option and then combined to provide overall summary measures for the action alternatives.

2.4 No Action Alternative

A decision to not build the proposed line constitutes the No Action Alternative. Electrical effects levels for the No Action Alternative are calculated from the existing lines along the various routes in the absence of the proposed 500-kV line. Electrical effects for the No Action Alternative along the routes of the four action alternatives are summarized by computing distance-averaged means for the levels from the existing lines. There are no electrical effects along the new right-of-way sections for the No Action Alternative.

3.0 Electric Field

3.1 Basic Concepts

An electric field is said to exist in a region of space if an electrical charge, at rest in that space, experiences a force of electrical origin (i.e., electric fields cause free charges to move). Electric field is a vector quantity: that is, it has both magnitude and direction. The direction corresponds to the direction that a positive charge would move in the field. Sources of electric fields are unbalanced electrical charges (positive or negative) and time-varying magnetic fields. Transmission lines, distribution lines, house wiring, and appliances generate electric fields in their vicinity because of the unbalanced electrical charges associated with voltage on the conductors. On the power system in North America, the voltage and charge on the energized conductors are cyclic (plus to minus to plus) at a rate of 60 times per second. This changing voltage results in electric fields near sources that are also time-varying at a frequency of 60 hertz (Hz; a frequency unit equivalent to cycles per second).

As noted earlier, electric fields are expressed in units of volts per meter (V/m) or kilovolts (thousands of volts) per meter (kV/m). Electric- and magnetic-field magnitudes in this report are expressed in root-mean-square (rms) units. For sinusoidal waves, the rms amplitude is given as the peak amplitude divided by the square root of two.

The spatial uniformity of an electric field depends on the source of the field and the distance from that source. On the ground, under a transmission line, the electric field is nearly constant in magnitude and direction over distances of several feet (1 meter). However, close to transmission- or distribution-line conductors, the field decreases rapidly with distance from the conductors. Similarly, near small sources such as appliances, the field is not uniform and falls off even more rapidly with distance from the device. If an energized conductor (source) is inside a grounded conducting enclosure, then the electric field outside the enclosure is zero, and the source is said to be shielded.

Electric fields interact with the charges in all matter, including living systems. When a conducting object, such as a vehicle or person, is located in a time-varying electric field near a transmission line, the external electric field exerts forces on the charges in the object, and electric fields and currents are

induced in the object. If the object is grounded, then the total current induced in the body (the "short-circuit current") flows to earth. The distribution of the currents within, say, the human body, depends on the electrical conductivities of various parts of the body: for example, muscle and blood have higher conductivity than bone and would therefore experience higher currents.

At the boundary surface between air and the conducting object, the field in the air is perpendicular to the conductor surface and is much, much larger than the field in the conductor itself. For example, the average surface field on a human standing in a 10 kV/m field is 27 kV/m; the internal fields in the body are much smaller: approximately 0.008 V/m in the torso and 0.45 V/m in the ankles.

3.2 Transmission Line Electric Fields

The electric field created by a high-voltage transmission line extends from the energized conductors to other conducting objects such as the ground, towers, vegetation, buildings, vehicles, and people. The calculated strength of the electric field at a height of 3.28 ft. (1 m) above an unvegetated, flat earth is frequently used to describe the electric field under straight parallel transmission lines. The most important transmission-line parameters that determine the electric field at a 1-m height are conductor height above ground and line voltage.

Calculations of electric fields from transmission lines are performed with computer programs based on well-known physical principles (cf., Deno and Zaffanella, 1982). The calculated values under these conditions represent an ideal situation. When practical conditions approach this ideal model, measurements and calculations agree. Often, however, conditions are far from ideal because of variable terrain and vegetation. In these cases, fields are calculated for ideal conditions, with the lowest conductor clearances to provide upper bounds on the electric field under the transmission lines. With the use of more complex models or empirical results, it is also possible to account accurately for variations in conductor height, topography, and changes in line direction. Because the fields from different sources add vectorially, it is possible to compute the fields from several different lines if the electrical and geometrical properties of the lines are known. However, in general, electric fields near transmission lines with vegetation below are highly complex and cannot be calculated. Measured fields in such situations are highly variable.

For evaluation of EMF from transmission lines, the fields must be calculated for a specific line condition. The NESC states the condition for evaluating electric-field-induced short-circuit current for lines with voltage above 98 kV, line-to-ground, as follows: conductors are at a minimum clearance from ground corresponding to a conductor temperature of 120°F (50°C), and at a maximum voltage (IEEE, 2002). BPA has supplied the needed information for calculating electric and magnetic fields from the proposed transmission lines: the maximum operating voltage, the estimated peak current in 2019, and the minimum conductor clearances.

There are standard techniques for measuring transmission-line electric fields (IEEE, 1987). Provided that the conditions at a measurement site closely approximate those of the ideal situation assumed for calculations, measurements of electric fields agree well with the calculated values. If the ideal conditions are not approximated, the measured field can differ substantially from calculated values. Usually the actual electric field at ground level is reduced from the calculated values by various common objects that act as shields.

Maximum or peak field values occur over a small area on the right-of-way at mid-span, where conductors are closest to the ground (minimum clearance). As the location of an electric-field profile approaches a tower, the conductor clearance increases, and the peak field decreases. A grounded tower will reduce the electric field considerably by shielding.

For traditional transmission lines, such as the proposed line, where the right-of-way extends laterally well beyond the conductors, electric fields at the edge of the right-of-way are not as sensitive as the peak field to conductor height. Computed values at the edge of the right-of-way for any line height are fairly representative of what can be expected all along the transmission-line corridor. However, the presence of vegetation on and at the edge of the right-of-way will reduce actual electric-field levels below calculated values.

3.3 Calculated Values of Electric Fields

The calculated values of electric fields at 3.28 ft. (1 m) above ground for all route segments and line sections in the proposed I-5 Corridor Reinforcement Project are presented in the appendix to this report. The appendix also contains lateral profiles of the electric field out to 1,000 feet on either side of the centerline of the proposed line for all route segments. Maximum and average field values are also tabulated. Tables in the appendix allow readers to look up calculated values by alternative, option, route segment, line section, or calculation number.

Data for each alternative and option, including the No Action Alternative, are then summarized in Tables 3 to 7 in this report. Calculated maximum electric fields at various distances from the proposed line on new right-of-way are summarized in Table 3; tables 4 to 7 show electric field calculations for both new and existing right-of-way for all alternatives and options.

For all alternatives and options, the calculated electric fields expected on the right-of-way of the proposed line will depend on the particular segment. To facilitate comparison among alternatives and options, calculations shown in Tables 4 to 7 are of distance-weighted means for electric fields on and at the edge of the right-of-way. The electric fields designated as maximum on-right-of-way values (identified as “On ROW” in the tables) are the distance-weighted mean of the maximum (peak) fields for all segments in an alternative or option. These maximum fields would occur in a small area near mid-span with the conductors at minimum clearance and maximum voltage (550 kV). The average “On ROW” field values estimate the average along an entire span of these maximum (peak) fields with the proposed line operating at average voltage (539 kV). Both the maximum and average “On ROW” values represent conservative (upper limit) estimates for the electric fields expected to occur on the right-of-way.

The maximum and average edge-of-right-of-way (identified as “Edge of ROW” in the tables) fields are also distance-weighted averages across all segments in an alternative or option. They represent the fields at the edge of the right-of-way under the clearance and voltage conditions specified for the maximum and average fields on the right-of-way.

For all alternatives and options the maximum (peak) values “On ROW” range from 8.8 to 9.0 kV/m. The average peak field “On ROW” ranges from 5.3 to 5.8 kV/m. The peak fields for the proposed line on new right-of-way would be 8.8 kV/m under maximum conditions and 5.3 kV/m under average conditions.

The maximum values expected at the “Edge of ROW” of the proposed line range from 0.6 to 2.4 kV/m. The low field values would occur when low voltage lines are present at the opposite edge from the proposed 500-kV line. The maximum and average electric fields at the “Edge of ROW” on new right-of-way would be 2.3 kV/m.

Electric field plots for all sections of the proposed line on existing and new rights-of-way are contained in the appendix to this report. Two examples are included in this report. The electric field plot for the proposed line operating on a new right-of-way is shown in Figure 2. An example of the electric fields near the proposed line on an existing right-of-way is shown in Figure 3.

Calculated electric field levels for the proposed line on new right-of-way are shown in Table 3 for locations on the right-of-way ("Peak on ROW"), at the edge of the right-of-way ("at Edge of ROW"), and at 150 and 300 feet from centerline. The maximum levels, which would occur very infrequently, would be 8.8 kV/m "Peak on ROW" and 2.3 kV/m "at Edge of ROW" (75 feet from the proposed line). The average levels would be 5.3 kV/m "Peak on ROW" and slightly less than 2.3 kV/m "at Edge of ROW." By 150 feet from the proposed line both the maximum and average electric fields would be 0.5 kV/m; by 300 feet from the proposed line, the electric fields would be 0.1 kV/m.

The maximum (peak) electric field values on the right-of-way would occur only at locations almost directly under the conductors, near mid-span, where the conductors are at minimum clearance. The conditions of minimum conductor clearance at maximum voltage occur very infrequently. Thus, the calculated peak electric field levels are rarely reached under real-life conditions, because the actual line height is generally above the minimum value used in the computer model, because the actual voltage is below the maximum value used in the model, and because vegetation within and near the edge of the right-of-way tends to shield the field at ground level.

As noted, Tables 4 to 7 show distance-weighted means for electric fields on and at the edge of the right-of-way to allow comparison among alternatives and options. The maximum peak fields on the existing rights-of-way averaged over the entire route would be very similar to the maximum peak field expected for the proposed line on new right-of-way: that is, maximum peak fields of 8.8 kV/m and average peak fields of about 5.3 kV/m. However, electric fields at the edges of existing rights-of-way tend to be lower than for the new rights-of-way, because the existing rights-of-way have one edge adjacent to a lower voltage line.

The No Action Alternative would produce lower fields on and at the edges of the rights-of-way than the four alternatives (excluding options). When the 12 options are considered, the field levels from the No Action Alternative field levels can be higher than the proposed line, particularly where 500-kV lines are present: Central Options 1 and 2, and Crossover Options 2 and 3. The segments with adjacent 500-kV lines are all located between the three possible substation locations at the northern end of the project.

Where new right-of-way is required, there are currently no electric fields present for the No Action Alternative.

3.4 Environmental Electric Fields

The electric fields associated with the proposed I-5 Corridor Reinforcement Project can be compared with those found in other environments. Sources of 60-Hz electric (and magnetic) fields exist everywhere electricity is used; levels of these fields in the modern environment vary over a wide range. Electric-field levels associated with the use of electrical energy are orders of magnitude greater than the naturally occurring 60-Hz fields of about 0.0001 V/m, which stem from atmospheric and extraterrestrial sources.

Electric fields in outdoor, publicly accessible places range from less than 1 V/m to 12 kV/m; the large fields exist close to high-voltage transmission lines of 500 kV or higher. In remote areas without electrical service, 60-Hz field levels can be much lower than 1 V/m. Electric fields in home and work environments generally are not spatially uniform like those of transmission lines; therefore, care must be taken when making comparisons between fields from different sources such as appliances and electric lines. In addition, fields from all sources can be strongly modified by the presence of conducting objects. However, it is helpful to know the levels of electric fields generated in domestic and office environments to compare commonly experienced field levels with those near transmission lines.

Numerous measurements of residential electric fields have been reported for various parts of the United States, Canada, and Europe. Measurements of domestic 60-Hz electric fields indicate that levels are highly variable and source-dependent. Electric-field levels are not easily predicted because walls and other objects act as shields, because conducting objects perturb the field, and because homes contain numerous localized sources. Internal sources (wiring, fixtures, and appliances) seem to predominate in producing electric fields inside houses. Average measured electric fields in residences are generally in the range of 5 to 20 V/m. In a large occupational exposure monitoring project that included electric-field measurements at homes, average exposures for all groups away from work were generally less than 10 V/m (Bracken, 1990).

Electric fields from household appliances are localized and decrease rapidly with distance from the source. Local electric fields measured at 1 ft. (0.3 m) from small household appliances are typically in the range of 30 to 60 V/m. In a survey, reported by Deno and Zaffanella (1982), field measurements at a 1-ft. (0.3-m) distance from common domestic and workshop sources were found to range from 3 to 70 V/m. The localized fields from appliances are not uniform, and care should be taken in comparing them with transmission-line fields.

Electric blankets can generate higher localized electric fields. Florig et al. (1987) carried out extensive empirical and theoretical analysis of electric-field exposure from electric blankets and presented results in terms of uniform equivalent fields such as those near transmission lines. Depending on what parameter was chosen to represent intensity of exposure and the grounding status of the subject, the equivalent vertical 60-Hz electric-field exposure ranged from 20 to over 3500 V/m. The largest equivalent field corresponds to the measured field on the chest with the blanket-user grounded. The average field on the chest of an ungrounded blanket-user yields an equivalent vertical field of 960 V/m. As manufacturers have become aware of the controversy surrounding EMF exposures, electric blankets have been redesigned to reduce magnetic fields. However, electric fields from these “low field” blankets are still comparable with those from older designs (Bassen et al., 1991).

Generally, people in occupations not directly related to high-voltage equipment are exposed to electric fields comparable with those of residential exposures. For example, the average electric field measured in 14 commercial and retail locations in rural Wisconsin and Michigan was 4.8 V/m (IIT Research Institute, 1984). Median electric field was about 3.4 V/m. These values are about one-third the values in residences reported in the same study. Electric field levels in public buildings such as shops, offices, and malls appear to be comparable with levels in residences.

In a survey of 1,882 volunteers from utilities, electric field exposures were measured for 2,082 work days and 657 non-work days (Bracken, 1990). Electric field exposures for occupations other than those directly related to high-voltage equipment were equivalent to those for non-work exposure.

Thus, except for the relatively few occupations where high-voltage sources are prevalent, electric fields encountered in the workplace are probably similar to those of residential exposures. Even in electric utility occupations where high field sources are present, exposures to high fields are limited on average to minutes per day.

Electric fields found in publicly accessible areas near high-voltage transmission lines can typically range up to 3 kV/m for 230-kV lines, to 10 kV/m for 500-kV lines, and to 12 kV/m for 765-kV lines. Although these peak levels are considerably higher than the levels found in other public areas, they are present only in limited areas on rights-of-way.

The calculated electric fields for the proposed I-5 Corridor Reinforcement 500-kV transmission line are consistent with the levels reported for other 500-kV transmission lines in Washington, Oregon and

elsewhere. The calculated electric fields on and at the edge of the right-of-way of the proposed transmission line would be much higher than levels normally encountered in residences and offices.

4.0 Magnetic Field

4.1 Basic Concepts

Magnetic fields can be characterized by the force they exert on a moving charge or on an electrical current. As with the electric field, the magnetic field is a vector quantity characterized by both magnitude and direction. Electrical currents generate magnetic fields. In the case of transmission lines, distribution lines, house wiring, and appliances, the 60-Hz electric current flowing in the conductors generates a time-varying, 60-Hz magnetic field in the vicinity of these sources. The strength of a magnetic field is measured in terms of magnetic lines of force per unit area, or magnetic flux density. The term “magnetic field,” as used here, is synonymous with magnetic flux density and is expressed in units of gauss (G) or milligauss (mG). (The tesla (T) is the unit of magnetic flux density preferred in scientific publications, where 1.0 gauss equals one ten-thousandth of a tesla (0.1 mT) and 1.0 mG equals 0.1 microtesla [µT]).

The uniformity of a magnetic field depends on the nature and proximity of the source, just as the uniformity of an electric field does. Transmission-line-generated magnetic fields are quite uniform over horizontal and vertical distances of several feet near the ground. However, for small sources such as appliances, the magnetic field decreases rapidly over distances comparable with the size of the device.

The interaction of a time-varying magnetic field with conducting objects results in induced electric fields and currents in the object. A changing magnetic field through an area generates a voltage around any conducting loop enclosing the area (Faraday's law). This is the physical basis for the operation of an electrical transformer. For a time-varying sinusoidal magnetic field, the magnitude of the induced voltage around the loop is proportional to the area of the loop, the frequency of the field, and the magnitude of the field. The induced voltage around the loop results in an induced electric field and current flow in the loop material. The induced current that flows in the loop depends on the conductivity of the loop as well as its area.

4.2 Transmission-line Magnetic Fields

The magnetic field generated by currents on transmission-line conductors extends from the conductors through the air and into the ground. The magnitude of the field at a height of 3.28 ft. (1 m) is frequently used to describe the magnetic field under transmission lines. Because the magnetic field is not affected by non-ferrous materials, the field is not influenced by normal objects on the ground under the line. The direction of the maximum field varies with location. (The electric field, by contrast, is essentially vertical near the ground.) The most important transmission-line parameters that determine the magnetic field at 3.28 ft. (1 m) height are conductor height above ground and magnitude of the currents flowing in the conductors. As distance from the transmission line conductors increases, the magnetic field decreases.

Calculations of magnetic fields from transmission lines are performed using well-known physical principles (cf., Deno and Zaffanella, 1982). The calculated values usually represent the ideal straight parallel-conductor configuration. For simplicity, a flat earth is usually assumed. Balanced currents (currents of the same magnitude for each phase) are also assumed. This is usually valid for transmission lines, where loads on all three phases are maintained in balance during operation. Induced image currents in the earth are usually ignored for calculations of magnetic field under or near the right-of-way. The resulting error is negligible. Only at distances greater than 300 ft. (91 m) from a line do such

contributions become significant (Deno and Zaffanella, 1982). The clearance for magnetic field calculations for the proposed line was the same as that used for electric field evaluations.

Standard techniques for measuring magnetic fields near transmission lines are described in ANSI IEEE Standard No. 644-1994 (1994). Measured magnetic fields agree well with calculated values, provided the currents and line heights that go into the calculation correspond to the actual values for the line. To realize such agreement, it is necessary to get accurate current readings during field measurements (because currents on transmission lines can vary considerably over short periods of time) and also to account for all field sources in the vicinity of the measurements.

As with electric fields, maximum (peak) magnetic fields occur in areas near the centerline and at mid-span where conductors are the lowest. The magnetic field at the edge of the right-of-way is not very dependent on line height. If more than one line is present, the peak field will depend on the relative electrical phasing of the conductors and the relative direction of power flow in the lines.

4.3 Calculated Values for Magnetic Fields

The appendix to this report contains tables and plots of the calculated values of the magnetic field at 3.28 ft. (1 m) height for all of the proposed 500-kV transmission line sections. Field values on the right-of-way and at the edge of the right-of-way are given for projected maximum currents and minimum clearance. Field levels at the same locations for average current and average conductor clearance are also given. This information is then summarized in Tables 3 to 7 in this report. Calculated maximum magnetic fields on new right-of-way are summarized in Table 3. Tables 4 to 7 show calculated magnetic fields (expressed in distance-weighted means) on new and existing right-of-way by alternative and option. In addition, examples of magnetic field plots for the proposed line operating on a new right-of-way and existing right-of-way are shown in Figures 4 and 5.

The magnetic fields designated as maximum on-right-of-way values (designated as “On ROW” in the tables) represent the maximum (peak) fields that could occur infrequently in a small area near mid-span with the conductors at minimum clearance and maximum current (1080 A). The average on-right-of-way field values estimate the average along an entire span of these maximum (peak) fields with the proposed line operating at average current (324 A). Both the maximum and average on-right-of-way values represent conservative (upper limit) estimates for the electric fields expected to occur on the right-of-way.

The maximum and average edge-of-right-of-way (“Edge of ROW”) magnetic fields represent calculated values at the edge of the right-of-way under the clearance and voltage conditions specified for the maximum and average fields on the right-of-way.

Maximum magnetic field levels along the four alternatives (excluding options) would be 184 mG “On ROW” and 48 mG at “Edge of ROW” (75 feet from the proposed line). The average levels would be much lower: 35 mG “On ROW” and 12 mG at “Edge of ROW.” By 150 feet from the proposed line, magnetic fields would fall to a maximum of 13 mG and an average of 4 mG; at 300 feet from the proposed line, the maximum field would be 4 mG and the average 1 mG. The latter is comparable to average levels in homes in the United States.

Figures 4 and 5 in this report provide visual representations of the potentially highest magnetic fields under the proposed I-5 Corridor Reinforcement 500-kV line. The actual day-to-day magnetic field levels would be lower. They would vary as currents change daily and seasonally and as clearances change with ambient temperature. As shown in these tables and figures, the average fields along the line over a year would be considerably reduced from the maximum values, as a result of increased clearances and reduced current.

The large number of existing right-of-way sections that comprise the alternative routes makes it impractical to tabulate results off the right-of-way for each of these. However, the field values for the proposed line alone shown in Table 3 provide an indication of the magnetic fields that can be expected off the right-of-way when the proposed line is on an existing right-of-way. In such cases, one edge of the right-of-way will be adjacent to the proposed line and it will be the dominant source of fields outside the right-of-way. Consequently, the values at 150 and 300 feet shown in Table 3 will be representative of the fields beyond the edge nearest to the proposed line. On the far side of an existing right-of-way, an existing lower voltage line with lower currents will be present and magnetic (and electric) fields will be lower than on the near side. In this case, the field values off the right-of-way from the proposed line alone can be considered an upper bound on the fields off the fight-of-way. However, if an existing 500-kV line is present on the far side of the right-of-way then the fields can be higher than those for the proposed line alone. This occurs in Central Option 1 and Crossover Options 2 and 3 (Tables 5 and 6).

To compare the magnetic field levels between action alternatives, the magnetic fields for each alternative and option were characterized in the same manner as were electric fields. A distance-weighted average of each parameter was computed using the tabulated values in the appendix of this report for each line section along the entire length of each alternative and option. The distance-weighted average fields were calculated separately for sections with new and existing right-of-way for the four alternatives. Similar computations were performed for the options in each alternative.

For clarity, the results for the 12 options are presented separately in Tables 4 to7, and discussed only in instances where there would be a significant change to the results for the overall action alternative. The tables show the distance-weighted average of the maximum and average fields on and at the edge of the right-of-way. The No Action levels are also shown for those sections where the proposed transmission line would be located on existing rights-of-way.

The maximum “On ROW” 60-Hz magnetic fields along the four alternatives (excluding options) would range between 174 to 184 mG (all numbers in this section are distance-weighted averages). The lowest value would occur on existing rights-of-way for the West Alternative and the highest value applies to the other three alternatives. The range of maximum fields “On ROW” for the 12 options would be 139 to 276 mG. The larger upper limit for the options would be due to the presence of existing 500-kV lines with high maximum currents on short segments (2.5 to 4.1 miles) of the Central and Crossover options.

For the No Action Alternative, maximum fields “On ROW” along the four alternatives (excluding options) would range from 96 to 135 mG. When considering all options, the range of maximum fields “On ROW” on existing rights-of-way for the No Action Alternative would be 63 to 235 mG, with the highest value occurring where there is an existing 500-kV lines.

Estimated average fields “On ROW” for the four alternatives (excluding options) would range from 32 to 36 mG. The range of average fields “On ROW” for the 12 options would be 28 to 68 mG. The average field on the existing rights-of-way for the No Action Alternative would range from 11 to 49 mG under all options. In sections where new right-of-way would be used for the proposed line, magnetic fields for the No Action Alternative would be zero. Distance-weighted maximum and average fields for the “Edge of ROW” for all action alternatives and the No Action Alternative are shown in Tables 4 to 7.

Beyond the edge of rights-of-way, magnetic fields fall off rapidly. For example, a maximum magnetic field of 48 mG at the edge of new right-of-way would drop to 13 mG at a distance of 150 feet from centerline, and to 3 mG at 300 feet. For the same example, the average field would drop from 12 mG at the edge of the right-of-way to 4 mG at 150 feet to 1 mG at 300 feet. This means that beyond a few hundred feet, transmission line magnetic fields approach common ambient levels.

4.4 Environmental Magnetic Fields

Transmission lines are not the only source of magnetic fields; as with 60-Hz electric fields, 60-Hz magnetic fields are present throughout the environment of a society that relies on electricity as a principal energy source. The magnetic fields associated with the proposed I-5 Corridor Reinforcement 500-kV line can be compared with fields from other sources. The range of 60-Hz magnetic-field exposures in publicly accessible locations such as open spaces, transmission-line rights-of-way, streets, pedestrian walkways, parks, shopping malls, parking lots, shops, hotels, public transportation, and so on range from less than 0.1 mG to about 1 G, with the highest values occurring near small appliances with electric motors. In occupational settings in electric utilities, where high currents are present, magnetic-field exposures for workers can be above 1 G. At 60 Hz, the magnitude of the natural magnetic field is approximately 0.0005 mG.

Several investigations of residential fields have been conducted. In a large study to identify and quantify significant sources of 60-Hz magnetic fields in residences, measurements were made in 996 houses, randomly selected throughout the country (Zaffanella, 1993). The most common sources of residential fields were power lines, the grounding system of residences, and appliances. Field levels were characterized by both point-in-time (spot) measurements and 24-hour measurements. Spot measurements averaged over all rooms in a house exceeded 0.6 mG in 50 percent of the houses and 2.9 mG in 5 percent of houses. Power lines generally produced the largest average fields in a house over a 24-hour period. On the other hand, grounding system currents proved to be a more significant source of the highest fields in a house. Appliances were found to produce the highest local fields; however, fields fell off rapidly with increased distance. For example, the median field near microwave ovens was 36.9 mG at a distance of 10.5 in (0.27 m) and 2.1 mG at 46 in (1.17 m). Across the entire sample of 996 houses, higher magnetic fields were found in, among others, urban areas (vs. rural); multi-unit dwellings (vs. single-family); old houses (vs. new); and houses with grounding to a municipal water system.

In an extensive measurement project to characterize the magnetic-field exposure of the general population, over 1000 randomly selected persons in the United States wore a personal exposure meter for 24 hours and recorded their location in a simple diary (Zaffanella and Kalton, 1998). Based on the measurements of 853 persons, the estimated 24-hour average exposure for the general population is 1.24 mG and the estimated median exposure is 0.88 mG. The average field “at home, not in bed” is 1.27 mG and “at home, in bed” is 1.11 mG. Average personal exposures were found to be largest “at work” (mean of 1.79 mG and median of 1.01 mG) and lowest “at home, in bed” (mean of 1.11 mG and median of 0.49 mG). Average fields in school were also low (mean of 0.88 mG and median of 0.69 mG). Factors associated with higher exposures at home were smaller residences, duplexes and apartments, metallic rather than plastic water pipes, and nearby overhead distribution lines.

As noted above, magnetic fields from appliances are localized and decrease rapidly with distance from the source. Localized 60-Hz magnetic fields have been measured near about 100 household appliances such as ranges, refrigerators, electric drills, food mixers, and shavers (Gauger, 1985). At a distance of 1 ft. (0.3 m), the maximum magnetic field ranged from 0.3 to 270 mG, with 95 percent of the measurements below 100 mG. Ninety-five percent of the levels at a distance of 4.9 ft. (1.5 m) were less than 1 mG. Devices that use light-weight, high-torque motors with little magnetic shielding exhibited the largest fields. These included vacuum cleaners and small hand-held appliances and tools. Microwave ovens with large power transformers also exhibited relatively large fields. Electric blankets have been a much-studied source of magnetic-field exposure because of the length of time they are used and because of the close proximity to the body. Florig and Hoburg (1988) estimated that the average magnetic field in a person using an electric blanket was 15 mG, and that the maximum field

could be 100 mG. New "low-field" blankets have magnetic fields at least 10 times lower than those from conventional blankets (Bassen et al., 1991).

In a domestic magnetic-field survey, Silva et al. (1989) measured fields near different appliances at locations typifying normal use (e.g., sitting at a typewriter or standing at a stove). Specific appliances with relatively large fields included can openers (n = 9), with typical fields ranging from 30 to 225 mG and a maximum value up to 2.7 G; shavers (n = 4), with typical fields from 50 to 300 mG and maximum fields up to 6.9 G; and electric drills (n = 2), with typical fields from 56 to 190 mG and maximum fields up to 1.5 G. The fields from such appliances fall off very rapidly with distance and are only present for short periods. Thus, although instantaneous magnetic-field levels close to small hand-held appliances can be quite large, they do not contribute to average area levels in residences. The technology of newer energy-efficient appliances is likely to reduce fields from appliances further. Battery-powered appliances and devices generally do not generate 60-Hz magnetic fields.

Although studies of residential magnetic fields have not all considered the same independent parameters, the following consistent characterization of residential magnetic fields emerges from the data:

1. External sources play a large role in determining residential magnetic-field levels. Transmission lines, when nearby, are an important external source. Unbalanced ground currents on neutral conductors and other conductors, such as water pipes in and near a house, can represent a significant source of magnetic field. Distribution lines per se, unless they are quite close to a residence, do not appear to be a traditional distance-dependent source.
2. Homes with overhead electrical service appear to have higher average fields than those with underground service.
3. Appliances represent a localized source of magnetic fields that can be much higher than average or area fields. However, fields from appliances approach area levels at distances greater than 3 ft. (1 m) from the device.

Although important variables in determining residential magnetic fields have been identified, quantification and modeling of their influence on fields at specific locations is not yet possible. However, a general characterization of residential magnetic-field level is possible: average levels in the United States are in the range of 0.5 to 1.0 mG, with the average field in a small number of homes exceeding this range by as much as a factor of 10 or more. Average personal exposure levels are slightly higher, possibly due to use of appliances and varying distances to other sources. Maximum fields can be much higher.

Magnetic fields in commercial and retail locations are comparable with those in residences. As with appliances, certain equipment or machines can be a local source of higher magnetic fields. Utility workers who work close to transformers, generators, cables, transmission lines, and distribution systems clearly experience high-level fields. Other sources of fields in the workplace include motors, welding machines, computers, and office equipment. In publicly accessible indoor areas, such as offices and stores, field levels are generally comparable with residential levels, unless a high-current source is nearby.

Because high-current sources of magnetic field are more prevalent than high-voltage sources, occupational environments with relatively high magnetic fields encompass a more diverse set of occupations than do those with high electric fields. For example, in occupational magnetic-field measurements reported by Bowman et al. (1988), the geometric mean field from 105 measurements of magnetic field in "electrical worker" job locations was 5.0 mG. "Electrical worker" environments

showed the following elevated magnetic-field levels (geometric mean greater than 20 mG): industrial power supplies, alternating current (ac) welding machines, and sputtering systems for electronic assembly.

Measurements of personal exposure to magnetic fields were made for 1,882 volunteer utility workers for a total of 4,411 workdays (Bracken, 1990). Median workday mean exposures ranged from 0.5 mG for clerical workers without computers to 7.2 mG for substation operators. Occupations not specifically associated with transmission and distribution facilities had median workday exposures less than 1.5 mG, while those associated with such facilities had median exposures above 2.3 mG. Magnetic-field exposures measured in homes during this study were comparable with those recorded in offices.

Magnetic fields in publicly accessible outdoor areas seem to be, as expected, directly related to proximity to electric-power transmission and distribution facilities. Near such facilities, magnetic fields are generally higher than indoors (residential). Higher-voltage facilities tend to have higher fields. Typical maximum magnetic fields in publicly accessible areas near transmission facilities can range from less than a few milligauss up to 300 mG or more, near heavily loaded lines operated at 230 to 765 kV. The levels depend on the line load, conductor height, and location on the right-of-way. Because magnetic fields near high-voltage transmission lines depend on the current in the line, they can vary daily and seasonally.

Fields near distribution lines and equipment are generally lower than those near transmission lines. Measurements in Montreal indicated that typical fields directly above underground distribution systems were 5 to 19 mG (Heroux, 1987). Beneath overhead distribution lines, typical fields were 1.5 to 5 mG on the primary side of the transformer, and 4 to 10 mG on the secondary side. Near ground-based transformers used in residential areas, fields were 80 to 1000 mG at the surface and 10 to 100 mG at a distance of 1 ft. (0.3 m).

The magnetic fields from the proposed line would be comparable to or less than those from existing 500-kV lines in Washington and elsewhere. On and near the right-of-way of the proposed line, magnetic fields would be well above average residential levels. However, the fields from the line would decrease rapidly and approach common ambient levels at distances greater than a few hundred feet from the line. Furthermore, the fields at the edge of the right-of-way would not be above those encountered during normal activities near common sources such as hand-held appliances.

5.0 Electric and Magnetic Field (EMF) Effects

Possible effects associated with the interaction of EMF from transmission lines with people on and near a right-of-way fall into two categories: short-term effects that can be perceived and may represent a nuisance, and possible long-term health effects. Only short-term effects are discussed here. Whether there are long-term health effects associated with transmission-line fields is controversial. In recent years, considerable research on possible biological effects of EMF has been conducted. A review of these studies and their implications for health-related effects is provided in a separate technical report (see Appendix G).

5.1 Electric Fields: Short-term Effects

Short-term effects from transmission line electric fields are associated with perception of induced currents and voltages or perception of the field. Induced current or spark discharge shocks can be experienced under certain conditions when a person contacts objects in an electric field. Such effects

occur in the fields associated with transmission lines that have voltages of 230-kV or higher. These effects could occur infrequently under the proposed I-5 Corridor Reinforcement 500-kV line.

Steady-state currents are those that flow continuously after a person contacts an object and provides a path to ground for the induced current. The amplitude of the steady-state current depends on the induced current to the object in question and on the grounding path. The magnitude of the induced current to vehicles and objects under the proposed line will depend on the electric-field strength and the size and shape of the object. When an object is electrically grounded, the voltage on the object is reduced to zero, and it is not a source of current or voltage shocks. If the object is poorly grounded or not grounded at all, then it acquires some voltage relative to earth and is a possible source of current or voltage shocks.

The responses of persons to steady-state current shocks have been extensively studied, and levels of response documented (Keesey and Letcher, 1969; IEEE, 1978). Primary shocks are those that can result in direct physiological harm. Such shocks will not be possible from induced currents under the existing or proposed lines, because clearances above ground required by the NESC preclude such shocks from large vehicles and grounding practices eliminate large stationary objects as sources of such shocks.

Secondary shocks are defined as those that could cause an involuntary and potentially harmful movement, but no direct physiological harm. Secondary shocks could occur under the proposed 500-kV line when making contact with ungrounded conducting objects such as vehicles or equipment. However, such occurrences are anticipated to be very infrequent. Shocks, when they occur under the 500-kV line, are most likely to be below the nuisance level. Induced currents are extremely unlikely to be perceived off the right-of-way of the proposed line.

Induced currents are always present in electric fields under transmission lines and will be present near the proposed line. However, during initial construction, BPA routinely grounds metal objects that are located on or near the right-of-way. The grounding eliminates these objects as sources of induced current and voltage shocks. Multiple grounding points are used to provide redundant paths for induced current flow. After construction, BPA would respond to any complaints and install or repair grounding to mitigate nuisance shocks.

Unlike fences or buildings, mobile objects such as vehicles and farm machinery cannot be grounded permanently. Limiting the possibility of induced currents from such objects to persons is accomplished in several ways. First, required clearances for above-ground conductors tend to limit field strengths to levels that do not represent a hazard or nuisance. The NESC (2002) requires that, for lines with voltage exceeding 98 kV line-to-ground (170 kV line-to-line), sufficient conductor clearance be maintained to limit the induced short-circuit current in the largest anticipated vehicle under the line to 5 milliamperes (mA) or less. This can be accomplished by limiting access or by increasing conductor clearances in areas where large vehicles could be present. BPA and other utilities design and operate lines to be in compliance with the NESC.

For the proposed line, conductor clearances at 50°C conductor temperature would be increased to at least 50 ft. (15.2 m) over road crossings along the route to meet the BPA requirement that electric fields be less than 5.0 kV/m at road crossings. The actual clearance to meet the criterion would depend on the configuration and parallel lines. As indicated earlier, in some sections line heights were increased by from 1 to 4 feet to meet the BPA limit of 9 kV/m on the right-of-way. Similarly, the conductor clearance at each road crossing would be checked during the line design stage to ensure that the BPA 5-kV/m and NESC 5-mA criteria are met. Line clearances would also be increased in accordance with the NESC, such as over railroads and water areas suitable for sailing.

The largest truck allowed on roads in Oregon and Washington without a special permit is 14 feet high by 8.5 feet wide by 75 feet long (4.3 x 2.6 x 22.9 m). The induced currents to such a vehicle oriented perpendicular to the line in a maximum field of 5 kV/m (at 3.28 foot height) would be 4.5 mA (Reilly, 1979). For smaller trucks, the maximum induced currents for perpendicular orientation to the proposed line would be less than this value. (Larger special-permitted trucks, such as triple trailers, can be up to 105 feet in length, but are not expected on the roads crossed by the proposed line. However, because they average the field over such a long distance, the maximum induced current to a 105-foot vehicle oriented perpendicular to the 500-kV line at a road crossing would be less than 4.5 mA.) Thus, the NESC 5-mA criterion would be met for perpendicular road crossings of the proposed line. These large vehicles are not anticipated to be off highways or oriented parallel and on the right-of-way of the proposed line. As discussed below, these are worst-case estimates of induced currents at road crossings; conditions for their occurrence are rare.

Several factors tend to reduce the levels of potential induced current shocks from vehicles:

1. Activities are distributed over the whole right-of-way, and only a small percentage of time is spent in areas where the field is at or close to the maximum value.
2. At road crossings, vehicles are aligned perpendicular to the conductors, resulting in a substantial reduction in induced current.
3. The conductor clearance at road crossings may not be at minimum values because of lower conductor temperatures and/or location of the road crossing away from mid-span.
4. The largest vehicles are permitted only on certain highways.
5. Off-road vehicles are in contact with soil or vegetation, which reduces shock currents substantially.

Induced voltages occur on objects, such as vehicles, in an electric field where there is an inadequate electrical ground. If the voltage is sufficiently high, then a spark discharge shock can occur as contact is made with the object. Such shocks are similar to "carpet" shocks that occur, for example, when a person touches a doorknob after walking across a carpet on a dry day. The number and severity of spark discharge shocks depend on electric-field strength. Based on the low frequency of complaints reported by Glasgow and Carstensen (1981) for 500-kV ac transmission lines (one complaint per year for each 1,500 mi. or 2400 km of 500-kV line), nuisance shocks, which are primarily spark discharges, do not appear to be a serious impediment to allowed activities under 500-kV lines. Recommended safety practices and restricted activities on BPA transmission line rights-of-way are described in the BPA booklet “Living and Working Safely Around High-Voltage Transmission Lines” (USDOE, 2007; www.bpa.gov/corporate/pubs/Public_Service/LivingAndWorking.pdf).

In electric fields higher than will occur under the proposed line, it is theoretically possible for a spark discharge from the induced voltage on a large vehicle to ignite gasoline vapor during refueling. The probability for exactly the right conditions to occur for ignition is extremely remote. The additional clearance of conductors provided at road crossings reduces the electric field in areas where vehicles are prevalent and reduces the chances for such events. Even so, BPA recommends that vehicles should not be refueled under the proposed line unless specific precautions are taken to ground the vehicle and the fueling source (USDOE, 2007).

Under certain conditions, the electric field can be perceived through hair movement on an upraised hand or arm of a person standing on the ground under high-voltage transmission lines. The median field for perception in this manner was 7 kV/m for 136 persons; only about 12 percent could perceive fields of 2 kV/m or less (Deno and Zaffanella, 1982). In areas under the conductors at mid-span, the fields

at ground level would exceed the levels where field perception normally occurs. In these instances, field perception could occur on the right-of-way of the proposed line. It is unlikely that the field would be perceived beyond the edge of the right-of-way. Where vegetation provides shielding, the field would not be perceived.

Conductive shielding reduces both the electric field and induced effects such as shocks. Persons inside a vehicle cab or canopy are shielded from the electric field. Similarly, a row of trees or a lower-voltage distribution line reduces the field on the ground in the vicinity. Metal pipes, wiring, and other conductors in a residence or building shield the interior from the transmission-line electric field.

The electric fields from the proposed 500-kV line would be comparable to those from existing 500-kV lines in the project area and elsewhere. Potential impacts of electric fields can be mitigated through grounding policies, adherence to the NESC, and increased clearances above the minimums specified by the NESC. Worst-case levels are used for safety analyses but, in practice, induced currents and voltages are reduced considerably by unintentional grounding. Shielding by conducting objects, such as vehicles and vegetation, also reduces the potential for electric-field effects.

5.2 Magnetic Field: Short-term Effects

Magnetic fields associated with transmission and distribution systems can induce voltage and current in long conducting objects that are parallel to the transmission line. As with electric-field induction, these induced voltages and currents are a potential source of shocks. A fence, irrigation pipe, pipeline, electrical distribution line, or telephone line forms a conducting loop when it is grounded at both ends. The earth forms the other portion of the loop. The magnetic field from a transmission line can induce a current to flow in such a loop if it is oriented parallel to the line. If only one end of the fence is grounded, then an induced voltage appears across the open end of the loop. The possibility for a shock exists if a person closes the loop at the open end by contacting both the ground and the conductor. The magnitude of this potential shock depends on the following factors: the magnitude of the field; the length of the object (the longer the object, the larger the induced voltage); the orientation of the object with respect to the transmission line (parallel as opposed to perpendicular, where no induction would occur); and the amount of electrical resistance in the loop (high resistance limits the current flow).

Magnetically induced currents from power lines have been investigated for many years; calculation methods and mitigating measures are available. A comprehensive study of gas pipelines near transmission lines developed prediction methods and mitigation techniques specifically for induced voltages on pipelines (Dabkowski and Taflove, 1979; Taflove and Dabkowski, 1979). Similar techniques and procedures are available for irrigation pipes and fences. Grounding policies employed by utilities for long fences reduce the potential magnitude of induced voltage.

The magnitude of the coupling with both pipes and fences is very dependent on the electrical unbalance (unequal currents) among the three phases of the line. Thus, a distribution line where a phase outage may go unnoticed for long periods of time can represent a larger source of induced currents than a transmission line where the loads are well-balanced (Jaffa and Stewart, 1981).

Knowledge of the phenomenon, grounding practices, and the availability of mitigation measures mean that magnetic-induction effects from the proposed 500-kV transmission line will be minimal.

Magnetic fields from transmission and distribution facilities can interfere with certain electronic equipment. Magnetic fields have been observed to cause distortion of the image on older VDTs and computer monitors that employ cathode ray tubes. This can occur in fields as low as 10 mG, depending on the type and size of the monitor (Baishiki et al., 1990; Banfai et al., 2000). Generally, the problem arose when computer monitors were in use near electrical distribution facilities in large office buildings.

Contemporary display devices using flat-panel technologies, such as liquid-crystal or plasma displays are not affected.

Interference from magnetic fields can be mitigated by shielding the affected device or moving it to an area with lower fields. Interference from 60-Hz fields with computers and control circuits in vehicles and other equipment is not anticipated at the field levels found under and near the proposed 500-kV transmission line.

The magnetic fields from the proposed line will be comparable to or less than those from existing 500-kV lines in the area of the proposed line and elsewhere in Washington and Oregon.

6.0 Regulations

Regulations that apply to transmission-line electric and magnetic fields fall into two categories. Safety standards or codes are intended to limit or eliminate electric shocks that could seriously injure or kill persons. Field limits or guidelines are intended to limit electric- and magnetic-field exposures that can cause nuisance shocks or might cause health effects. In no case has a limit or standard been established because of a known or demonstrated health effect.

The proposed line would be designed to meet the NESC (IEEE, 2002), which specifies how far transmission-line conductors must be from the ground and other objects. The clearances specified in the code provide safe distances that prevent harmful shocks to workers and the public. In addition, people who live and work near transmission lines must be aware of safety precautions to avoid electrical (which is not necessarily physical) contact with the conductors. For example, farmers should not up-end irrigation pipes under a transmission or other electrical line. In addition, as a matter of safety, the NESC specifies that electric-field-induced currents from transmission lines to vehicles must be below the 5 mA ("let go") threshold deemed a lower limit for primary shock. BPA publishes and distributes a booklet that describes safe practices to protect against shock hazards around power lines (USDOE, 2007).

Field limits or guidelines have been adopted in several states and countries and by national and international organizations (Maddock, 1992). Electric field limits have generally been based on minimizing nuisance shocks or field perception. The intent of magnetic-field limits has been to limit exposures to existing levels, given the uncertainty of their potential for health effects.

General guidelines for EMF exposure have been established for occupational and public exposure by national and international organizations. The limits established by three such guidelines are described in Table 8.

The American Conference of Governmental Industrial Hygienists (ACGIH) sets guidelines (Threshold Limit Values or TLVs) for occupational exposures to environmental agents (ACGIH, 2009). In general, a TLV represents the level below which it is believed that nearly all workers may be exposed repeatedly without adverse health effects. For EMF, the TLVs represent ceiling levels. For 60-Hz electric fields, occupational exposures should not exceed the TLV of 25 kV/m. However, the ACGIH also recognizes the potential for startle reactions from spark discharges and short-circuit currents in fields greater than 5 kV/m, and recommends implementing grounding practices. They recommend the use of conductive clothing for work in fields exceeding 15 kV/m. The TLV for occupational exposure to 60-Hz magnetic fields is a ceiling level of 10 G (10,000 mG) (ACGIH, 2009).

The International Committee on Non-ionizing Radiation Protection (ICNIRP), working in cooperation with the World Health Organization (WHO) has developed guidelines for occupational and public exposures to EMF (ICNIRP, 2010). For occupational exposures at 60 Hz, the recommended limits to exposure are 8.3 kV/m for electric fields and 4.2 G (4,200 mG) for magnetic fields. The electric-field level can be

exceeded, provided precautions are taken to prevent spark discharge and induced current shocks. For the general public, the ICNIRP guidelines recommend exposure limits of 4.2 kV/m for electric fields and 2.0 G (2000 mG) for magnetic fields (ICNIRP, 2010).

More recently the International Committee on Electromagnetic Safety (ICES) under the auspices of the IEEE has established exposure guidelines for 60-Hz electric and magnetic fields (ICES, 2002). The ICES recommended limits for occupational exposures are 20 kV/m for electric fields and 27,100 mG for magnetic fields. The recommended limits for the general public are lower: 5 kV/m for the general public, except on power line rights-of-way where the limit is 10 kV/m; and 9,040 mG for magnetic fields.

Electric and magnetic fields from various sources (including automobile ignitions, appliances and, possibly, transmission lines) can interfere with implanted cardiac pacemakers. In light of this potential problem, manufacturers design devices to be immune from such interference. However, research has shown that these efforts have not been completely successful and that a few models of older pacemakers still in use could be affected by 60-Hz fields from transmission lines. There were also numerous models of pacemakers that were not affected by fields larger than those found under transmission lines. Because of the known potential for interference with pacemakers by 60-Hz fields, the ACGIH recommends that, lacking additional information from the manufacturer of their pacemaker, wearers of pacemakers and similar medical-assist devices limit their exposure to electric fields of 1 kV/m or less and to magnetic fields to 1 G (1,000 mG) or less (ACGIH, 2009). Additional discussion of interference with implanted devices is given in the accompanying technical report on health effects (Appendix G).

There are currently no national standards in the United States for 60-Hz electric and magnetic fields. The state of Washington does not have guidelines for electric or magnetic fields from transmission lines. The state of Oregon has a limit on the maximum electric field allowed under a line of 9 kV/m. Several other states have established mandatory or suggested limits on 60-Hz electric and (in two cases) magnetic fields. Six states have specific electric-field limits that apply to transmission lines: Florida, Minnesota, Montana, New Jersey, New York, and Oregon. Florida and New York have established regulations for magnetic fields. These regulations are summarized in Table 9.

Government agencies and utilities operating transmission systems have established design criteria that include EMF levels. BPA has maximum allowable electric fields of 9 and 2.5 kV/m on and at the edge of the right-of-way, respectively (USDOE, 2010). BPA also has maximum-allowable electric field strengths of 5 kV/m, 3.5 kV/m, and 2.5 kV/m for road crossings, shopping center parking lots, and commercial/ industrial parking lots, respectively. The latter levels are based on limiting the maximum short-circuit currents from anticipated vehicles to less than 1 mA in shopping center lots and to less than 2 mA in commercial parking lots.

The electric fields from the proposed 500-kV line would meet the ACGIH standards, provided wearers of pacemakers and similar medical-assist devices are discouraged from unshielded right-of-way use. (A passenger in an automobile under the line would be shielded from the electric field.) The electric fields in limited areas on the right-of-way would exceed the ICNIRP guideline for public exposure, but would be below IEEE guideline limits. The magnetic fields from the proposed line would be below the ACGIH, ICNIRP, and IEEE limits.

The estimated peak electric fields on the right-of-way of the proposed transmission line would meet limits set in Florida, New York and Oregon, but not those of Minnesota and Montana (see Table 9). The BPA maximum allowable electric field limit would be met for all configurations of the proposed line. The edge of right-of-way electric fields from the proposed line would be below limits set in Florida and New Jersey, but above those in Montana and New York.

The magnetic field at the edge of the right-of-way from the proposed line would be below the regulatory levels of states where such regulations exist.

7.0 Audible Noise

7.1 Basic Concepts

Audible noise (AN), as defined here, represents an unwanted sound, as from a transmission line, transformer, airport, or vehicle traffic. Sound is a pressure wave caused by a sound source vibrating or displacing air. The ear converts the pressure fluctuations into auditory sensations. AN from a source is superimposed on the background or ambient noise that is present before the source is introduced.

The amplitude of a sound wave is the incremental pressure resulting from sound above atmospheric pressure. The sound-pressure level is the fundamental measure of AN; it is generally measured on a logarithmic scale with respect to a reference pressure. The sound-pressure level (SPL) in decibels (dB) is given by:

$$SPL = 20 \log (P/P_o)dB$$

where P is the effective rms (root-mean-square) sound pressure, P_O is the reference pressure, and the logarithm (log) is to the base 10. The reference pressure for measurements concerned with hearing is usually taken as 20 micropascals (Pa), which is the approximate threshold of hearing for the human ear. A logarithmic scale is used to encompass the wide range of sound levels present in the environment. The range of human hearing is from 0 dB up to about 140 dB, a ratio of 10 million in pressure (EPA, 1978).

Logarithmic scales, such as the decibel scale, are not directly additive: to combine decibel levels, the dB values must be converted back to their respective equivalent pressure values, the total rms pressure level found, and the dB value of the total recalculated. For example, adding two sounds of equal level on the dB scale results in a 3 dB increase in sound level. Such an increase in sound pressure level of 3 dB, which corresponds to a doubling of the energy in the sound wave, is barely discernible by the human ear. It requires an increase of about 10 dB in SPL to produce a subjective doubling of sound level for humans. The upper range of hearing for humans (140 dB) corresponds to a sharply painful response (EPA, 1978). The computation method described above was incorporated into the derivation of a distance weighted mean noise level as a summary measure for each alternative,

Humans respond to sounds in the frequency range of 16 to 20,000 Hz. The human response depends on frequency, with the most sensitive range roughly between 2000 and 4000 Hz. The frequency-dependent sensitivity is reflected in various weighting scales for measuring audible noise. The A-weighted scale weights the various frequency components of a noise in approximately the same way that the human ear responds. This scale is generally used to measure and describe levels of environmental sounds such as those from vehicles or occupational sources. The A-weighted scale is also used to characterize transmission-line noise. Sound levels measured on the A-scale are expressed in units of dBA.

AN levels and, in particular, corona-generated audible noise (see below) vary in time. In order to account for fluctuating sound levels, statistical descriptors have been developed for environmental noise. Exceedence levels (L levels) refer to the A-weighted sound level that is exceeded for a specified percentage of the time. Thus, the L_5 level refers to the noise level that is exceeded only 5 percent of the time. L_{50} refers to the sound level exceeded 50 percent of the time. Sound-level measurements and predictions for transmission lines are often expressed in terms of exceedence levels, with the L_5 level representing the maximum level and the L_{50} level representing a median level.

Table 10 shows AN levels from various common sources. Clearly, there is wide variation. Noise exposure depends on how much time an individual spends in different locations. Outdoor noise generally does not contribute to indoor levels (EPA, 1974). Activities in a building or residence generally dominate interior AN levels.

BPA has established a transmission-line design criterion for corona-generated audible noise (L_{50}, foul weather) of 50 dBA at the edge of the right-of-way (USDOE, 2006). This criterion applies to new line construction and is under typical conditions of foul weather, altitude, and system voltage for the line. It is generally only of concern for 500-kV lines. If a new line is being built adjacent to an existing line, possibly of an older and noisier design, the criterion allows the 50 dBA criterion to be exceeded if the increase from the existing noise level is no more than 3 dBA.

The Washington Administrative Code provides noise limitations by class of property, residential, commercial or industrial (Washington State, 1975). Transmission lines are classified as industrial and may cause a maximum permissible noise level of 60 dBA to intrude into residential property. During nighttime hours (10 p.m. to 7 a.m.), the maximum permissible limit for noise from industrial to residential areas is reduced to 50 dBA. This latter level applies to transmission lines that operate continuously. The state of Washington Department of Ecology accepts the 50 dBA level at the edge of the right-of-way for transmission lines, but encouraged BPA to design lines with lower audible noise levels (WDOE, 1981).

Audible noise from substations is generated predominantly by equipment such as transformers, reactors and other wire-wound equipment. It is characterized by a 120 Hz hum that is associated with magnetic-field caused vibrations in the equipment. Noise from such equipment varies by voltage and other operating conditions. The BPA design level for substation noise is 50 dBA at the substation property line for new construction (USDOE, 2010). The design level is met by obtaining equipment that meets specified noise limits and, for new substations, by securing a no-built buffer beyond the substation perimeter fence.

In industrial, business, commercial, or mixed use zones the AN level from substations may exceed 50 dBA but must still meet any state or local AN requirements. The design criteria also allow the 50 dBA design level to be exceeded in remote areas where development of noise sensitive properties is highly unlikely.

The EPA has established a guideline of 55 dBA for the annual average day-night level (L_{dn}) in outdoor areas [EPA, 1978]. In computing this value, a 10 dB correction (penalty) is added to night-time noise between the hours of 10 p.m. and 7 a.m.

7.2 Transmission Line Audible Noise

Corona is the partial electrical breakdown of the insulating properties of air around the conductors of a transmission line. In a small volume near the surface of the conductors, energy and heat are dissipated. Part of this energy is in the form of small local pressure changes that result in audible noise. Corona-generated audible noise can be characterized as a hissing, crackling sound that, under certain conditions, is accompanied by a 120-Hz hum. Corona-generated audible noise is of concern primarily for contemporary lines operating at voltages of 345 kV and higher during foul weather. The proposed 500-kV line will produce some noise under foul weather conditions.

The conductors of high-voltage transmission lines are designed to be corona-free under ideal conditions. However, protrusions on the conductor surface—particularly water droplets on or dripping off the conductors—cause electric fields near the conductor surface to exceed corona onset levels, and corona occurs. Therefore, audible noise from transmission lines is generally a foul-weather (wet-conductor)

phenomenon. Wet conductors can occur during periods of rain, fog, snow, or icing. Based on hourly meteorological records from 2005 to 2009 at the Portland International Airport, such conditions are expected to occur about 21 percent of the time during the year in the general area of the proposed line. Continuous records for these meteorological conditions were not found for other locations in the project area.

For a few months after line construction, residual grease or oil on the conductors can cause water to bead up on the surface. This results in more corona sources and slightly higher levels of audible noise and electromagnetic interference if the line is energized. However, the new conductors "age" in a few months, and the level of corona activity decreases to the predicted equilibrium value. During fair weather, insects and dust on the conductor can also serve as sources of corona.

7.3 Predicted Audible Noise Levels

L_{50} foul-weather audible noise levels were calculated for average voltage of 539 kV and average conductor heights for foul-weather conditions. The calculated values of the L_{50} foul-weather audible noise level for all of the proposed 500-kV transmission-line sections can be found in the appendix to this report. Specifically, the appendix contains a table of noise levels at the edge of the right-of-way and a plot of noise levels as a function of distance from the line for each proposed transmission line section.

An audible noise plot for the proposed line operating on a new right-of-way is shown in Figure 6. The L_{50} foul-weather level at the edge of the right-of-way is 47 dBA. The audible noise falls about 3 dBA for every doubling of distance. Therefore at 150 feet from the proposed centerline the noise level would be about 44 dBA; at 300 feet, 41 dBA and at 600 feet, 38 dBA.

The large number of existing right-of-way sections that comprise the alternative routes make it impractical to tabulate results for each of these. However, the 3 dBA drop in audible noise at the distances described above for the new right-of-way provide an indication of the noise levels that can be expected off the right-of-way when the proposed line is on an existing right-of-way.

The distance-weighted average levels of corona-generated audible noise at the edge of the right-of-way for the alternatives, options and No Action alternative are given in Tables 11 to 14. Across all alternatives and options, the calculated L_{50} foul-weather noise levels at the edge of the right-of-way depend on the width of the right-of-way and the adjacent lines in the route segment or line section. The highest of the distance-weighted average noise levels from the two sides of the right-of-way was used to characterize the summary measure for each alternative.

Where existing lines are in the right-of-way, distance-weighted average foul-weather noise levels for the alternatives (excluding options) at the edge of the right-of-way would range from 47 to 48 dBA as shown in Tables 11-14. Thus, audible noise from all four alternatives would be comparable by this measure. Calculated noise levels at the edge of existing rights-of-way for all 12 options would range from 47 to 56 dBA. Audible noise would exceed 50 dBA in some sections in West Option 3, Central Option 1, and Crossover Options 2 and 3. (There is one section exceeding 50 dBA in East Option 3.) In all these instances, the increase in the noise levels above the No Action Alternative would be less than 3 dBA, so all sections would meet BPA noise criteria. As noted above the L_{50} foul-weather level at the edge of a new right-of-way with no adjacent lines is 47 dBA.

Noise levels at the edge of the No Action Alternative's existing rights-of-way range from 37 to 57 dBA. In the highest case, an existing 500-kV of older design is on the existing right-of-way. Audible noise levels for the No Action Alternative are lower than those for the action alternatives, with one exception (Crossover Option 2).

During fair-weather conditions, which occur about 80 percent of the time, audible noise levels at the edge of the right-of-way would be about 20 dBA lower (if corona were present). These lower levels could be masked by ambient noise on and off the right-of-way.

7.4 Discussion

Along much of the proposed routes there would be increases in the perceived noise above current ambient levels during foul weather at the edges of the right-of-way. This would be especially true in areas adjacent to the edge of the right-of-way next to the proposed 500-kV line. However, even there, the corona-generated noise during foul weather would be masked to some extent by naturally occurring sounds such as wind and rain on foliage. The calculated foul-weather corona noise levels for the proposed line would be comparable to, or less, than those from existing 500-kV lines in Oregon and Washington. Relatively lower levels would be especially prevalent in line segments with existing wide rights-of-way that allow a large separation between the proposed 500-kV line and the opposite edge.

Off the right-of-way corona-generated noise during fair weather will likely be masked or so low as to not be perceived even in fair weather. During foul-weather ambient noise levels can be high due to rain hitting foliage or buildings and wind. These sounds can mask corona noise both on and off the right-of-way. Furthermore people tend to be inside with windows closed, providing additional attenuation when corona noise is present.

Off the right-of-way, the foul-weather levels of audible noise from the proposed line would be well below the 55 dBA level that can produce interference with speech outdoors. Residential buildings provide significant sound attenuation (-12 dBA with windows open; -24 dBA with windows closed). Therefore indoor noise levels off the right-of-way would be well below the 45 dBA level where interference with speech indoors can occur and below the 35 dBA level where sleep interference can occur (EPA, 1973; EPA, 1978).

The highest noise level of 50-dBA for the action alternatives (without options) would meet the BPA design criterion and, hence, the statutory limits established in both Oregon and Washington. The computed annual L_{dn} level for transmission lines operating in areas with 20 percent foul weather is about $L_{dn} = L_{50} + 1$ dB (Bracken, 1987). Therefore, assuming such conditions in the I-5 Corridor Reinforcement Project area, the estimated worst case L_{dn} at the edge of the right-of-way would be approximately 51 dBA, which is below the EPA L_{dn} guideline of 55 dBA.

At the proposed substations, audible noise levels will be predominantly due to foul weather corona noise from incoming and outgoing transmission lines. There are no transformers proposed for the new substations. (Even if there were, noise levels produced from new transformers are required to meet BPA specifications that limit noise to 50 dBA at the edge of the substation.) Thus, the proposed substations would meet the 50 dBA criterion as it applies to substations (USDOE, 2010).

Thus all applicable federal, state, and local regulations will be met by the proposed transmission line and substations.

8.0 Electromagnetic Interference

8.1 Basic Concepts

Corona on transmission-line conductors can also generate electromagnetic noise in the frequency bands used for radio and television signals. The noise can interfere with AM radio signals and, in the past, with broadcast television signals on Channels 2 to 6. With the introduction of digital television technology,

the broadcast frequencies for these channels have been increased and corona-generated interference with their signals is no longer a potential problem.

In certain circumstances, corona-generated electromagnetic interference (EMI) can also affect communications systems and other sensitive receivers. Interference with electromagnetic signals by corona-generated noise is generally associated with lines operating at voltages of 345 kV or higher. The bundle of three 1.3-inch diameter conductors used in the design of the proposed 500-kV line will mitigate corona generation and keep EMI levels at acceptable levels.

Spark gaps on distribution lines and on low-voltage wood-pole transmission lines have been a more common source of RI/TVI than is corona from high-voltage electrical systems. This gap-type interference is primarily a fair-weather phenomenon caused by loose hardware and wires. The proposed transmission line would be constructed with modern hardware that eliminates such problems and therefore minimizes gap noise. Consequently, this source of EMI is not anticipated for the proposed line.

No state has limits for either RI or TVI. In the United States, electromagnetic interference from power transmission systems is governed by the Federal Communications Commission (FCC) Rules and Regulations presently in existence (Federal Communications Commission, 1988). A power transmission system falls into the FCC category of "incidental radiation device," which is defined as "a device that radiates radio frequency energy during the course of its operation although the device is not intentionally designed to generate radio frequency energy." Such a device "shall be operated so that the radio frequency energy that is emitted does not cause harmful interference. In the event that harmful interference is caused, the operator of the device shall promptly take steps to eliminate the harmful interference." For purposes of these regulations, harmful interference is defined as: "any emission, radiation or induction which endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radio communication service operating in accordance with this chapter" (Federal Communications Commission, 1988: Vol II, part 15. 47CFR, Ch. 1).

Electric power companies have been able to work quite well under the present FCC rule because harmful interference can generally be eliminated. It has been estimated that more than 95 percent of power line sources that caused interference were due to gap-type discharges. These can be found and completely eliminated, when required to prevent interference (USDOE, 1980). Complaints related to corona-generated interference occur infrequently. This is especially true due to increased use of FM radio, cable television and satellite television, which are not subject to corona-generated interference. Mitigation of corona-generated interference with conventional broadcast radio and television receivers can be accomplished in several ways, such as use of a directional antenna or relocation of an existing antenna (USDOE, 1977; USDOE, 1980; Loftness et al., 1981).

8.2 Radio Interference (RI)

Radio reception in the AM broadcast band (535 to 1605 kilohertz (kHz)) is most often affected by corona-generated EMI. FM radio reception is rarely affected. Generally, only residences very near to transmission lines can be affected by RI. The IEEE Radio Noise Design Guide identifies an acceptable limit of fair-weather RI as expressed in decibels above 1 microvolt per meter (dBμV/m) of about 40 dB(μV/m) at 1 megahertz (MHz) (IEEE Committee Report, 1971). This limit applies at 100 ft. (30 m) from the outside conductor. As a general rule, average levels during foul weather (when the conductors are wet) are 16 to 22 dBμV/m higher than average fair-weather levels.

8.2.1 Predicted RI Levels

Distance-weighted L_{50} fair-weather RI levels were predicted for all line sections at 100 ft. (30 m) from the outside conductor. The results are summarized in Tables 11 to 14. The L_{50} fair weather levels for all configurations are at or below the acceptable limit of about 40 dBμV/m and are therefore compliant with the IEEE guideline level. The RI levels for the proposed 500-kV configurations would exceed those from the existing lower voltage lines.

8.3 Television Interference (TVI)

Corona-caused TVI occurs during foul weather and generally has been of concern for transmission lines with voltages of 345 kV or above, and only for conventional receivers within about 600 ft. (183 m) of a line. As indicated above, the conversion to digital television signals has resulted in the affected channels (2 to 6) being broadcast at much higher frequencies where TVI has not been present.

8.3.1 Predicted TVI Levels

For comparison with existing 500-kV lines, the predicted foul-weather TVI levels at 75MHz from the proposed configurations operating at 539 kV are shown in Tables 11 to 14. These distance-weighted average levels are given for 100 ft. (30 m) from the outside conductor. The highest average levels at these points for the alternatives and options would range from 18 to 21 dBμV/m with two exceptions: Levels near Crossover Options 2 and 3 that include an existing 500-kV are higher, 27 and 24 dBμV/m, respectively. In these cases, the higher levels are also present from the existing lines in the No Action Alternative. These levels are comparable to or lower than those from existing 500-kV lines in Oregon and Washington. As with RI the largest values occur when the proposed 500-kV line is directly adjacent to the edge of the right-of-way.

The conversion of broadcast television signals from analog to digital has reduced the likelihood of interference with television reception significantly. Several factors further reduce the likelihood of TVI occurrence. Corona-generated EMI occurs only in foul weather; consequently, signals will not be interfered with most of the time, which is characterized by fair weather. Because television antennas are directional, the impact of TVI is related to the location and orientation of the antenna relative to the transmission line. If the antenna were pointed away from the line, then TVI from the line would affect reception much less than if the antenna were pointed towards the line. Since the level of TVI falls off with distance, the potential for interference becomes minimal at distances greater than several hundred feet from the centerline.

Other forms of TVI from transmission lines are signal reflection (ghosting) and signal blocking caused by the relative locations of the transmission structure and the receiving antenna with respect to the incoming television signal. Again only houses within several hundred feet of the proposed line would possibly be affected.

Television systems that operate at higher frequencies, such as satellite receivers, are not affected by corona-generated EMI. Cable television systems are also not affected.

In the unlikely event that interference with television reception occurs, it can be corrected by any of several approaches: improving the receiving antenna system; installing a remote antenna; installing an antenna for TV stations less vulnerable to interference; connecting to an existing cable system; or installing a translator (cf. USDOE, 1977). BPA has an active program to identify, investigate, and mitigate legitimate RI and TVI complaints. It is anticipated that any instances of TVI caused by the proposed line could be effectively mitigated.

8.4 Interference with Other Devices

Corona-generated interference can conceivably cause disruption on other communications bands. However, interference is very unlikely with newer devices (cell phones and GPS units) that operate with digital signals and at frequencies well above those where corona-generated interference is prevalent. Mobile-radio communications are not susceptible to transmission-line interference because they are generally frequency modulated (FM). In the unlikely event that interference occurs with these or other communications, mitigation can be achieved with the same techniques used for TV and AM radio interference. To be in compliance with FCC regulations, BPA will work with owners and operators of communications facilities along the alternative routes to identify possible mitigation measures and to implement them in the event of interference from the proposed transmission line.

8.5 Conclusion

Predicted EMI levels for the proposed 500-kV transmission line are comparable to, or lower, than those that already exist near 500-kV lines and no impacts of corona-generated interference on radio, television, or other reception are anticipated. Based on land use surveys and population density estimates, the number of houses that could be affected by EMI would vary by alternative, with the West Alternative having the most potential for impact and the East Alternative the least. Whether interference occurs will depend on which action alternative or option is selected, as well as the type of receivers and devices that are present. Furthermore, if interference should occur, there are various methods for correcting it; BPA has a program to respond to legitimate complaints.

9.0 Other Corona Effects

Corona is visible as a bluish glow or as bluish plumes. On the proposed 500-kV line, corona levels would be very low, so that corona on the conductors would be observable only under the darkest conditions and only with the aid of binoculars, if at all. Without a period of adaptation for the eyes and without intentional looking for the corona, it would probably not be noticeable.

When corona is present, the air surrounding the conductors is ionized and many chemical reactions take place, producing small amounts of ozone and other oxidants. Ozone is approximately 90 percent of the oxidants, while the remaining 10 percent is composed principally of nitrogen oxides. The national primary ambient air quality standard for ozone is 75 parts per billion averaged over eight hours. The maximum incremental ozone levels at ground level produced by corona activity on the proposed transmission line during foul weather would be much less than 1 part per billion. This level is insignificant when compared with natural levels and fluctuations in natural levels.

10.0 Summary

Electric and magnetic fields from the proposed transmission line have been characterized using well-known techniques accepted within the scientific and engineering community. The expected maximum electric and magnetic fields on and at the edge of the right-of-way from the proposed line at minimum design clearance would be comparable to those from existing 500-kV lines in Washington, Oregon and elsewhere.

The electric fields from the proposed line would meet regulatory limits for public exposure in some states and guidelines established by IEEE. However, the electric fields from the line could exceed the regulatory limits or guidelines for peak fields established in one state (Minnesota) and by ICNIRP. The

magnetic fields from the proposed line would be within the regulatory limits of the two states that have established such limits and below the guidelines for public exposure established by ICNIRP and IEEE. Washington does not have any electric- or magnetic-field regulatory limits or guidelines.

Short-term effects from transmission-line fields are well understood and can be mitigated. Nuisance shocks arising from electric-field induced currents and voltages could be perceivable on the right-of-way of the proposed line. It is common practice to ground permanent conducting objects during and after construction to mitigate against such occurrences.

Corona-generated audible noise from the line would be perceivable during foul weather. The levels would be comparable to or less than those near existing 500-kV transmission lines in Oregon and Washington, would meet BPA design criteria, would be in compliance with noise regulations in Oregon and Washington, and would be below levels specified in EPA guidelines.

Corona-generated electromagnetic interference from the proposed line would be comparable to or less than that from existing 500-kV lines in Washington. AM radio interference levels would be at or below limits identified as acceptable. Television interference, a foul-weather phenomenon, is anticipated to be comparable to or less than that from existing 500-kV lines in Washington and Oregon. The recent introduction of digital television technology significantly reduces the potential for corona-generated TVI from both new and existing lines. However, if legitimate complaints arise, BPA has a mitigation program.

Table 15 presents a group of summary measures for average electric field, magnetic field and audible noise levels at the edge of the right-of-way along each alternative. This table provides a means to compare long-term levels of the three parameters among action alternatives. Line segments in the action alternative options were included only in the computation of the segment maximum and minimum levels. The impact of this exclusion on the other summary measures is expected to be minimal, except for the three options that include existing 500-kV lines. The effects on magnetic fields and audible noise of inclusion of these options have been cited previously.

The differences in average levels of electric fields between alternatives are dependent to some extent on right-of-way type. The Central and East alternatives with 90 percent new right-of-way tend to have higher electric fields at the edge-of the right-of way. The West Alternative with only 2 percent of new right-of-way has the lowest average electric fields at the edge of the right-of-way. However, the differences in electric-field levels are not sufficient to affect the anticipated induction effects that occur under all 500-kV lines.

A comparison of magnetic fields in Table 15 indicates that the preponderance of new right-of-way in the Central and East alternatives also leads to slightly higher average magnetic fields at the edge of the right-of-way. The route segment maximums in all alternatives are very comparable. The differences in magnetic field levels between alternatives are all slight.

The average audible noise levels for all alternatives are about 47 dBA. Incorporation of the option(s) with existing 500-kV lines would result in localized areas with perceptibly higher noise levels. However, in these cases, changes to noise levels from the No Action Alternative at the edge of the right-of-way would not be discernable to the human ear. Like audible noise, radio and television interference levels are directly related to corona level and will exhibit the same consistency across alternatives.

The comparison of average edge of right-of-way values in Table 15 indicates differences between some of the alternatives. However the magnitude of the differences is not deemed sufficient to differentiate the level of effects that are anticipated from the different alternatives. Therefore the level of impact as measured by frequency of occurrence of effects such as nuisance shocks, audible noise annoyance or

television interference will depend more on the number of people living on or utilizing the land within several hundred feet of the line than on the levels of the physical parameters.

Summaries of land-use area crossed by the action alternatives and zoning within 1,000 feet of the proposed line indicate that there are significant differences in the estimated number of people that live or will ultimately live and use the land near the different alternatives (Chapter 5; Golder, 2011).

- The West Alternative and options would occupy predominantly (98 percent) existing right-of-way, which crosses the highest proportion (17 percent) of populated area compared to the other action alternatives – about 7 percent urban/suburban and 10 percent rural. Most of the rural area is undeveloped. Beyond the right-of-way – from the right-of-way edge out to 1,000 feet on either side of the line – the West Alternative and options would encompass a greater percentage of property zoned for residential use than the other alternatives: about 46 percent of property along the West Alternative is zoned for residential use.
- The Central Alternative and options would primarily use new right-of-way (about 90 percent) that would run through predominantly forest land (around 90 percent of land use crossed). Only 3 percent of the land crossed by the right-of-way would be populated – 1 percent urban/suburban and 2 percent rural (exception: Central Option 2 would cross 4 percent rural land). About 14 percent of the land beyond the right-of-way (out to 1,000 feet on both sides) of the East Alternative and options is zoned for residential use.
- The East Alternatives and options would primarily use new right-of-way (about 90 percent) that would run through predominantly forest land (around 90 percent of land use crossed). Only 3 percent of the land crossed by the right-of-way would be populated – about 1 percent urban/suburban and 2 percent rural (exception: East Option 1 would cross 4 percent rural land). About 7 percent of the land beyond the right-of-way (out to 1,000 feet) of the East Alternative and options is zoned for residential use.
- The Crossover Alternative and options would require about 55 percent new right-of-way that would cross predominantly forest land (about 76 percent). About 8 percent of the land crossed by the right-of-way would be populated – about 1 percent urban/suburban and 7 percent rural. About 14 percent of the land beyond the right-of-way (out to 1,000 feet) of the Crossover Alternative and options is zoned for residential use.

The distribution of land uses and zoning along the various alternatives suggests that the overall impact of electrical effects would be greater along the West Alternative than along the other alternatives. The impacts of electrical effects would be comparable along the other three alternatives.

List of References Cited

ACGIH (American Conference of Governmental Industrial Hygienists). 2009. 2009 TLVs and BEIs: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. American Conference of Governmental Industrial Hygienists, Cincinnati. 254 pages.

Baishiki, R.S.; Johnson, G.B.; Zaffanella, L.E.; Bracken, T.D.; Sussman, S.S.; Rauch, G.B.; and Silva, J.M. 1990. Studies of Power System Magnetic Fields: Characterization of Sources in Residential Environments, Measurement of Exposure, Influence On Computer Screens. (36-104) CIGRE, Paris, France. 10 pages.

Banfai, B.; Karady, G.G.; Kim, C.J.; and Maracas, K.B. 2000. Magnetic field effects on CRT computer monitors. IEEE Trans. on Power Delivery 15, 307-312.

Bassen, H.; Casamento, J.; and Crowl, B. 1991. Reduction of electric and magnetic field emissions from electric blankets (Meeting abstract). *In*: Bioelectromagnetics Society, 13th Annual Meeting, 23-27 June, Salt Lake City. Bioelectromagnetics Society, New York, 20.

Bowman, J.D.; Garabrant, D.H.; Sobel, E.; and Peters, J.M. June 1988. Exposures to Extremely Low Frequency (ELF) Electromagnetic Fields in Occupations With Elevated Leukemia Rates. Applied Industrial Hygienics, 3(6, June):189-194.

Bracken, T.D. 1987. Audible Noise from High Voltage Transmission Facilities. A Briefing Paper Prepared for State of Florida Department of Environmental Regulation. (DER Contract No. SP122) State of Florida Department of Environmental Regulation.

Bracken, T.D. 1990. The EMDEX Project: Technology Transfer and Occupational Measurements, Volumes 1-3 Interim Report. EPRI Report EN-7048. (EPRI EN-7048) Electric Power Research Institute, Palo Alto, CA.

Chartier, V.L. April 1983. Empirical Expressions for Calculating High Voltage Transmission Corona Phenomena, First Annual Seminar Technical Career Program for Professional Engineers. Bonneville Power Administration, Portland, Oregon. April 1983, 75-82.

Chartier, V.L. and Stearns, R.D. January 1981. Formulas for Predicting Audible Noise from Overhead High Voltage AC and DC Lines. IEEE Transactions on Power Apparatus and Systems, PAS-100(No. 1, January 1981):121-129.

Dabkowski, J. and Taflove, A. May/June 1979. Prediction Method for Buried Pipeline Voltages Due to 60 Hz AC Inductive Coupling. Part II: Field Test Verification. IEEE Transactions on Power Apparatus and Systems, PAS-98(3, May/June):788-794.

Deno, D.W. and Zaffanella, L. 1982. Field effects of overhead transmission lines and stations. Chap. 8. *In*: Transmission Line Reference Book: 345 KV and Above. Second ed. (Ed: LaForest, J.J.). Electric Power Research Institute, Palo Alto, CA, 329-419.

EPA (Environmental Protection Agency). July 1973. Public Health and Welfare Criteria for Noise. (No. 500/9-73-002, July 27, 1973.) U.S. Environmental Protection Agency, Washington, D.C.

EPA. 1974. Information On Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety. (No. PB-239 429.) U.S. Environmental Protection Agency, Washington, D.C.

EPA. 1978. Protective Noise Levels. Condensed Version of EPA Levels Document. (No. PB82-138827) U.S Environmental Protection Agency, Washington, DC.

Exponent. 2009. Update of EMF Research – 2009. Technical report prepared for Bonneville Power Administration by Exponent, New York, NY (April 2009).

Federal Communications Commission. 1988. Federal Communications Commission Rules and Regulations. 10-1-88 ed. Vol. II part 15, 47 CFR, Ch. 1.

Florig, H.K. and Hoburg, J.F. 1988. Electric and Magnetic Field Exposure Associated With Electric Blankets. Project Resume. Contractor's Review. U.S. Department of Energy/Electric Power Research Institute.

Florig, H.K.; Hoburg, J.F.; and Morgan, M.G. April 1987. Electric Field Exposure from Electric Blankets. IEEE Transactions on Power Delivery, PWRD-2(2, April):527-536.

Gauger, J. September 1985. Household Appliance Magnetic Field Survey. IEEE Transactions on Power Apparatus and Systems, 104(9, September):2436-2445.

Glasgow, A.R. and Carstensen, E.L. February 1981. The Shock Record for 500 and 750 KV Transmission Lines in North America. IEEE Transactions on Power Apparatus and Systems, 100(2, February):559-562.

Golder Associates, Inc. 2011. Technical report summarizing zoning and population data prepared for Bonneville Power Administration by Golder Associates, Inc., Redmond, WA (March 2011).

Heroux, P. 1987. 60-Hz Electric and Magnetic Fields Generated By a Distribution Network. Bioelectromagnetics, 8(2):135-148.

ICES (International Committee on Electromagnetic Safety): 2002. IEEE PC95.6-2002 Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0 to 3 kHz. Institute of Electrical and Electronics Engineers, Piscataway, NJ.

ICNIRP (International Committee on Non-ionizing Radiation Protection). 2010. ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1Hz – 100 kHz). Health Physics, 99 (6):818-836.

IEEE (Institute of Electrical and Electronics Engineers, Inc.). 1978. Electric and Magnetic Field Coupling from High Voltage AC Power Transmission Lines -- Classification of Short-Term Effects On People. IEEE Transactions on Power Apparatus and Systems, PAS-97:2243-2252.

IEEE. 1994. IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines. ANSI/IEEE Std. 644-1994, New York, NY.

IEEE. 2002. National Electrical Safety Code. 2002 ed. Institute of Electrical and Electronics Engineers, Inc., New York, NY. 287 pages.

IEEE Committee Report. March/April 1971. Radio Noise Design Guide for High Voltage Transmission Lines. IEEE Transactions on Power Apparatus and Systems, PAS-90(No. 2, March/April):833-842.

IEEE Committee Report. October 1982. A Comparison of Methods for Calculating Audible Noise of High Voltage Transmission Lines. IEEE Transactions on Power Apparatus and Systems, 101(10, October):4090-4099.

IIT Research Institute. 1984. Representative Electromagnetic Field Intensities Near the Clam Lake (WI) and Republic (MI) ELF Facilities. Report Prepared for Naval Electronics Systems Command, PME 110 E Washington, D.C. 20360. (Under contract N00039-84-C0070.) IIT Research Institute, Chicago, IL. 60 pages.

Jaffa, K.C. and Stewart, J.B. March 1981. Magnetic Field Induction from Overhead Transmission and Distribution Power Lines On Buried Irrigation Pipelines. IEEE Transactions on Power Apparatus and Systems, PAS-100(3, March):990-1000.

Keesey, J.C. and Letcher, F.S. 1969. Minimum Thresholds for Physiological Responses to Flow of Alternating Electric Current Through the Human Body At Power-Transmission Frequencies. (Report No. 1) Naval Medical Research Institute, Project MR 005.08-0030B, Bethesda, MD. 25 pages.

Loftness, M.O.; Chartier, V.L.; and Reiner, G.L. 1981. EMI Correction Techniques for Transmission Line Corona. (August 18-20, 1981, pp. 351-361.) Proceedings of the 1981 IEEE International Symposium on Electromagnetic Compatibility, Boulder, CO.

Maddock, B.J. September 1992. Guidelines and Standards for Exposure to Electric and Magnetic Fields At Power Frequencies. (Panel 2-05, CIGRE meeting August 30-September 5, 1992) CIGRE, Paris.

NOAA, National Oceanic & Atmospheric Administration. 2010. National Climatic Data Center (NCDC). http://www.ncdc.noaa.gov/oa/ncdc.html

Olsen, R.G.; Schennum, S.D.; and Chartier, V.L. April 1992. Comparison of Several Methods for Calculating Power Line Electromagnetic Interference Levels and Calibration With Long Term Data. IEEE Transactions on Power Delivery, 7(April, 1992):903-913.

Reilly, J.P. 1979. Electric Field Induction on Long Objects -- A Methodology for Transmission Line Impact Studies. IEEE Transactions on Power Apparatus and Systems, PAS-98(6, Nov/Dec):1841-1852.

Sheppard, A.R. and Eisenbud, M. 1977. Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency. New York University Press, New York.

Silva, M.; Hummon, N.; Rutter, D.; and Hooper, C. 1989. Power Frequency Magnetic Fields in the Home. IEEE Transactions on Power Delivery, 4:465-478.

Taflove, A. and Dabkowski, J. May/June 1979. Prediction Method for Buried Pipeline Voltages Due to 60 Hz AC Inductive Coupling. Part I: Analysis. IEEE Transactions on Power Apparatus and Systems, PAS-98(3, May/June):780-787.

USDOE (U.S. Department of Energy), Bonneville Power Administration. March 1977. A Practical Handbook for the Location, Prevention and Correction of Television Interference from Overhead Power Lines. Portland, OR.

USDOE, Bonneville Power Administration. May 1980. A Practical Handbook for the Correction of Radio Interference from Overhead Powerlines and Facilities. (May 1980.) Portland, OR.

USDOE, Bonneville Power Administration. 1986. Electrical and Biological Effects of Transmission Lines: A Review. (DOE/BP 524 January 1986) Portland, OR.

USDOE, Bonneville Power Administration. 1996. Electrical and Biological Effects of Transmission Lines: A Review. (DOE/BP 2938 December 1996 1M) Portland, OR.

USDOE, Bonneville Power Administration. 2006. Audible Noise Policy. TBL Policy T2006-1. Bonneville Power Administration, Portland, OR.

USDOE, Bonneville Power Administration. 2007. Living and Working Safely Around High-Voltage Power Lines. (DOE/BP-3804). Portland, OR. 12 pages.

USDOE, Bonneville Power Administration. undated. "Corona and Field Effects" Computer Program (Public Domain Software). Bonneville Power Administration, P.O. Box 491-ELE, Vancouver, WA 98666.

Washington, State of. 1975. Washington Administrative Code, Chapter 173-60 WAC Maximum Environmental Noise Levels. Department of Ecology, Olympia, WA.

WDOE (Washington Department of Ecology). 1981. Letter from D.E. Saunders to J.H. Brunke, BPA, dated 9/3/81 regarding EDNA classification for substations and transmission line. State of Washington Department of Ecology, Olympia, WA.

Zaffanella, L.E. 1993. Survey of Residential Magnetic Field Sources. Vol. 1: Goals, results, and conclusions. (EPRI TR-102759-V1, Project 3335-02) Electric Power Research Institute, Palo Alto, CA.

Zaffanella, L.E. and Kalton, G.W. 1998. Survey of personal magnetic field exposure, Phase II: 1000-perosn survey. Interim Report. EMF RAPID Program Engineering Project #6. Enertech Consultants, Lee, MA.

List of Preparers

T. Dan Bracken was the principal author of this report. He received a B.S. degree in physics from Dartmouth College and M.S. and Ph.D. degrees in physics from Stanford University. Dr. Bracken has been involved with research on and characterization of electric- and magnetic-field effects from transmission lines for over 35 years, first as a physicist with the Bonneville Power Administration (BPA) (1973 - 1980) and since then as a consultant. His firm, T. Dan Bracken, Inc., offers technical expertise in areas of electric- and magnetic-field measurements, instrumentation, environmental effects of transmission lines, exposure assessment and project management. Technical support was provided by Danna Liebhaber and Rick Stearns of BPA. The model for field and corona calculations was implemented by Charles York of BPA. Elizabeth Malliris provided editorial support in the preparation of this report.

Table 1: Physical Dimensions and Electrical Characteristics of the Proposed Single-circuit 500 kV transmission line for the I-5 Corridor Reinforcement Project.

Line Characteristic	Proposed I-5 Corridor Reinforcement 500-kV Line[2]
Voltage, kV Maximum/Average[1]	550/539
Circuit Configuration[2]	Single
Proposed Current, A Peak/Average	1080/324
Electric Phasing	Orientation varies.
Clearance, ft. Minimum/Average[1, 2]	35/47
Tower configuration	Delta
Phase spacing, ft.	46H, 31.5V
Conductor: #/Diameter, in.	3/1.3
Centerline distance to edge of ROW, ft.[3]	75
Centerline distance to existing lines, ft.	Variable
Average altitude, ft.	500-1000

[1] Average voltage and average clearance used for corona calculations.

[2] To meet the BPA 9 kV/m limit for peak electric field, the minimum and average design clearances were increased by from 1 to 4 feet in some sections.

[3] The distance to the edge of the right-of-way on existing rights-of-way will vary but will always be at least 75 feet.

Table 2: Mileage and Segments of the Action Alternatives of the I-5 Corridor Reinforcement Project

Characteristic		Action Alternative			
		West	Central	Crossover	East
Length, miles	Total	67.5	77.3	74	75.5
	New ROW	1.4 (2%)	69.5 (90%)	42.7 (58%)	67.7 (90%)
	Existing ROW	66.1	7.8	31.3	7.8
	Option 1	3.1	2.5	7.3	17.6
	Option 2	9.0	15.7	4.1	23.5
	Option 3	13.1	14.9	4.2	3.7
Segments, number	Alternative	9	18	18	11
	Option 1	3	1	3	4
	Option 2	7	5	2	5
	Option 3	7	3	2	1

Table 3: Electric and Magnetic Fields from the Proposed 500-kV Transmission Line When Operated on New Right-of-way

Field Location	Electric Field, kV/m[1]		Magnetic Field, mG[2]	
	Maximum	Average	Maximum	Average
Peak on ROW	8.8	5.3	184	35
At Edge of ROW	2.3	2.3	48	12
At 150 feet from Centerline	0.5	0.5	13	4
At 300 feet from Centerline	0.1	0.1	3	1

[1] Maximum electric fields are calculated for maximum voltage and minimum clearance. Average electric fields are calculated for average voltage and average clearance.

[2] Maximum magnetic fields are calculated for maximum current and minimum clearance. Average magnetic fields are calculated for average current and average clearance.

Table 4: Distance-weighted Average Electric and Magnetic Field Levels for the West Alternative and Options

West Alternative				Electric Field, kV/m		Magnetic Field, mG	
Right-of-Way	Length, miles [1, 2]	Field Location	Field Descriptor[3]	Proposed Action	No Action	Proposed Action	No Action
New	1.4	On ROW	Average	5.3	–	35	–
			Maximum	8.8		184	
		Edge of ROW	Average	2.3		12	
			Maximum	2.3		48	
Existing	64.2	On ROW	Average	5.4	2.0	36	24
			Maximum	8.8	3.8	182	134
		Edge of ROW	Average	1.4	0.5	10	5
			Maximum	1.4	0.5	36	21
West Option 1[4]							
New	2.0 (0.3)	Same as new ROW values shown above for West Alternative					
Existing	1.1 (2.7)	On ROW	Average	5.6	2.3	28	19
			Maximum	8.9	4.0	139	94
		Edge of ROW	Average	0.6	0.6	10	4
			Maximum	0.6	0.5	35	13
West Option 2							
New	1.7 (1.0)	Same as new ROW values shown above for West Alternative					
Existing	7.3 (6.1)	On ROW	Average	5.6	2.4	35	32
			Maximum	8.8	4.4	158	119
		Edge of ROW	Average	1.0	0.8	10	8
			Maximum	1.1	0.8	34	23
West Option 3							
New	1.5 (1.0)	Same as new ROW values shown above for West Alternative					
Existing	11.5 (6.1)	On ROW	Average	5.6	2.8	41	43
			Maximum	8.8	5.2	163	136
		Edge of ROW	Average	1.3	0.6	12	9
			Maximum	1.3	0.5	35	21

[1] Lengths in parentheses are for the original segments in the West Alternative that would be replaced by the option.
[2] The lengths for alternatives and options cited in this table include only those segments used in the calculations of average levels. The omitted segments included the Columbia River crossing and short segments where conductor locations varied over the length of the segment and/or where another line crossed the route. Calculations in these segments were not practical with the calculation model. Inclusion of these segments would not significantly change the average values of fields and corona effects along the alternatives or options.
[3] All field descriptors are distance-weighted means of the fields on or at the edge of the ROW. The edge-of-ROW values are computed from fields on both sides of the route. Average electric fields are computed for maximum voltages and average clearances along the route; likewise, average magnetic fields are computed for average

currents and average clearances. Maximum electric fields are computed for maximum voltages and minimum clearances; maximum magnetic fields are computed for maximum currents and minimum clearances.

[4] The field levels for all West options are very similar to those in the segments they would replace. The inclusion of one of these options would not significantly affect the overall mean field levels for the alternative.

Table 5: Distance-weighted Average Electric and Magnetic Field Levels for the Central Alternative and Options

Central Alternative				Electric Field, kV/m		Magnetic Field, mG	
Right-of-Way	Length, miles [1, 2]	Field Location	Field Descriptor[3]	Proposed Action	No Action	Proposed Action	No Action
New	69.5	On ROW	Average	5.3	—	35	–
			Maximum	8.8		184	
		Edge of ROW	Average	2.3		12	
			Maximum	2.3		48	
Existing	6.8	On ROW	Average	5.4	2.1	33	31
			Maximum	8.9	3.8	175	135
		Edge of ROW	Average	1.1	1.0	9	11
			Maximum	1.1	1.0	32	36
Central Option 1[4]							
New	0	Same as edge of ROW values shown above for Central Alternative					
Existing	2.5 (0.0)	On ROW	Average	5.5	5.5	62	49
			Maximum	9.0	9.0	257	235
		Edge of ROW	Average	2.3	1.4	15	10
			Maximum	2.4	1.5	59	40
Central Option 2							
New	15.0 (18.0)	Same as edge of ROW values shown above for Central Alternative					
Existing	0.4 (0.0)	On ROW	Average	5.5	2.0	34	11
			Maximum	8.8	3.7	180	78
		Edge of ROW	Average	1.6	0.7	7	3
			Maximum	1.7	0.8	27	15
Central Option 3							
New	14.9 (20.8)	Same as edge of ROW values shown above for Central Alternative					
Existing	0	On ROW	Average	—	—	—	—
			Maximum				
		Edge of ROW	Average				
			Maximum				

[1] Lengths in parentheses are for the original segments in the Central Alternative that would be replaced by the option.
[2] See note 2 of Table 4.
[3] All field descriptors are distance-weighted means of the fields on or at the edge of the ROW. The edge-of-ROW values are computed from fields on both sides of the route. Average electric fields are computed for maximum voltages and average clearances along the route; likewise, average magnetic fields are computed for average currents and average clearances. Maximum electric fields are computed for maximum voltages and minimum clearances; maximum magnetic fields are computed for maximum currents and minimum clearances.
[4] The segments in the Central options do not replace any existing segments. Using one of these options would not significantly affect average field levels for the alternative. However, there would be localized increases in magnetic fields for Option 1.

Table 6: Distance-weighted Average Electric and Magnetic Field Levels for the Crossover Alternative and Options

Crossover Alternative				Electric Field, kV/m		Magnetic Field, mG	
Right-of-Way	Length, miles[1,2]	Field Location	Field Descriptor[3]	Proposed Action	No Action	Proposed Action	No Action
New	42.7	On ROW	Average	5.3	–	35	–
			Maximum	8.8		184	
		Edge of ROW	Average	2.3		12	
			Maximum	2.3		48	
Existing	29.7	On ROW	Average	5.4	2.0	34	17
			Maximum	8.9	3.7	182	96
		Edge of ROW	Average	1.3	0.5	3	3
			Maximum	1.3	0.5	26	12
Crossover Option 1[4]							
New	0.7 (2.1)	Same as edge of ROW values shown above for Crossover Alternative					
Existing	6.6	On ROW	Average	5.5	1.5	29	11
			Maximum	8.8	2.8	150	63
		Edge of ROW	Average	0.9	0.3	9	2
			Maximum	0.9	0.3	34	24
Crossover Option 2							
New	0	Same as edge of ROW values shown above for Crossover Alternative					
Existing	4.1 (0.0)	On ROW	Average	5.8	5.5	68	49
			Maximum	8.8	9	270	235
		Edge of ROW	Average	1.9	2	14	16
			Maximum	2.1	2.1	51	57
Crossover Option 3							
New	0	Same as edge of ROW values shown above for Crossover Alternative					
Existing	4.2 (0.0)	On ROW	Average	5.8	5.5	68	49
			Maximum	8.9	9	276	235
		Edge of ROW	Average	2.2	1.6	13	12
			Maximum	2.3	1.7	52	45

[1] Lengths in parentheses are for the original segments in the Crossover Alternative that would be replaced by the option.
[2] See note 2 of Table 4.
[3] All field descriptors are distance-weighted means of the fields on or at the edge of the ROW. The edge-of-ROW values are computed from fields on both sides of the route. Average electric fields are computed for maximum voltages and average clearances along the route; likewise, average magnetic fields are computed for average currents and average clearances. Maximum electric fields are computed for maximum voltages and minimum clearances; maximum magnetic fields are computed for maximum currents and minimum clearances.
[4] The segments in the Crossover options do not replace any existing segments. Using one of these options would not significantly affect average field levels for the alternative. However, there would be localized increases in the magnetic fields for Options 2 and 3.

Table 7: Distance-weighted Average Electric and Magnetic Field Levels for the East Alternative and Options

East Alternative				Electric Field, kV/m		Magnetic Field, mG	
Right-of-Way	Length, miles[1, 2]	Field Location	Field Descriptor[3]	Proposed Action	No Action	Proposed Action	No Action
New	67.7	On ROW	Average	5.3	–	35	–
			Maximum	8.8		184	
		Edge of ROW	Average	2.3		12	
			Maximum	2.3		48	
Existing	6.8	On ROW	Average	5.4	2.1	32	31
			Maximum	8.9	3.8	174	135
		Edge of ROW	Average	1.1	1.0	9	11
			Maximum	1.1	1.0	32	36
East Option 1[4]							
New	17.6 (19.4)	Same as edge of ROW values shown above for East Alternative					
Existing	0	On ROW	Average	–	–	–	–
			Maximum				
		Edge of ROW	Average				
			Maximum				
East Option 2							
New	23.5 (22.5)	Same as edge of ROW values shown above for East Alternative					
Existing	0	On ROW	Average	–	–	–	–
			Maximum				
		Edge of ROW	Average				
			Maximum				
East Option 3							
New	1.9 (2.6)	Same as edge of ROW values shown above for East Alternative					
Existing	1.8	On ROW	Average	5.7	2.9	53	48
			Maximum	8.8	5.3	186	133
		Edge of ROW	Average	1.2	0.2	6	4
			Maximum	1.4	0.2	27	8

[1] Lengths in parentheses are for the original segments in the East Alternative that would be replaced by the option.
[2] See note 2 of Table 4.
[3] All field descriptors are distance-weighted means of the fields on or at the edge of the ROW. The edge-of-ROW values are computed from fields on both sides of the route. Average electric fields are computed for maximum voltages and average clearances along the route; likewise, average magnetic fields are computed for average currents and average clearances. Maximum electric fields are computed for maximum voltages and minimum clearances; maximum magnetic fields are computed for maximum currents and minimum clearances.

[4] The segments in the East options do not replace any existing segments. Using one of these options would not significantly affect average field levels for the alternative.

Table 8: Electric- and Magnetic-field Exposure Guidelines

Organization	Type of Exposure	Electric Field, kV/m	Magnetic Field, mG
ACGIH	Occupational	25[1]	10,000
ICNIRP	Occupational	8.3[2]	4,200
	General Public	4.2	2000
IEEE	Occupational	20	27,100
	General Public	5[3]	9,040

[1] Grounding is recommended above 5 –7 kV/m and conductive clothing is recommended above 15 kV/m.
[2] Increased to 16.7 kV/m if nuisance shocks are eliminated.
[3] Within power line rights-of-way, the guideline is 10 kV/m.

Sources: ACGIH, 2009; ICNIRP, 2010; ICES, 2002

Table 9: States with Transmission Line Field Limits

State Agency	Within Right-of-Way	At Edge of Right-of-Way	Comments
a. 60-Hz ELECTRIC-FIELD LIMIT, kV/m			
Florida Department of Environmental Regulation	8 (230 kV) 10 (500 kV)	2	Codified regulation, adopted after a public rulemaking hearing in 1989.
Minnesota Environ- mental Quality Board	8	–	12-kV/m limit on the high voltage direct current (HVDC) nominal electric field.
Montana Board of Natural Resources and Conservation	7[1]	1[2]	Codified regulation, adopted after a public rulemaking hearing in 1984.
New Jersey Department of Environmental Protection	–	3	Used only as a guideline for evaluating complaints.
New York State Public Service Commission	11.8 (7,11)[3]	1.6	Explicitly implemented in terms of a specified right-of-way width.
Oregon Facility Siting Council	9	–	Codified regulation, adopted after a public rulemaking hearing in 1980.
b. 60-Hz MAGNETIC-FIELD LIMIT, mG			
Florida Department of Environmental Regulation	–	150 (230 kV) 200 (500 kV)	Codified regulations, adopted after a public rulemaking hearing in 1989.
New York State Public Service Commission	–	200	Adopted August 29, 1990.

[1] At road crossings
[2] Landowner may waive limit
[3] At highway and private road crossings, respectively

Source: USDOE, 1996

Table 10: Common Noise Levels

Sound Level, dBA	Noise Source or Effect
130	Threshold of pain
110	Rock-and-roll band
80	Truck at 50 ft. (15.2 m)
70	Gas lawnmower at 100 ft. (30 m)
60	Normal conversation indoors
50	Moderate rainfall on foliage
49	Highest foul-weather L_{50} at edge of proposed 500-kV right-of-way
40	Refrigerator
25	Bedroom at night
0	Hearing threshold

Adapted from: USDOE, 1986; USDOE, 1996.

Table 11: Distance-weighted L_{50} Foul Weather Audible Noise Levels and Radio and Television Interference Levels for the West Alternative and Options

West Alternative		Audible Noise, dBA At Edge of ROW		Radio Interference, dBA(μV/m) At 100 ft from Outside Conductor		Television Interference, dBA(μV/m) At 100 ft from Outside Conductor	
Right-of-Way	Length, miles[1,2,3]	Proposed Action	No Action	Proposed Action	No Action	Proposed Action	No Action
New	1.4	47	—	36	—	21	—
Existing	64.2	48	43	34	29	19	15
West Option 1							
New	2.0	47	—	36	—	21	—
Existing	1.1	47	40	37	26	18	13
West Option 2							
New	1.7	47	—	36	—		—
Existing	7.3	49	47	36	32	19	18
West Option 3							
New	1.5	47	—	36	—		—
Existing	11.5	50	49	36	35	21	21

[1] Audible noise levels are distance-weighted means of the L50 foul weather levels at the edge of the right-of-way. The highest average value from the two edges is shown. Audible noise levels are computed for average voltages and average conductor heights.

[2] See note 2 of Table 4.

[3] All RI and TVI levels are distance-weighted means of interference levels at the edge of the ROW for average voltage and average line height. RI levels are computed for fair weather conditions and TVI for foul weather.

Table 12: Distance-weighted L_{50} Foul Weather Audible Noise Levels and Radio and Television Interference Levels for the Central Alternative and Options

Central Alternative		Audible Noise, dBA At Edge of ROW		Radio Interference, dBA(μV/m) At 100 ft from Outside Conductor		Television Interference, dBA(μV/m) At 100 ft from Outside Conductor	
Right-of-Way	Length, miles[1,2,3]	Proposed Action	No Action	Proposed Action	No Action	Proposed Action	No Action
New	69.5	47	—	36	—	21	—
Existing	6.8	47	42	37	27	18	14
Central Option 1							
New	0	—	—	—	—	—	—
Existing	2.5	53	52	36	36	21	20
Central Option 2							
New	15	47	—	36	—	21	—
Existing	0.4	47	41	34	24	19	11
Central Option 3							
New	14.9	47	—	36	—	21	—
Existing	0	—	—	—	—	—	—

[1] Audible noise levels are distance-weighted means of the L_{50} foul weather levels at the edge of the right-of-way. The highest average value from the two edges is shown. Audible noise levels are computed for average voltages and average conductor heights.

[2] See note 2 of Table 4.

[3] All RI and TVI levels are distance-weighted means of interference levels at the edge of the ROW for average voltage and average line height. RI levels are computed for fair weather conditions and TVI for foul weather.

Table 13: Distance-weighted L_{50} Foul Weather Audible Noise Levels and Radio and Television Interference Levels for the Crossover Alternative and Options

Crossover Alternative		Audible Noise, dBA At Edge of ROW		Radio Interference, dBA(μV/m) At 100 ft from Outside Conductor		Television Interference, dBA(μV/m) At 100 ft from Outside Conductor	
Right-of-Way	Length, miles[1,2,3]	Proposed Action	No Action	Proposed Action	No Action	Proposed Action	No Action
New	42.7	47	—	36	—	21	—
Existing	29.7	47	40	34	26	19	13
Crossover Option 1							
New	0.7	47	—	36	—	21	—
Existing	6.6	47	37	42	36	18	10
Crossover Option 2							
New	0	—	—	—	—	—	—
Existing	4.1	56	57	43	42	27	27
Crossover Option 3							
New	0	—	—	—	—	—	—
Existing	4.2	54	54	39	42	24	27

[1] Audible noise levels are distance-weighted means of the L_{50} foul weather levels at the edge of the right-of-way. The highest average value from the two edges is shown. Audible noise levels are computed for average voltages and average conductor heights.

[2] See note 2 of Table 4.

[3] All RI and TVI levels are distance-weighted means of interference levels at the edge of the ROW for average voltage and average line height. RI levels are computed for fair weather conditions and TVI for foul weather.

Table 14: Distance-weighted L_{50} Foul Weather Audible Noise Levels and Radio and Television Interference Levels for the East Alternative and Options

East Alternative		Audible Noise, dBA At Edge of ROW		Radio Interference, dBA(μV/m) At 100 ft from Outside Conductor		Television Interference, dBA(μV/m) At 100 ft from Outside Conductor	
Right-of-Way	Length, miles[1,2,3]	Proposed Action	No Action	Proposed Action	No Action	Proposed Action	No Action
New	67.7	47	—	36	—	21	—
Existing	6.8	48	42	35	27	—	—
East Option 1							
New	17.6	47	—	36	—	21	—
Existing	0	—	—	—	—	—	—
East Option 2							
New	23.5	47	—	36	—	21	—
Existing	0	—	—	—	—	—	—
East Option 3							
New	1.9	47	—	36	—	—	—
Existing	1.8	50	48	34	35	18	20

[1] Audible noise levels are distance-weighted means of the L_{50} foul weather levels at the edge of the right-of-way. The highest average value from the two edges is shown. Audible noise levels are computed for average voltages and average conductor heights.

[2] See note of Table 4.

[3] All RI and TVI levels are distance-weighted means of interference levels at the edge of the ROW for average voltage and average line height. RI levels are computed for fair weather conditions and TVI for foul weather.

Table 15: Average Electric Fields, Magnetic Fields and Audible Noise at the Edge of the Right-of-Way by Alternative.[1]

	Average Electric Field at Edge of ROW, kV/m			
Alternative	West	Central	Crossover	East
Section Maximum, kV/m	2.3	2.6	2.6	2.3
Distance-weighted Average, kV/m	1.4	2.2	1.8	2.2
Section Minimum, kV/m	0.1	0.1	0.1	0.1
Percentage of Route > 2 kV/m	28	89	62	91
Percentage of Route > 1 kV/m	51	92	76	94
Percent of Route with New ROW	2	90	58	90
	Average Magnetic Field at Edge of ROW, mG			
Alternative	West	Central	Crossover	East
Section Maximum, mG	20	19	19	13
Distance-weighted Average, mG	10	12	9	12
Section Minimum, mG	1	2	1	2
Percentage of Route > 20 mG	0	0	0	0
Percentage of Route > 10 mG	62	93	74	95
Percent of Route with New ROW	2	90	58	90
	Foul Weather L50 Audible Noise at Edge of ROW, dBA			
Alternative	West	Central	Crossover	East
Section Maximum, dBA	52	53	56	50
Distance-weighted Average, dBA	47	47	47	48
Section Minimum, dBA	41	43	41	43
Percentage of Route > 48 dBA	11	0	0	0
Percentage of Route > 45 dBA	78	95	81	96
Percent of Route with New ROW	2	90	58	90

[1] Levels from the options are not included in distance-weighted averages and percentages along routes.

Figure 1: Single-circuit Tower for I-5 Corridor Reinforcement Project

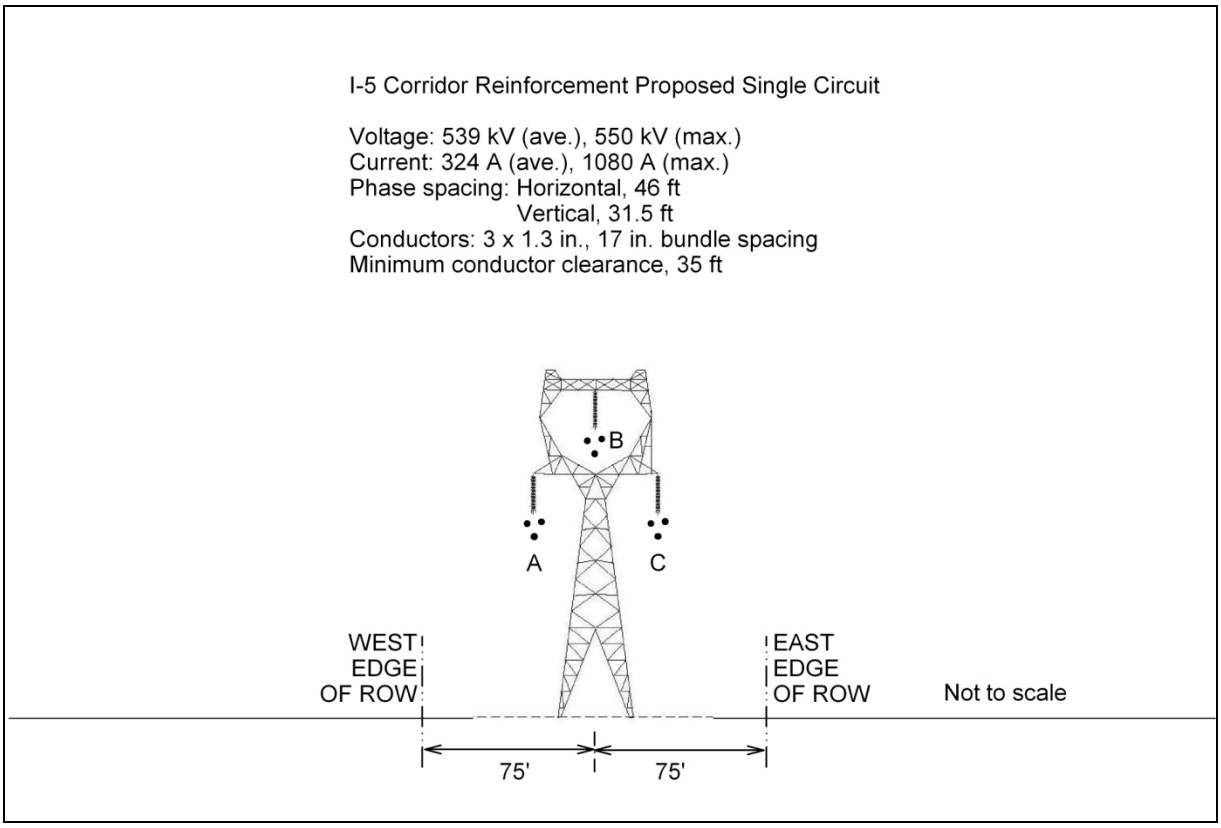


Figure 2: Plot of Electric Fields from Proposed Line on New ROW (Calculation 1.1.0)

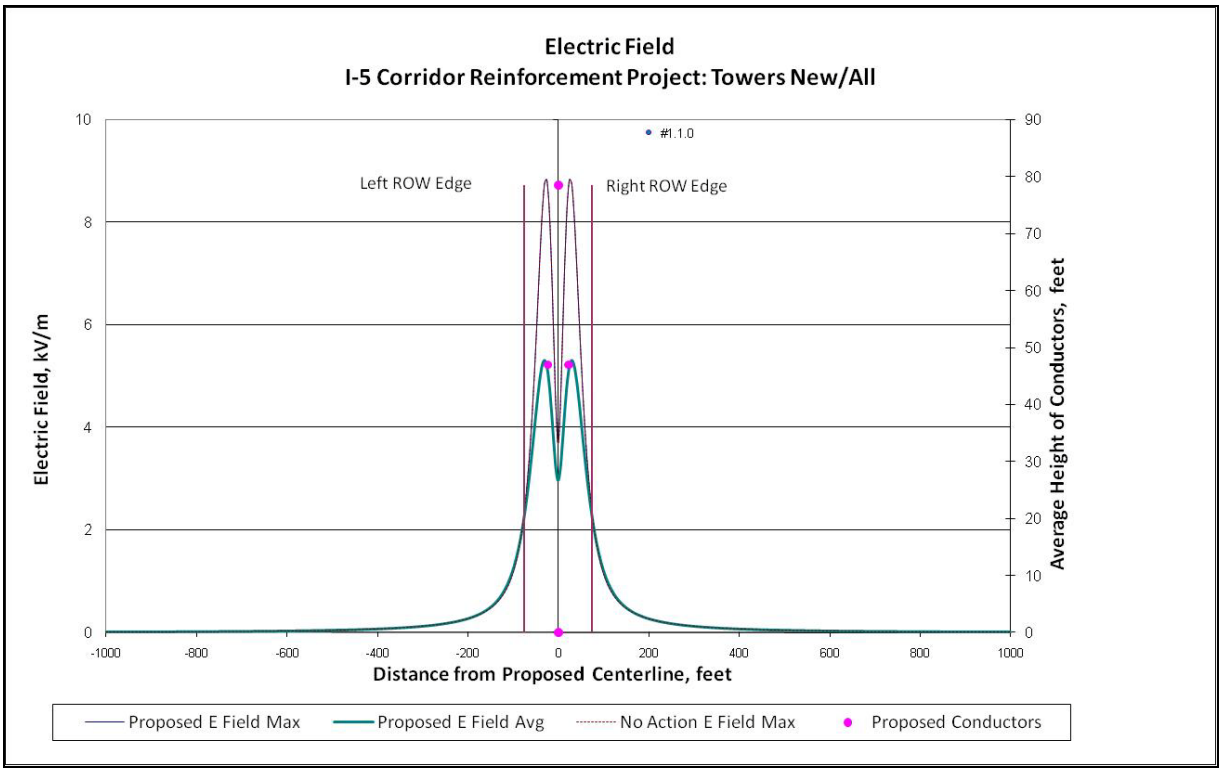


Figure 3: Example Plot of Electric Field from Proposed Line on Existing ROW (Calculation 25.2.0)

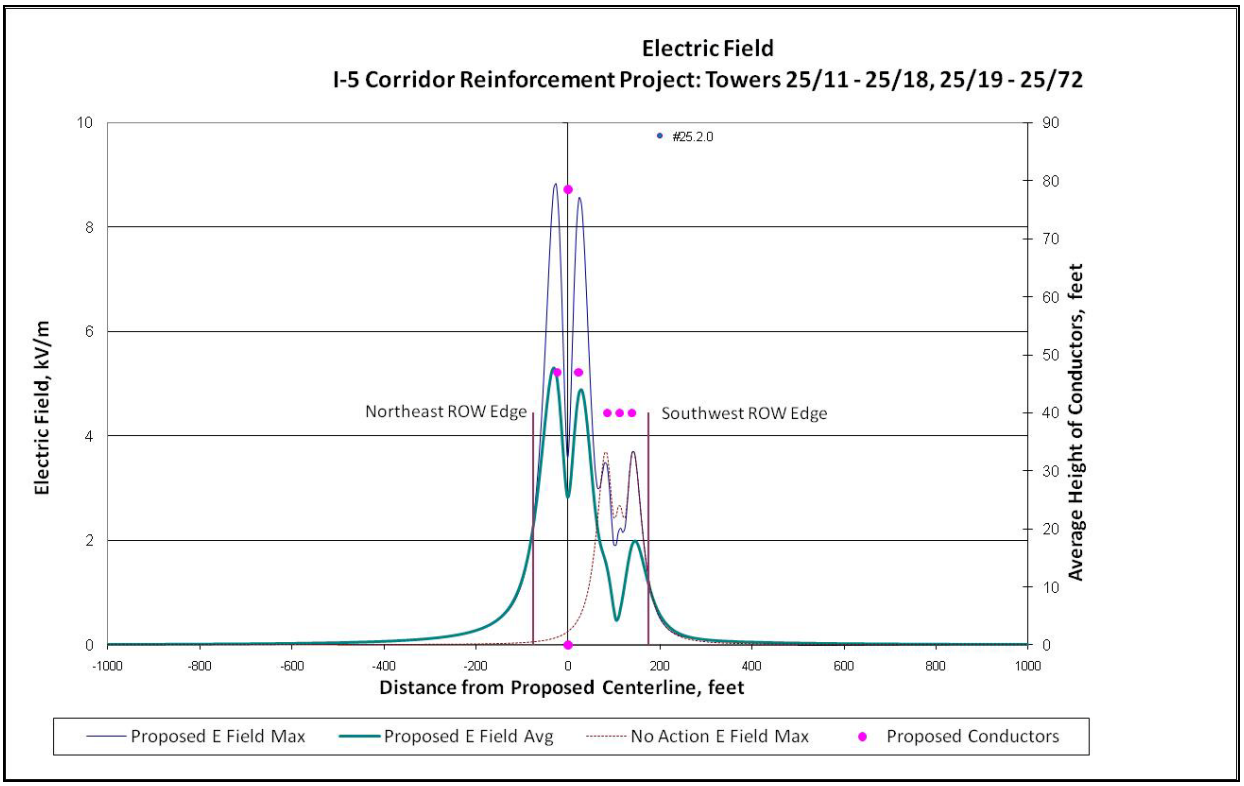


Figure 4: Plot of Magnetic Fields from Proposed Line on New ROW (Calculation 1.1.0)

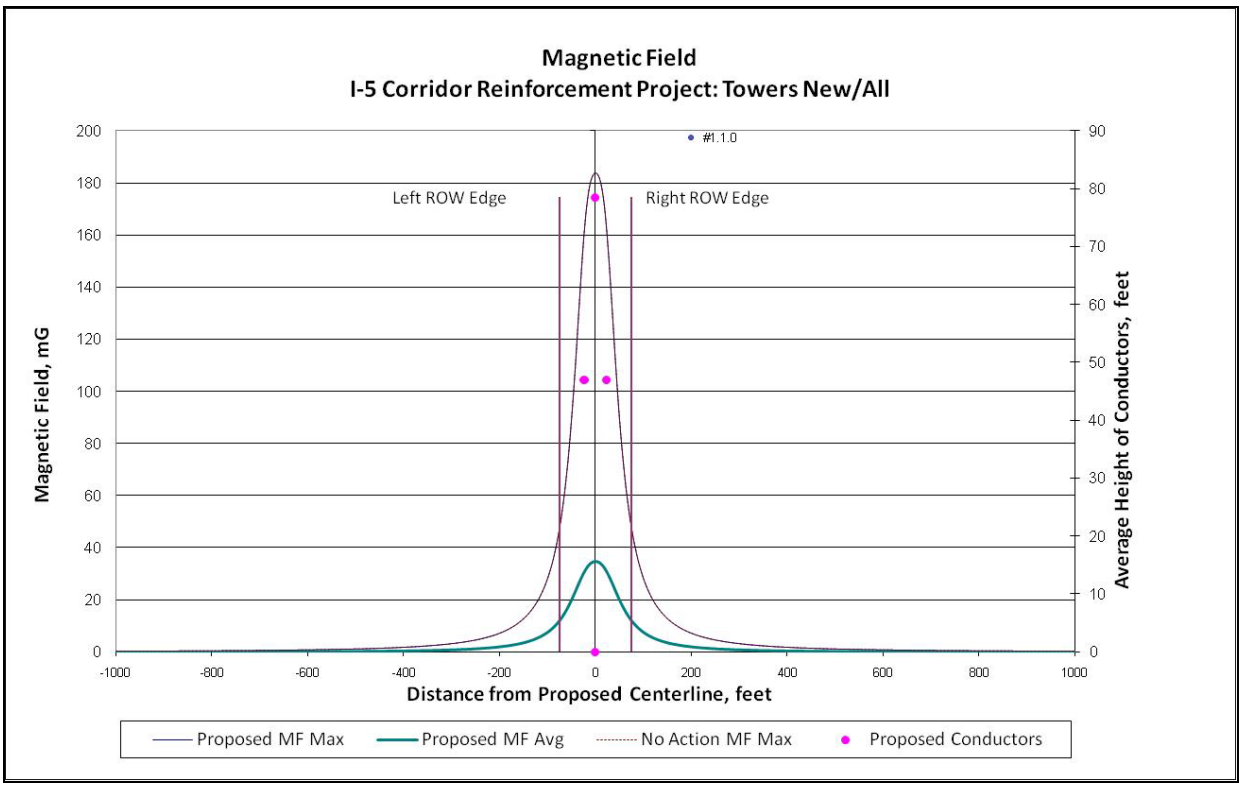


Figure 5: Example Plot of Magnetic Fields from Proposed Line on Existing ROW (Calculation 25.2.0)

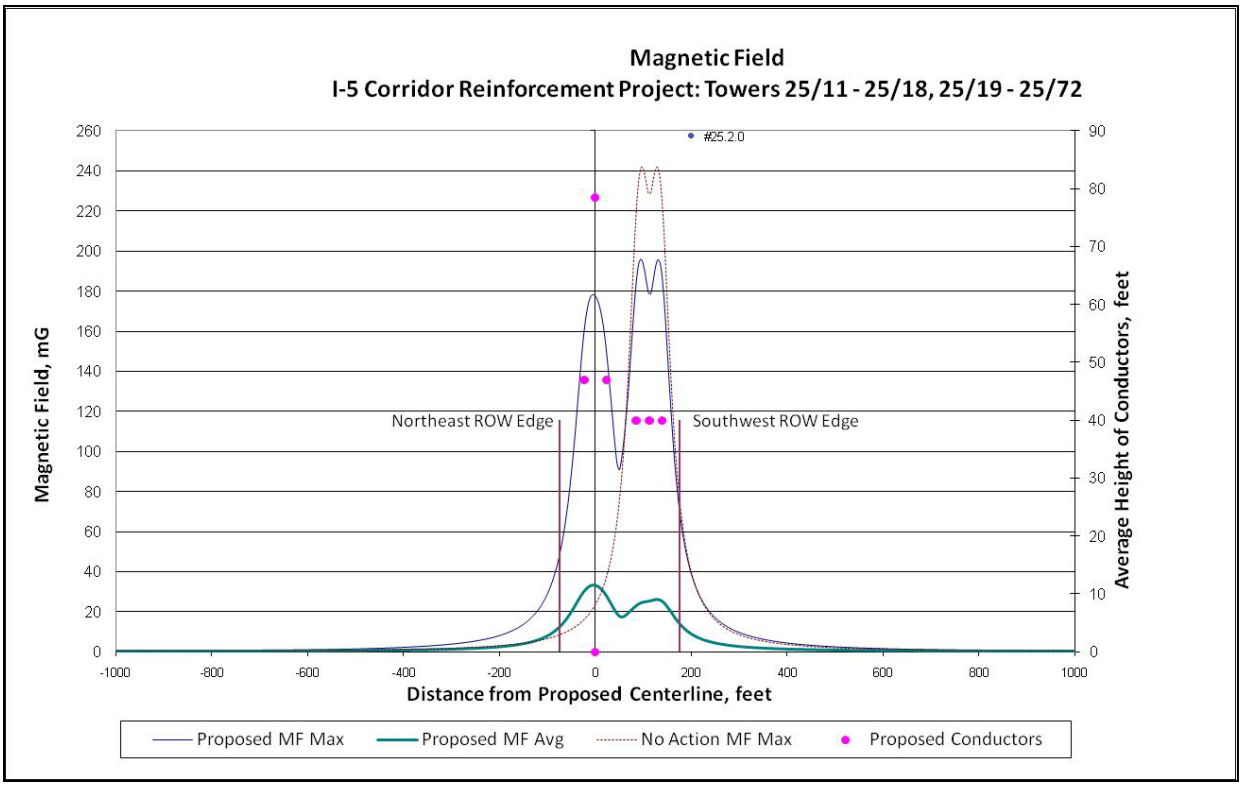


Figure 6: Plot of Audible Noise from Proposed Line on New ROW (Calculation 1.1.0)

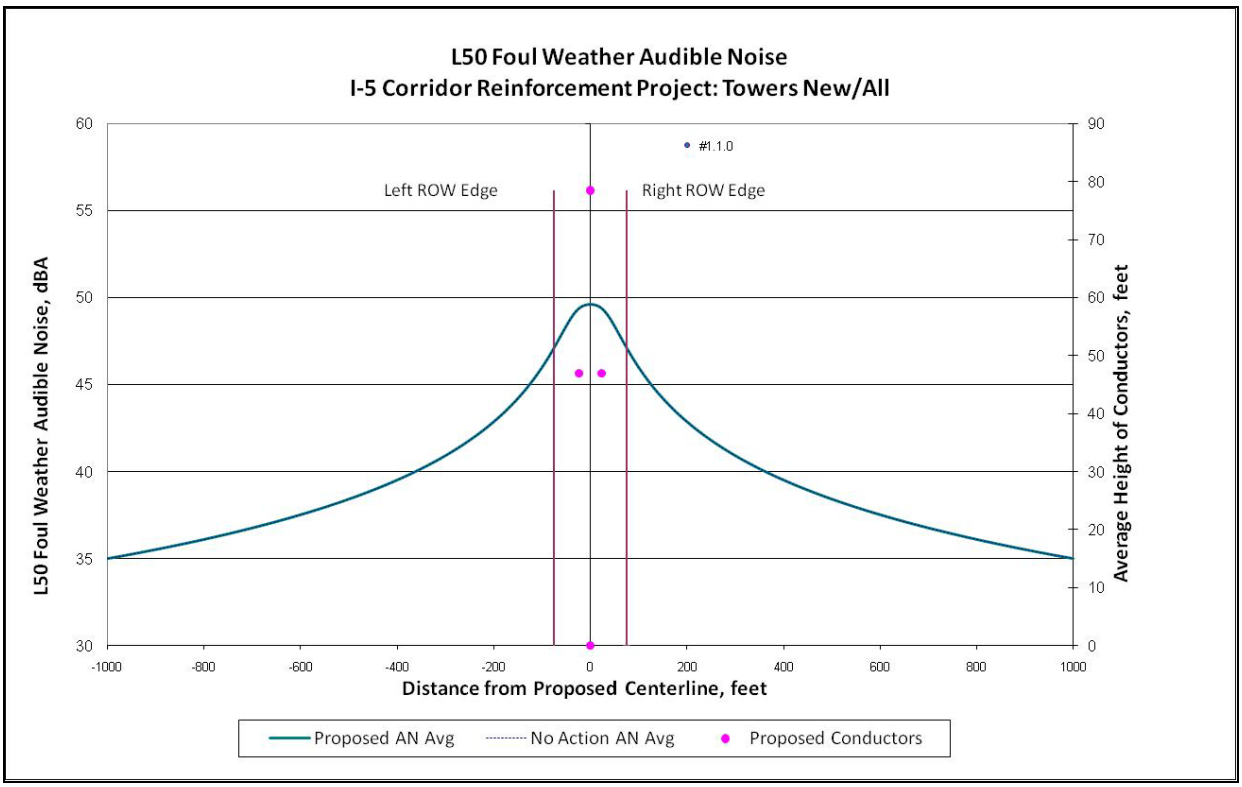
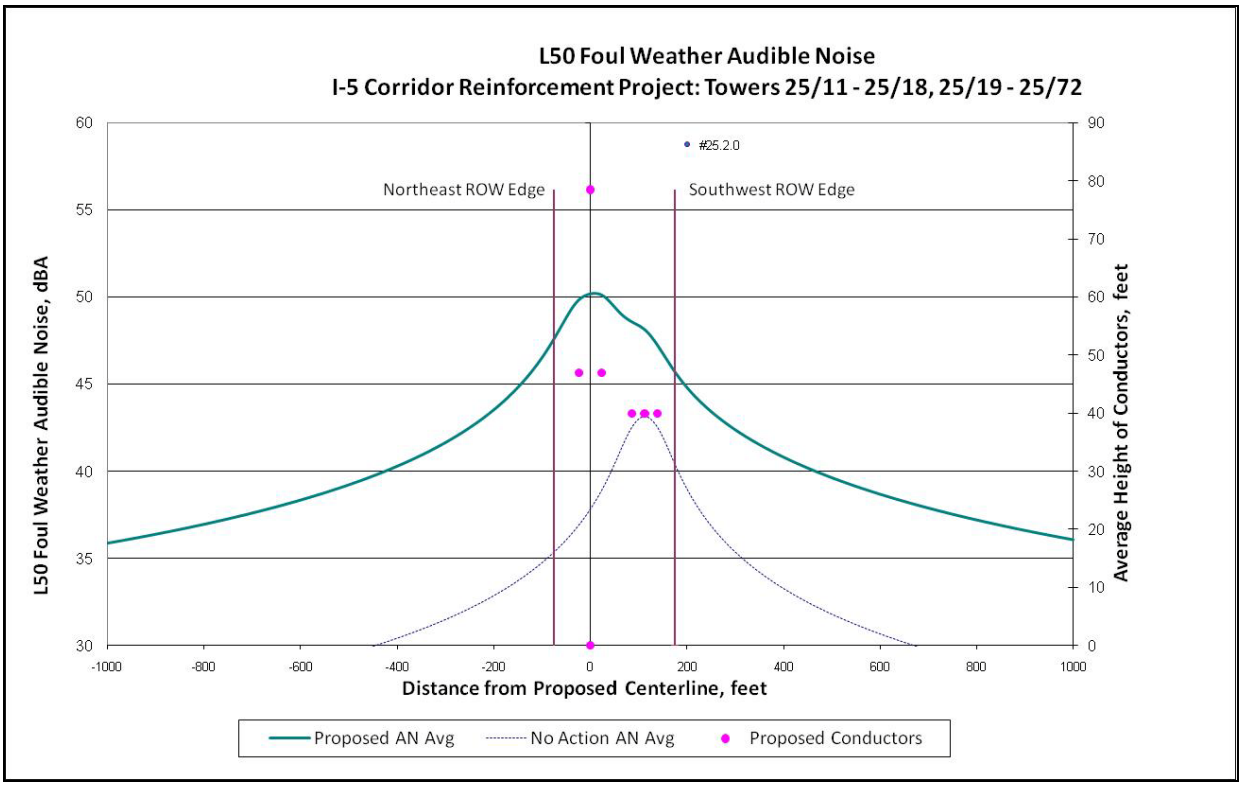


Figure 7: Example Plot of AN from Proposed Line on Existing ROW (Calculation 25.2.0)



Appendix

Electrical Effects Summaries
by Route Segments
for the I-5 Corridor Reinforcement Project

October 2011

Table of Contents

Definitions 1

Determining Field Levels at Specific Locations..... 2

Abbreviations and Acronyms 3

List of Tables

Table 1: Route Segments and Substations for West Alternative and Options..... 4

Table 2: Route Segments and Substations for Central Alternative and Options 5

Table 3: Route Segments and Substations for Crossover Alternative and Options 6

Table 4: Route Segments and Substations for East Alternative and Options 7

Table 5: Electrical Effects Calculation Numbers by Route Segment and Tower Numbers 8

Table 6: Route Segments and Tower Numbers by Electrical Effects Calculation Number 12

Table 7: Calculation 1.1.0 (New Right-of-Way) 17

Table 8: Calculation 2.1.0 19

Table 9: Calculation 2.1.1 21

Table 10: Calculation 2.2.0 23

Table 11: Calculation 2.2.1 25

Table 12: Calculation 9.2.0 27

Table 13: Calculation 9.3.0 29

Table 14: Calculation 9.3.1 31

Table 15: Calculation 9.3.2 33

Table 16: Calculation 25.2.0 35

Table 17: Calculation 25.2.1 37

Table 18: Calculation 25.3.0 39

Table 19: Calculation 25.4.0 41

Table 20: Calculation 25.5.0 43

Table 21: Calculation 36A.1.0..... 45

Table 22: Calculation 36A.2.0..... 47

Table 23: Calculation 36B.1.0 49

Table 24: Calculation 37.2.0 51

Table 25: Calculation 39.2.0 53
Table 26: Calculation 39.3.0 55
Table 27: Calculation 40.1.0 57
Table 28: Calculation 41.1.0 59
Table 29: Calculation 49.1.0 61
Table 30: Calculation 49.1.1 63
Table 31: Calculation 49.2.0 65
Table 32: Calculation 49.2.1 67
Table 33: Calculation 50.1.0 69
Table 34: Calculation 50.1.1 71
Table 35: Calculation 51.1.0 73
Table 36: Calculation 51.1.1 75
Table 37: Calculation 52.2.0 77
Table 38: Calculation A.1.0 79
Table 39: Calculation C.1.0 81
Table 40: Calculation D.1.0 83
Table 41: Calculation R.1.0 85

List of Figures

Figure 1: Calculation 1.1.0 – Electric Fields (New Right-of-Way) 17
Figure 2: Calculation 1.1.0 – Magnetic Fields (New Right-of-Way) 18
Figure 3: Calculation 1.1.0 – Audible Noise Levels (New Right-of-Way) 18
Figure 4: Calculation 2.1.0 – Electric Fields 19
Figure 5: Calculation 2.1.0 – Magnetic Fields 20
Figure 6: Calculation 2.1.0 – Audible Noise Levels 20
Figure 7: Calculation 2.1.1 – Electric Fields 21
Figure 8: Calculation 2.1.1 – Magnetic Fields 22
Figure 9: Calculation 2.1.1 – Audible Noise Levels 22
Figure 10: Calculation 2.2.0 – Electric Fields 23
Figure 11: Calculation 2.2.0 – Magnetic Fields 24
Figure 12: Calculation 2.2.0 – Audible Noise Levels 24

Figure 13: Calculation 2.2.1 – Electric Fields 25
Figure 14: Calculation 2.2.1 – Magnetic Fields 26
Figure 15: Calculation 2.2.1 – Audible Noise Levels 26
Figure 16: Calculation 9.2.0 – Electric Fields 27
Figure 17: Calculation 9.2.0 – Magnetic Fields 28
Figure 18: Calculation 9.2.0 – Audible Noise Levels 28
Figure 19: Calculation 9.3.0 – Electric Fields 29
Figure 20: Calculation 9.3.0 – Magnetic Fields 30
Figure 21: Calculation 9.3.0 – Audible Noise Levels 30
Figure 22: Calculation 9.3.1 – Electric Fields 31
Figure 23: Calculation 9.3.1 – Magnetic Fields 32
Figure 24: Calculation 9.3.1 – Audible Noise Levels 32
Figure 25: Calculation 9.3.2 – Electric Fields 33
Figure 26: Calculation 9.3.2 – Magnetic Fields 34
Figure 27: Calculation 9.3.2 – Audible Noise Levels 34
Figure 28: Calculation 25.2.0 – Electric Fields 35
Figure 29: Calculation 25.2.0 – Magnetic Fields 36
Figure 30: Calculation 25.2.0 – Audible Noise Levels 36
Figure 31: Calculation 25.2.1 – Electric Fields 37
Figure 32: Calculation 25.2.1 – Magnetic Fields 38
Figure 33: Calculation 25.2.1 – Audible Noise Levels 38
Figure 34: Calculation 25.3.0 – Electric Fields 39
Figure 35: Calculation 25.3.0 – Magnetic Fields 40
Figure 36: Calculation 25.3.0 – Audible Noise Levels 40
Figure 37: Calculation 25.4.0 – Electric Fields 41
Figure 38: Calculation 25.4.0 – Magnetic Fields 42
Figure 39: Calculation 25.4.0 – Audible Noise Levels 42
Figure 40: Calculation 25.5.0 – Electric Fields 43
Figure 41: Calculation 25.5.0 – Magnetic Fields 44
Figure 42: Calculation 25.5.0 – Audible Noise Levels 44
Figure 43: Calculation 36A.1.0 – Electric Fields 45

Figure 44: Calculation 36A.1.0 – Magnetic Fields 46
Figure 45: Calculation 36A.1.0 – Audible Noise Levels..... 46
Figure 46: Calculation 36A.2.0 – Electric Fields..... 47
Figure 47: Calculation 36A.2.0 – Magnetic Fields 48
Figure 48: Calculation 36A.2.0 – Audible Noise Levels..... 48
Figure 49: Calculation 36B.1.0 – Electric Fields..... 49
Figure 50: Calculation 36B.1.0 – Magnetic Fields..... 50
Figure 51: Calculation 36B.1.0 – Audible Noise Levels..... 50
Figure 52: Calculation 37.2.0 – Electric Fields 51
Figure 53: Calculation 37.2.0 – Magnetic Fields..... 52
Figure 54: Calculation 37.2.0 – Audible Noise Levels 52
Figure 55: Calculation 39.2.0 – Electric Fields 53
Figure 56: Calculation 39.2.0 – Magnetic Fields..... 54
Figure 57: Calculation 39.2.0 – Audible Noise Levels 54
Figure 58: Calculation 39.3.0 – Electric Fields 55
Figure 59: Calculation 39.3.0 – Magnetic Fields..... 56
Figure 60: Calculation 39.3.0 – Audible Noise Levels 56
Figure 61: Calculation 40.1.0 – Electric Fields 57
Figure 62: Calculation 40.1.0 – Magnetic Fields..... 58
Figure 63: Calculation 40.1.0 – Audible Noise Levels 58
Figure 64: Calculation 41.1.0 – Electric Fields 59
Figure 65: Calculation 41.1.0 – Magnetic Fields..... 60
Figure 66: Calculation 41.1.0 – Audible Noise Levels 60
Figure 67: Calculation 49.1.0 – Electric Fields 61
Figure 68: Calculation 49.1.0 – Magnetic Fields..... 62
Figure 69: Calculation 49.1.0 – Audible Noise Levels 62
Figure 70: Calculation 49.1.1 – Electric Fields 63
Figure 71: Calculation 49.1.1 – Magnetic Fields..... 64
Figure 72: Calculation 49.1.1 – Audible Noise Levels 64
Figure 73: Calculation 49.2.0 – Electric Fields 65
Figure 74: Calculation 49.2.0 – Magnetic Fields..... 66

Figure 75: Calculation 49.2.0 – Audible Noise Levels 66
Figure 76: Calculation 49.2.1 – Electric Fields 67
Figure 77: Calculation 49.2.1 – Magnetic Fields 68
Figure 78: Calculation 49.2.1 – Audible Noise Levels 68
Figure 79: Calculation 50.1.0 – Electric Fields 69
Figure 80: Calculation 50.1.0 – Magnetic Fields 70
Figure 81: Calculation 50.1.0 – Audible Noise Levels 70
Figure 82: Calculation 50.1.1 – Electric Fields 71
Figure 83: Calculation 50.1.1 – Magnetic Fields 72
Figure 84: Calculation 50.1.1 – Audible Noise Levels 72
Figure 85: Calculation 51.1.0 – Electric Fields 73
Figure 86: Calculation 51.1.0 – Magnetic Fields 74
Figure 87: Calculation 51.1.0 – Audible Noise Levels 74
Figure 88: Calculation 51.1.1 – Electric Fields 75
Figure 89: Calculation 51.1.1 – Magnetic Fields 76
Figure 90: Calculation 51.1.1 – Audible Noise Levels 76
Figure 91: Calculation 52.2.0 – Electric Fields 77
Figure 92: Calculation 52.2.0 – Magnetic Fields 78
Figure 93: Calculation 52.2.0 – Audible Noise Levels 78
Figure 94: Calculation A.1.0. – Electric Fields 79
Figure 95: Calculation A.1.0. – Magnetic Fields 80
Figure 96: Calculation A.1.0. – Audible Noise Levels 80
Figure 97: Calculation C.1.0. – Electric Fields 81
Figure 98: Calculation C.1.0. – Magnetic Fields 82
Figure 99: Calculation C.1.0. – Audible Noise Levels 82
Figure 100: Calculation D.1.0. – Electric Fields 83
Figure 101: Calculation D.1.0. – Magnetic Fields 84
Figure 102: Calculation D.1.0. – Audible Noise Levels 84
Figure 103: Calculation R.1.0. – Electric Fields 85
Figure 104: Calculation R.1.0. – Magnetic Fields 86
Figure 105: Calculation R.1.0. – Audible Noise Levels 86

Summaries of Electrical Effects by Proposed Route Segments

This appendix presents summaries of the levels of electric fields, magnetic fields, and corona-generated audible noise, radio interference, and television interference that would be produced by the I-5 Corridor Reinforcement Project. To characterize the electrical effects of the project, they have been calculated for each route segment and/or line section (see definitions below) that has unique physical and electrical characteristics. Calculations for 101 of 109 sections are included in this appendix. Calculations were not performed for eight sections due to their very short length, non-parallel conductors at transition points (which can skew calculations), or height at the Columbia River crossing (where conductors would be very high above the ground or river).

Definitions

The following terms are used in the summary data. Understanding them will help readers use tables later in the appendix, which list field summaries for specific locations along the transmission line routes. The summary data include: plots of average and maximum electric and magnetic fields for minimum ground clearance; plots of L50 (median) audible noise; tables of average and maximum electric and magnetic fields on and at the edge of the right-of-way; and tables of L50 levels for audible noise, radio interference, and television interference levels at the edge of the right-of-way (audible noise) or at 100 feet from the outside conductor (radio and television interference).

Action Alternatives. There are four action alternatives proposed for the transmission line. Each alternative includes constructing a 500-kV transmission line from a substation near Castle Rock, Washington, to a substation near Troutdale, Oregon. There are three possible locations for the substation at the northern terminus near Castle Rock and one location for the new substation near Troutdale. The action alternatives are shown in Maps 1-4 in the report.

Route Segments and Options. Each of the four alternatives is described by a series of fixed, linear route segments between geographic locations. Each alternative has a primary route, composed of one set of route segments, and three optional routes: Options 1, 2 and 3. Each option is composed of a different mix of route segments. Segments can be present in one or more alternatives and are designated by a unique alphanumeric label: for example, 25, A or 36A. Route segments and options for all four alternatives are shown in Maps 1-4 in the report and listed in Tables 1 through 4 in this appendix.

Tower Numbers. Location along a route segment is denoted by tower numbers beginning with Tower 1 and ending with the last tower in the segment: for example, Segment 25 extends from Tower 25/1 to Tower 25/152. Towers are numbered per the direction of power flow from the Castle Rock to Troutdale substations, which is generally north to south. The first and last tower of each route segment may have more than one number where segments intersect. For example, towers 1/18, 2/28 and 4/1 are the same tower, but have three designations because the tower is part of segments 1, 2, and 4. Tower numbers are shown on detailed project maps and can be found online at: http://gis.bpa.gov/gis/i5/gmviewer.html.

Line Sections. Although a route segment is unique geographically, it is not necessarily unique in the physical and electrical configurations that produce electrical effects. Therefore in some

cases a route segment is broken up into two or more line sections for calculations. These sections are delineated by starting and ending tower numbers. Possible changes along a route segment that can create a new section for calculations of electrical effects include the addition or absence of a parallel line on the right-of-way, a change in the electrical phasing of the new line, or a change in tower type.

Calculation Numbers. Each unique calculation represents a distinct physical and electrical configuration along a line section or sections, and includes fields from the new transmission lines and existing transmission lines, when present. A specific calculation may apply in one or more line sections in a route segment or in more than one segment. For example, many route segments and line sections require new right-of-way where there are no existing lines. The same calculation (1.0.0) is used to describe the electrical effects for all new rights-of-way sections.

Each calculation is identified by a calculation number consisting of three numbers: the first number is generally selected from the first route segment where the configuration occurs; the second number refers to a line section within a segment; and the third number, called a version number, refers to a section where the physical layout of the lines are the same as for a previous section, but a change in electrical phasing occurs. For example, 2.1.0 refers to the field calculation along Segment 2, line section 1, while 2.1.1 refers to the field calculation along the same segment but where there is a transposition in phasing along line section 1. Table 5 shows calculations listed by route segment and line section (tower numbers). Table 6 shows route segments and line sections (by tower numbers) listed by calculation number. Tables 7 through 41 show details for each distinct calculation (segment or section) and Figures 1 through 105 provide visual examples of maximum and average fields for each calculation.

Determining Field Levels at Specific Locations

The process for locating a specific site along a segment and determining the levels of electric fields, magnetic fields, audible noise, radio interference and television interference at the site is as follows:

1. From Maps 1 through 4 in the report, or the online project map, determine the route segment that is adjacent to the specific site.
2. From Table 5, determine if the segment is comprised of two or more line sections:
    - If the segment is not divided, then the electrical effects data is described by the calculation number associated with the segment.
    - If the segment is divided into two or more line sections, then determine the tower numbers closest to the specific site from the online project map. Using these tower numbers, determine from Table 5 which calculation number within the segment is associated with the towers near the specific site.
3. Locate the summary sheet for the selected calculation number. The summary sheets are in sequential order by segment following Table 6.
4. The summary sheets provide illustrated profiles of data for electric fields, magnetic fields, and audible noise as well as tabular data for these parameters and for radio and television interference.

Abbreviations and Acronyms

AN	Audible noise
Avg	Average
dB(µV/m)	Unit of electric field for radio and television interference: decibels above one microvolt per meter
dBA	Unit of sound level: decibels (A-weighted)
E Field	Electric field
Ft	Unit of distance: feet or foot
kV/m:	Unit of electric field: kilovolts per meter
L50	Statistical descriptor: Level of physical quantity exceeded 50 percent of the time (median)
Max	Maximum
MF	Magnetic field
mG	Unit of magnetic field: milligauss
PUD	Public Utility District
RI	Radio interference
ROW	Right-of-way
TVI	Television interference

Table 1: Route Segments and Substations for West Alternative and Options

Route Segments and Substations	West Alternative	West Option 1		West Option 2		West Option 3	
		Add	*Remove*	*Add*	*Remove*	*Add*	*Remove*
Northern Substation	Monahan						
Segments	2	36	36B	36	36B	36	36B
	4	40	41	36A	41	36A	41
	9	46	45	37	45	37	45
	25			38	50	38	50
	36B			43		39	
	41			48		T	
	45			51		49	
	50					51	
	52						
Southern Substation	Sundial						

Table 2: Route Segments and Substations for Central Alternative and Options

Route Segments and Substations	Central Alternative	Central Option 1		Central Option 2		Central Option 3	
		Add	*Remove*	*Add*	*Remove*	*Add*	*Remove*
Northern Substation	Baxter	Casey	Baxter	Monahan	Baxter		
Segments	B	A		1	B	M	L
	F			4	F	26	18
	G			5	G	30	28
	H			8			V
	10			11			
	12						
	15						
	23						
	L						
	18						
	28						
	V						
	P						
	35						
	T						
	49						
	51						
	52						
Southern Substation	Sundial						

Table 3: Route Segments and Substations for Crossover Alternative and Options

Route Segments and Substations	Crossover Alternative	Crossover Option 1		Crossover Option 2		Crossover Option 3	
		Add	***Remove***	***Add***	***Remove***	***Add***	***Remove***
Northern Substation	Monahan			Baxter	Monahan	Baxter	Monahan
Segments	B	47	51	C		D	
	F	48		E		E	
	G	50					
	H						
	10						
	12						
	15						
	23						
	L						
	18						
	28						
	V						
	P						
	35						
	T						
	49						
	51						
	52						
Southern Substation	Sundial						

Table 4: Route Segments and Substations for East Alternative and Options

Route Segments and Substations	East Alternative	East Option 1		East Option 2		East Option 3	
		Add	***Remove***	***Add***	***Remove***	***Add***	***Remove***
Northern Substation	Baxter	Monahan	Baxter				
Segments	B	3		U	O	R	Q
	F	7		V	Q		
	I	11		P	S		
	K	J		35			
	W			T			
	O						
	Q						
	S						
	49						
	51						
	52						
Southern Substation	Sundial						

Table 5: Electrical Effects Calculation Numbers by Route Segment and Tower Numbers

Segment	Calculation Section (tower to tower)	Calculation Number	Length Covered by Calculation (miles)	Comments
1	1/1-1/28	1.0.0	6.42	New ROW
2	2/1-2/7	2.1.0	1.64	
	2/7-2/18	2.1.1	2.32	Transposition[1]
	2/18-2/24	2.2.0	1.38	
	2/24-2/27	2.2.1	0.46	Transposition
	2/27-2/28	No Calc	0.24	Transposition
3	3/1-3/38	1.0.0	7.82	New ROW
4	4/1-4/3	No Calc	0.37	Transition spans[2]
	4/3-4/5	9.2.0	0.40	
5	5/1-5/10	1.0.0	1.93	New ROW
7	7/1-7/10	1.0.0	2.05	New ROW
8	8/1-8/9	1.0.0	1.61	New ROW
9	9/1-9/3	9.2.0	0.52	
	9/3-9/11	9.2.0	1.61	Configuration change
	9/11-9/20	9.2.0	1.94	
	9/20-9/21	9.3.0	0.50	
	9/21-9/28	9.3.0	1.54	
	9/28-9/82	9.3.1	12.62	Transposition
10	10/1-10/34	1.0.0	7.93	New ROW
11	11/1-11/21	1.0.0	5.00	New ROW
12	12/1-12/20	1.0.0	4.96	New ROW
14	14/1-14/7	1.0.0	1.50	New ROW
15	15/1-15/9	1.0.0	1.86	New ROW
18	18/1-18/32	1.0.0	7.17	New ROW
23	23/1-23/7	1.0.0	1.29	New ROW
25	25/1-25/7	9.3.1	1.35	
	25/7-25/11	9.3.2	0.75	Transposition
	25/11-25/18	25.2.0	1.64	Current change
	25/18-25/19	No Calc	0.47	25.2.0 with 12.5’ extra ROW; use 25.2.0

Segment	Calculation Section (tower to tower)	Calculation Number	Length Covered by Calculation (miles)	Comments
	25/19-25/72	25.2.0	11.00	
	25/72-25/106	25.2.1	6.47	Transposition
	25/106-25/110	25.3.0	0.63	
	25/110-25/141	25.4.0	5.67	
	25/141-25/151	25.5.0	1.71	
	25/151-25/152	25.5.0	0.18	
26	26/1-26/35	1.0.0	6.54	New ROW
28	28/1-28/27	1.0.0	5.94	New ROW
30	30/1-30/31	1.0.0	6.01	New ROW
35	35/1-35/15	1.0.0	2.52	New ROW
36	36/1-36/2	36A.1.0	0.22	
36A	36A/1-36A/5	36A.1.0	0.80	
	36A/5-36A/6	36A.2.0	0.23	
36B	36B/1-36B2	No Calc	0.18	Transition span
	36B/2-36B/7	36B.1.0	1.04	
	36B/7-36B/8	No Calc	0.19	Transition span
37	37/1-37/2	36A.2.0	0.21	
	37/2-37/4	37.2.0	0.46	
38	38/1-38/5	37.2.0	0.66	
39	39/1-39/20	37.2.0	4.05	
	39/20-39/23	39.2.0	0.62	
	39/23-39/27	39.3.0	0.68	
40	40/1-40/11	1.0.0	2.02	New ROW
	40/11-40/14	40.1.0	0.67	
41	41/1-41/2	41.1.0	0.14	
	41/2-41/8	41.1.0	1.13	
43	43/1-43/9	1.0.0	1.69	New ROW
	43/9-43/10	40.1.0	0.17	
45	45/1-45/3	41.1.0	0.35	
	45/3-45/6	1.0.0	0.32	New ROW
46	46/1-46/3	40.1.0	0.46	
47	47/1-47/4	40.1.0	0.69	

Segment	Calculation Section (tower to tower)	Calculation Number	Length Covered by Calculation (miles)	Comments
48	48/1-48/14	40.1.0	2.49	
	48/1-48/14	40.1.0	2.49	Reversed current for Crossover Opt. 1
49	49/1-49/7	1.0.0	1.23	New ROW
	49/7-49/10	49.1.0	0.69	
	49/7-49/10	49.1.1	0.69	Phasing change for Central Alt. and all options
	49/10-49/15	49.2.0	0.80	
	49/10-49/15	49.2.1	0.80	Phasing change for Central Alt. and all options
50	50/1-50/5	1.0.0	0.67	New ROW
	50/5-50/13	50.1.0	1.46	
	50/5-50/13	50.1.1	1.46	Phasing change for West Opt. 1 and Crossover Opt. 1
	50/13-50/21	41.1.0	1.16	
	50/21-50/26	50.1.0	0.80	
	50/21-50/26	50.1.1	0.80	Phasing change for West Opt. 1 and Crossover Opt. 1
51	51/1-51/11	51.1.0	2.07	
52	52/1-52/2	51.1.0	0.13	
	52/2-52/9	52.2.0	1.48	
	52/9-52/12	51.1.0	0.44	
	52/12-52/17	51.1.1	1.23	Transposition
	52/17-52/20	1.0.0	0.43	
	52/20-52/22	No Calc	0.47	River crossing
	52/22-52/24	No Calc	0.52	Entering Sundial Sub.
A	A/1-A/9	A.1.0	1.81	
	A/9-A/12	A.1.0	0.71	
B	B/1-B/5	1.0.0	0.78	New ROW
C	C/1-C/17	C.1.0	3.00	
D	D/1-D/17	D.1.0	2.86	
E	E/1-E/6	C.1.0	1.07	
	E/6-E/7	No Calc	0.28	Transition span

Segment	Calculation Section (tower to tower)	Calculation Number	Length Covered by Calculation (miles)	Comments
F	F/1-F/75	1.0.0	15.86	New ROW
G	G/1-G/8	1.0.0	1.39	New ROW
H	H/1-H/8	1.0.0	1.53	New ROW
I	I/1-1/13	1.0.0	2.77	New ROW
J	J/1-J/13	1.0.0	2.72	New ROW
K	K/1-K/94	1.0.0	22.80	New ROW
L	L/1-L/5	1.0.0	0.95	New ROW
	L/5-L/9	1.0.0	0.76	New ROW
M	M/1-M/11	1.0.0	2.39	New ROW
N	N/1-N/9	1.0.0	1.64	New ROW
O	O/1-O/83	1.0.0	19.47	New ROW
P	P/1-P/39	1.0.0	8.62	New ROW
Q	Q/1-Q/13	1.0.0	2.63	New ROW
R	R/1-R/10	1.0.0	1.93	New ROW
	R/10-R/19	R.1.0	1.75	
S	S/1-S/3	1.0.0	0.42	New ROW
T	T/1-T/3	1.0.0	0.31	New ROW
U	U/1-U/26	1.0.0	6.11	New ROW
V	V/1-V/27	1.0.0	5.96	New ROW
W	W/1-W/6	1.0.0	1.31	New ROW

[1] A transposition span is where the locations of the phase conductors (A, B, C) on the tower change; that is, instead of the A-phase being on the top, it is now on the bottom left and the other phases change accordingly. Such conductor location changes result in non-parallel conductors.
[2] A transition span is where the conductors go from one configuration to another, such as from a delta configuration to a flat configuration or from a single-circuit tower to one side of a double-circuit tower.

Table 6: Route Segments and Tower Numbers by Electrical Effects Calculation Number

Calculation Number	Segment	Calculation Section (tower to tower)	Length Covered by Calculation (miles)	Comments
1.0.0	1	1/1-1/28	6.42	New ROW
	3	3/1-3/38	7.82	New ROW
	5	5/1-5/10	1.93	New ROW
	7	7/1-7/10	2.05	New ROW
	8	8/1-8/9	1.61	New ROW
	10	10/1-10/34	7.93	New ROW
	11	11/1-11/21	5.00	New ROW
	12	12/1-12/20	4.96	New ROW
	14	14/1-14/7	1.50	New ROW
	15	15/1-15/9	1.86	New ROW
	18	18/1-18/32	7.17	New ROW
	23	23/1-23/7	1.29	New ROW
	26	26/1-26/35	6.54	New ROW
	28	28/1-28/27	5.94	New ROW
	30	30/1-30/31	6.01	New ROW
	35	35/1-35/15	2.52	New ROW
	40	40/1-40/11	2.02	New ROW
	43	43/1-43/9	1.69	New ROW
	45	45/3-45/6	0.32	New ROW
	49	49/1-49/7	1.23	New ROW
	50	50/1-50/5	0.67	New ROW
	52	52/17-52/20	0.43	New ROW
	B	B/1-B/5	0.78	New ROW
	F	F/1-F/75	15.86	New ROW
	G	G/1-G/8	1.39	New ROW
	H	H/1-H/8	1.53	New ROW
	I	I/1-1/13	2.77	New ROW
	J	J/1-J/13	2.72	New ROW
	K	K/1-K/94	22.80	New ROW
	L	L/1-L/5	0.95	New ROW

Calculation Number	Segment	Calculation Section (tower to tower)	Length Covered by Calculation (miles)	Comments
	L	L/5-L/9	0.76	New ROW
	M	M/1-M/11	2.39	New ROW
	N	N/1-N/9	1.64	New ROW
	O	O/1-O/83	19.47	New ROW
	P	P/1-P/39	8.62	New ROW
	Q	Q/1-Q/13	2.63	New ROW
	R	R/1-R/10	1.93	New ROW
	S	S/1-S/3	0.42	New ROW
	T	T/1-T/3	0.31	New ROW
	U	U/1-U/26	6.11	New ROW
	V	V/1-V/27	5.96	New ROW
	W	W/1-W/6	1.31	New ROW
2.1.0	2	2/1-2/7	1.64	
2.1.1	2	2/7-2/18	2.32	Transposition[1]
2.2.0	2	2/18-2/24	1.38	
2.2.1	2	2/24-2/27	0.46	Transposition
9.2.0	4	4/3-4/5	0.40	
	9	9/11-9/20	1.94	
	9	9/1-9/3	0.52	
	9	9/3-9/11	1.61	Configuration change
9.3.0	9	9/20-9/21	0.50	
	9	9/21-9/28	1.54	
9.3.1	9	9/28-9/82	12.62	Transposition
	25	25/1-25/7	1.35	
9.3.2	25	25/7-25/11	0.75	Transposition
25.2.0	25	25/11-25/18	1.64	Current change
	25	25/18-25/19	0.47	25.2.0 with 12.5' extra ROW; use 25.2.0
	25	25/19-25/72	11.00	
25.2.1	25	25/72-25/106	6.47	Transposition
25.3.0	25	25/106-25/110	0.63	
25.4.0	25	25/110-25/141	5.67	

Calculation Number	Segment	Calculation Section (tower to tower)	Length Covered by Calculation (miles)	Comments
25.5.0	25	25/141-25/151	1.71	
	25	25/151-25/152	0.18	
36A.1.0	36	36/1-36/2	0.22	
	36A	36A/1-36A/5	0.80	
36A.2.0	37	37/1-37/2	0.21	
	36A	36A/5-36A/6	0.23	
36B.1.0	36B	36B/2-36B/7	1.04	
37.2.0	37	37/2-37/4	0.46	
	38	38/1-38/5	0.66	
	39	39/1-39/20	4.05	
39.2.0	39	39/20-39/23	0.62	
39.3.0	39	39/23-39/27	0.68	
40.1.0	40	40/11-40/14	0.67	
	43	43/9-43/10	0.17	
	46	46/1-46/3	0.46	
	47	47/1-47/4	0.69	
	48	48/1-48/14	2.49	
40.1.1	48	48/1-48/14	2.49	Reverse current for Crossover Opt. 1
41.1.0	41	41/1-41/2	0.14	
	41	41/2-41/8	1.13	
	45	45/1-45/3	0.35	
	50	50/13-50/21	1.16	
49.1.0	49	49/7-49/10	0.69	
49.1.1	49	49/7-49/10	0.69	Phasing change for Central Alt. and all options
49.2.0	49	49/10-49/15	0.80	
49.2.1	49	49/10-49/15	0.80	Phasing change for Central Alt. and all options
50.1.0	50	50/21-50/26	0.80	
	50	50/5-50/13	1.46	
50.1.1	50	50/21-50/26	0.80	Phasing change for West Opt. 1 and Crossover Opt. 1

Calculation Number	Segment	Calculation Section (tower to tower)	Length Covered by Calculation (miles)	Comments
	50	50/5-50/13	1.46	Phasing change for West Opt. 1 and Crossover Opt. 1
51.1.0	51	51/1-51/11	2.07	
	52	52/1-52/2	0.13	
	52	52/9-52/12	0.44	
51.1.1	52	52/12-52/17	1.23	Transposition
52.2.0	52	52/2-52/9	1.48	
A.1.0	A	A/1-A/9	1.81	
	A	A/9-A/12	0.71	
C.1.0	C	C/1-C/17	3.00	
	E	E/1-E/6	1.07	
D.1.0	D	D/1-D/17	2.86	
R.1.0	R	R/10-R/19	1.75	
No Calc	2	2/27-2/28	0.24	Transition span[2]
No Calc	4	4/1-4/3	0.37	Transition spans
No Calc	52	52/20-52/22	0.47	Transition spans
No Calc	52	52/22-52/24	0.52	Transition spans
No Calc	36B	36B/1-36B2	0.18	Transition span
No Calc	36B	36B/7-36B/8	0.19	Transition span
No Calc	E	E/6-E/7	0.28	Transition span

[1] A transposition span is where the locations of the phase conductors (A, B, C) on the tower change; that is, instead of the A-phase being on the top, it is now on the bottom left and the other phases change accordingly. Such conductor location changes result in non-parallel conductors.
[2] A transition span is where the conductors go from one configuration to another, such as from a delta configuration to a flat configuration or from a single-circuit tower to one side of a double-circuit tower.

Table 7: Calculation 1.1.0 (New Right-of-Way)

Calculation 1.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
New	New/All					

Calculation 1.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Left Edge	Right Edge	Peak On ROW	Left Edge	Right Edge	Peak On ROW
Electric Field, kV/m	No Action	2.3	2.3	5.3	2.3	2.3	8.8
	Proposed	2.3	2.3	5.3	2.3	2.3	8.8
Magnetic Field, mG	No Action	12	12	35	48	48	184
	Proposed	12	12	35	48	48	184
Audible Noise, dBA Foul weather L50	No Action	47.1	47.1	Not Applicable			
	Proposed	47.1	47.1				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	36	36	Not Applicable			
	Proposed	36	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	21	21	Not Applicable			
	Proposed	21	21				

Figure 1: Calculation 1.1.0 – Electric Fields (New Right-of-Way)

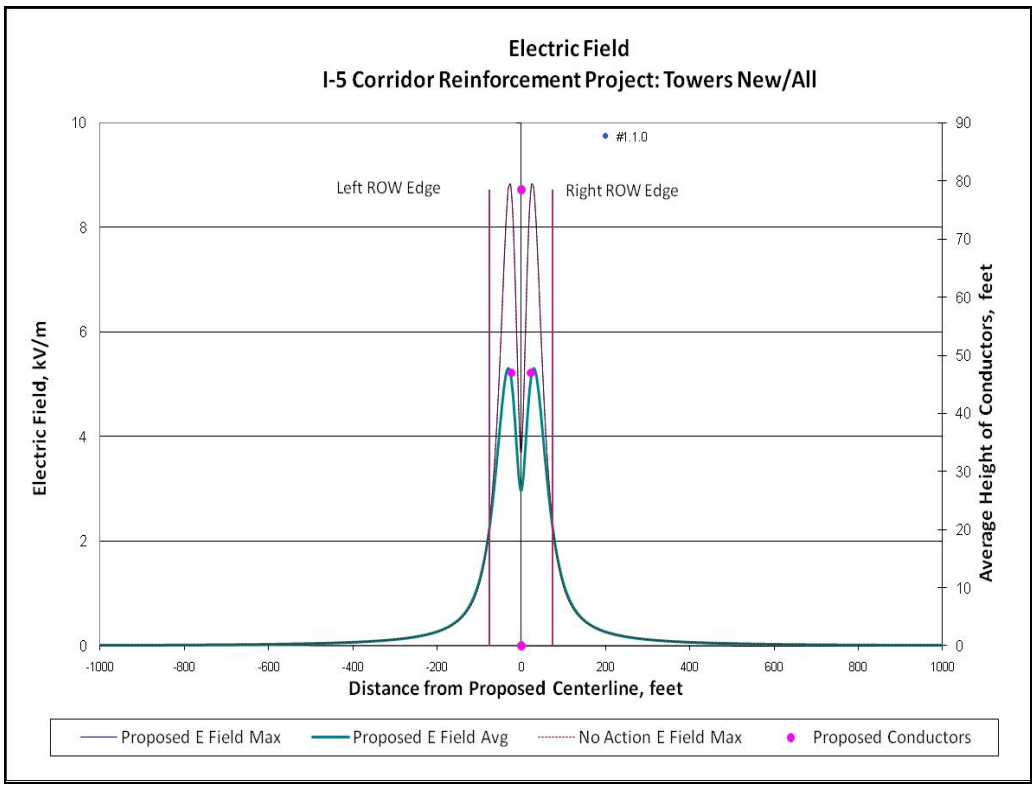


Figure 2: Calculation 1.1.0 – Magnetic Fields (New Right-of-Way)

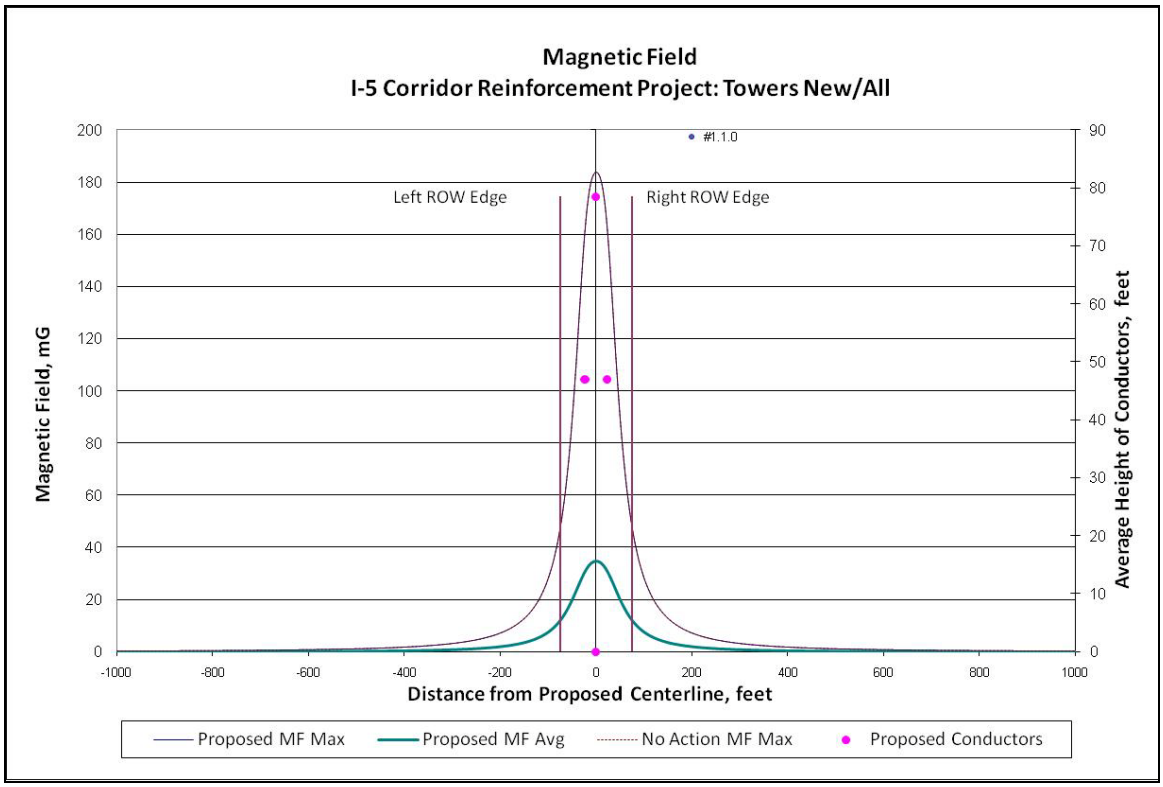


Figure 3: Calculation 1.1.0 – Audible Noise Levels (New Right-of-Way)

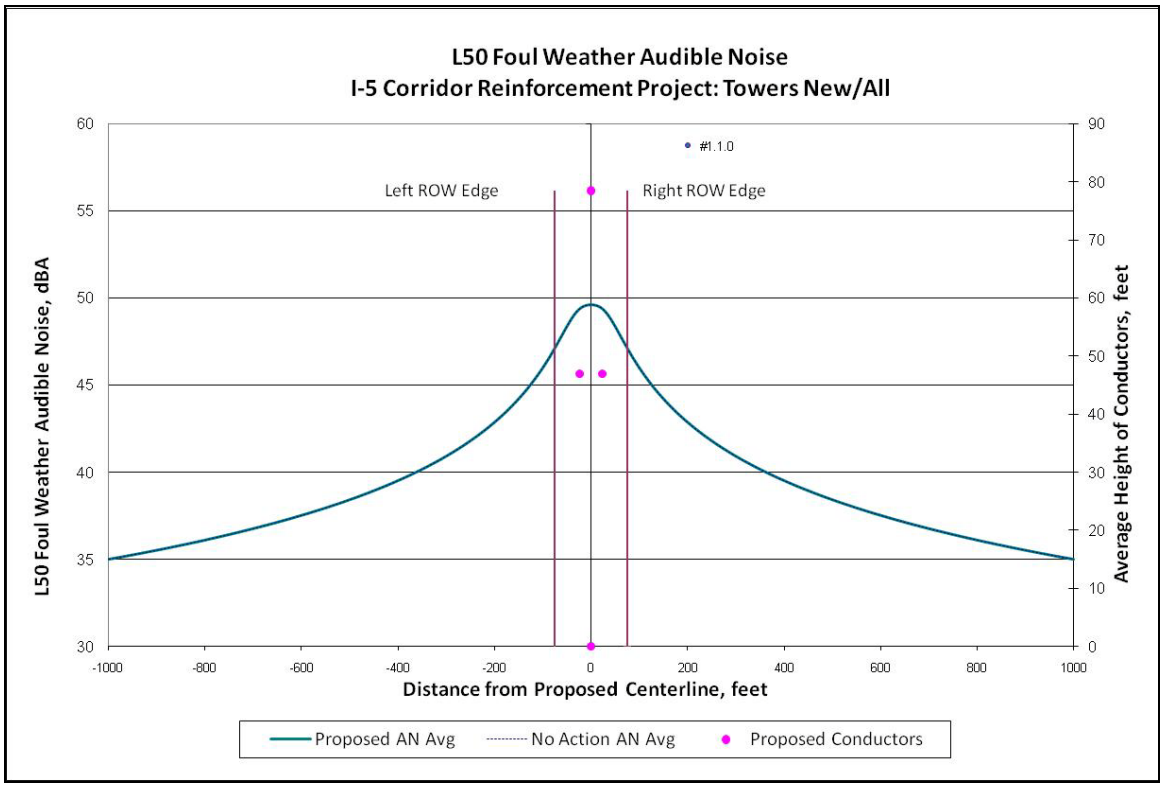


Table 8: Calculation 2.1.0

Calculation 2.1.0 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
2	2/1 - 2/7	1.64				

Calculation 2.1.0 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.6	1.9	0.1	0.5	3.7
	Proposed	1.6	0.5	5.6	1.6	0.4	9.0
Magnetic Field, mG	No Action	1	5	19	4	17	107
	Proposed	9	1	36	35	5	187
Audible Noise, dBA Foul weather L50	No Action	34.9	39.0	Not Applicable			
	Proposed	46.7	44.0				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	19	27	Not Applicable			
	Proposed	36	28				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	3	14	Not Applicable			
	Proposed	21	15				

Figure 4: Calculation 2.1.0 – Electric Fields

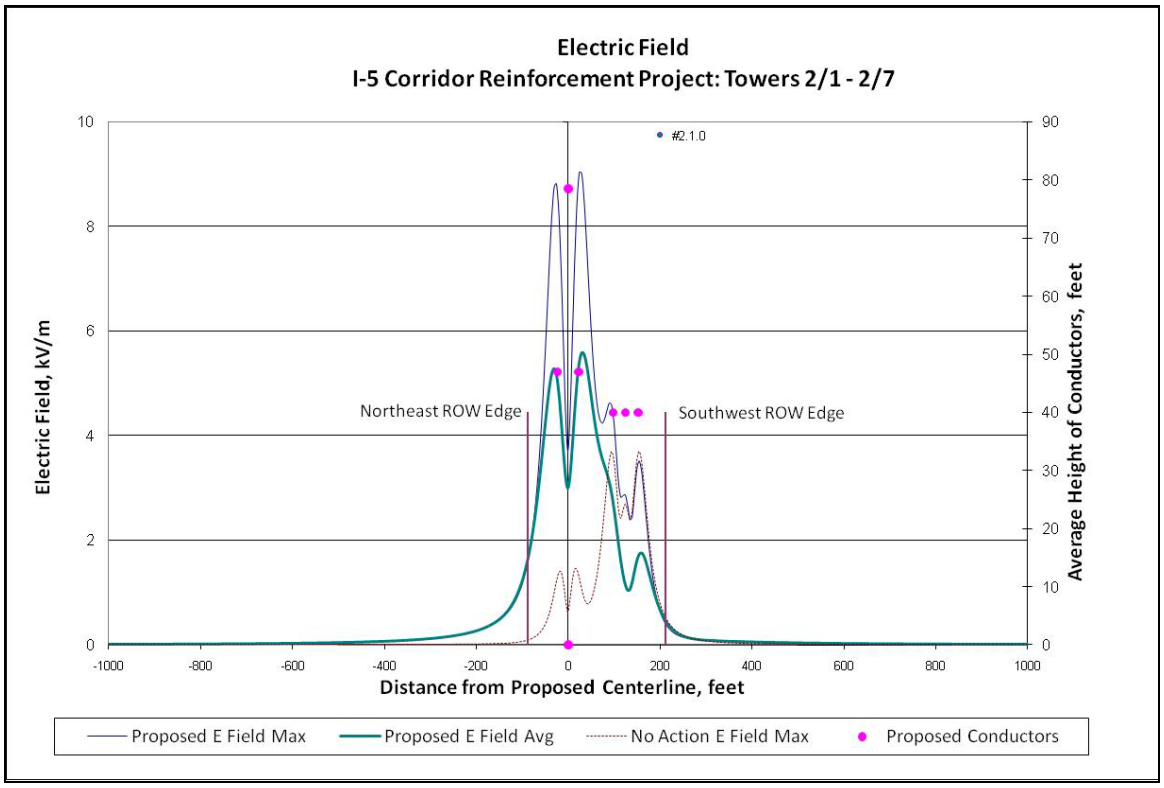


Figure 5: Calculation 2.1.0 – Magnetic Fields

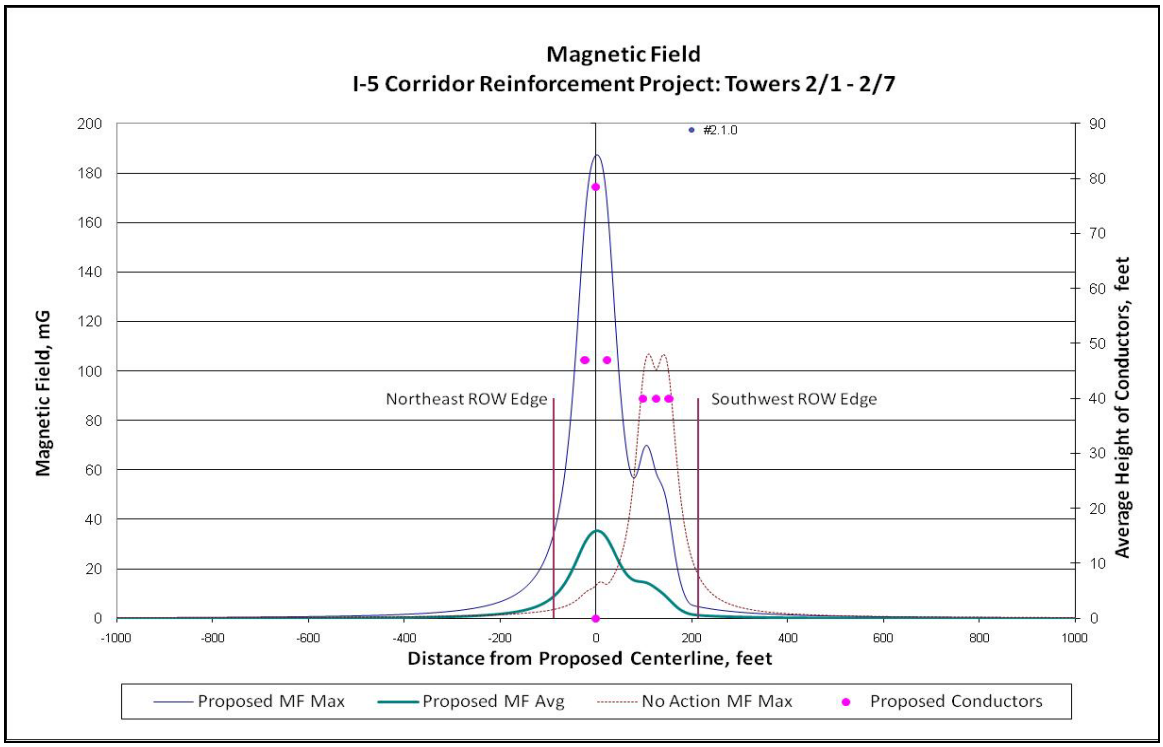


Figure 6: Calculation 2.1.0 – Audible Noise Levels

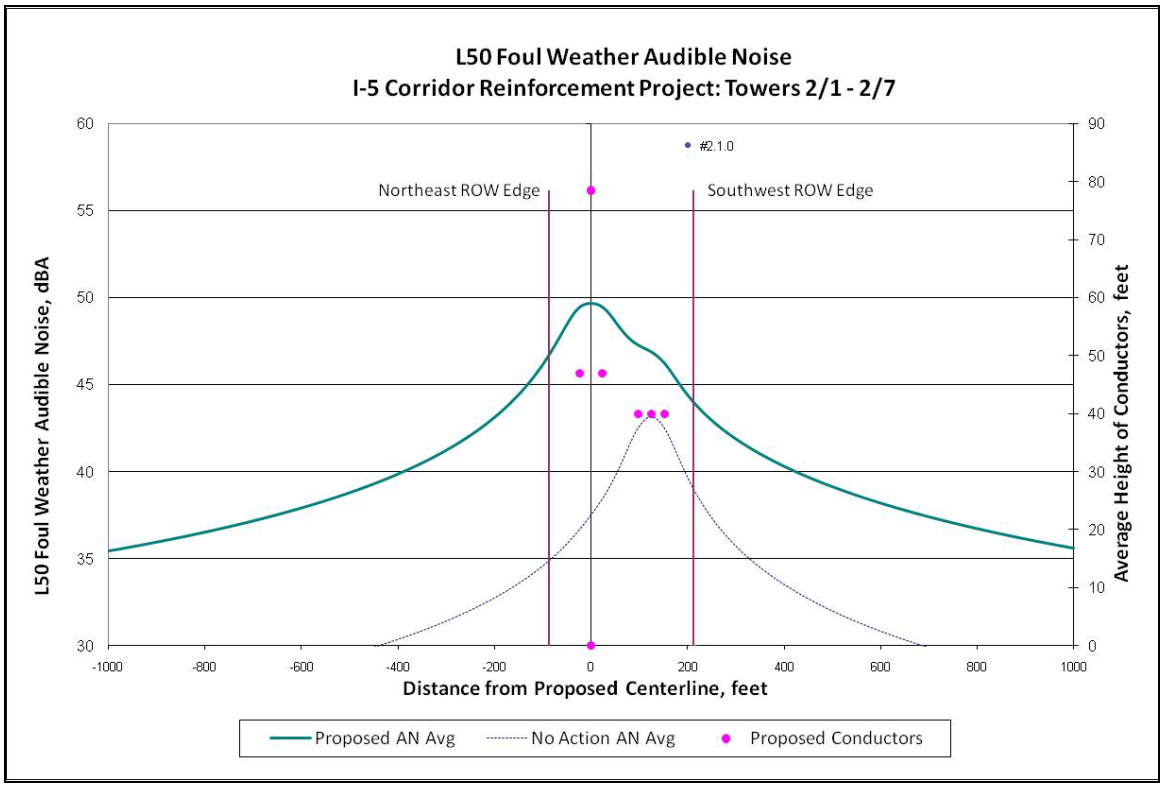


Table 9: Calculation 2.1.1

Calculation 2.1.1 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
2	2/7 - 2/18	1.64				

Calculation 2.1.1 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.6	2.0	0.1	0.5	3.8
	Proposed	1.7	0.8	5.3	1.6	0.7	8.9
Magnetic Field, mG	No Action	1	5	19	4	17	107
	Proposed	10	3	34	37	11	182
Audible Noise, dBA Foul weather L50	No Action	34.9	39.0	Not Applicable			
	Proposed	46.9	44.4				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	19	27	Not Applicable			
	Proposed	36	28				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	3	14	Not Applicable			
	Proposed	21	13				

Figure 7: Calculation 2.1.1 – Electric Fields

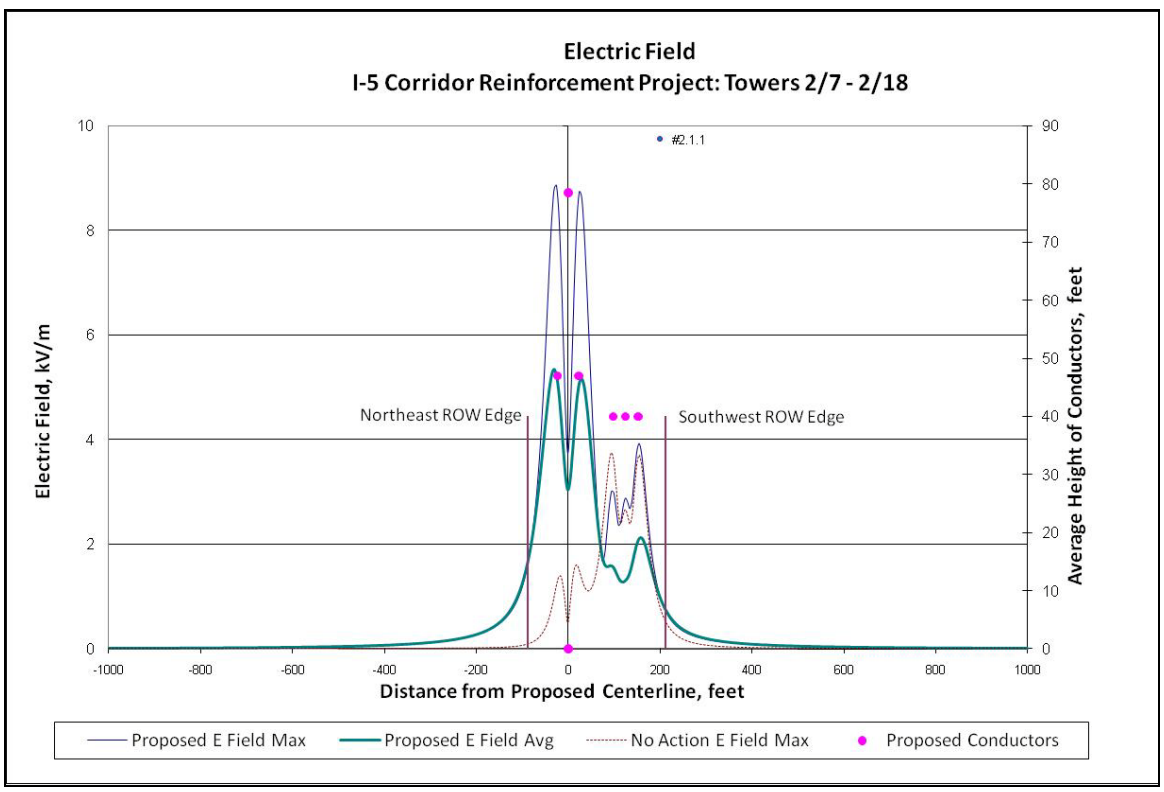


Figure 8: Calculation 2.1.1 – Magnetic Fields

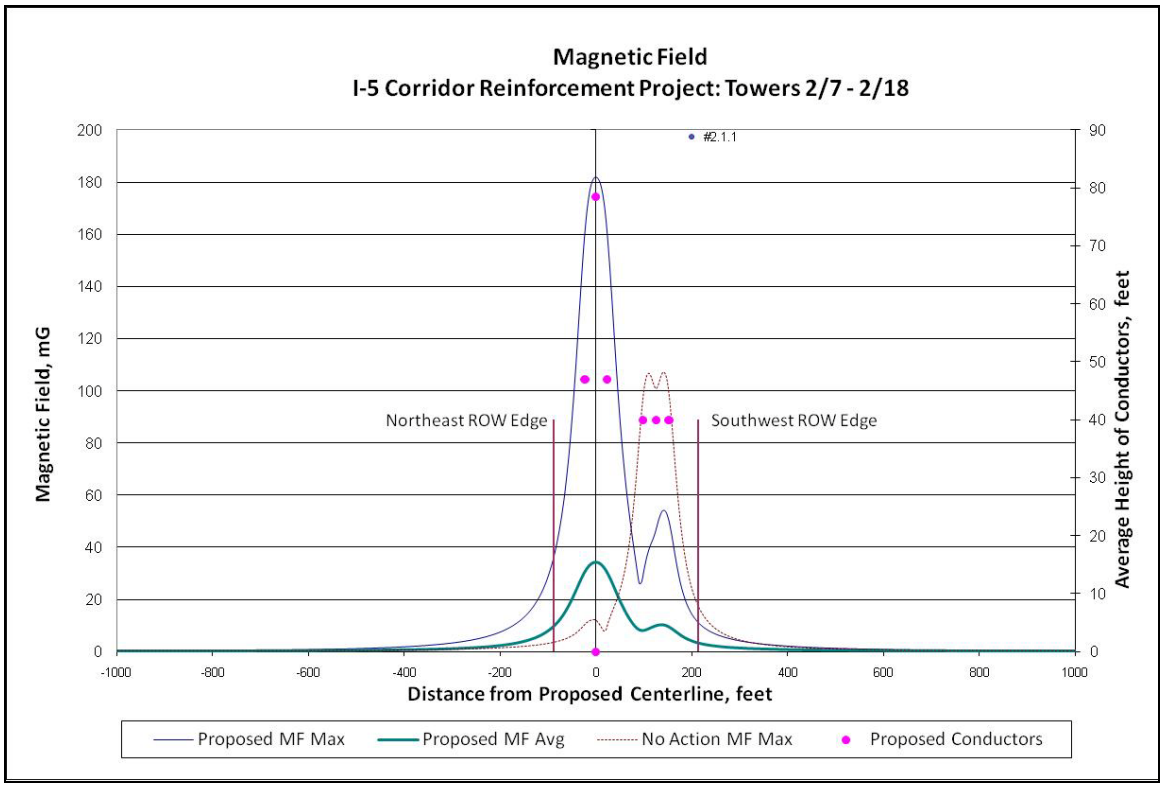


Figure 9: Calculation 2.1.1 – Audible Noise Levels

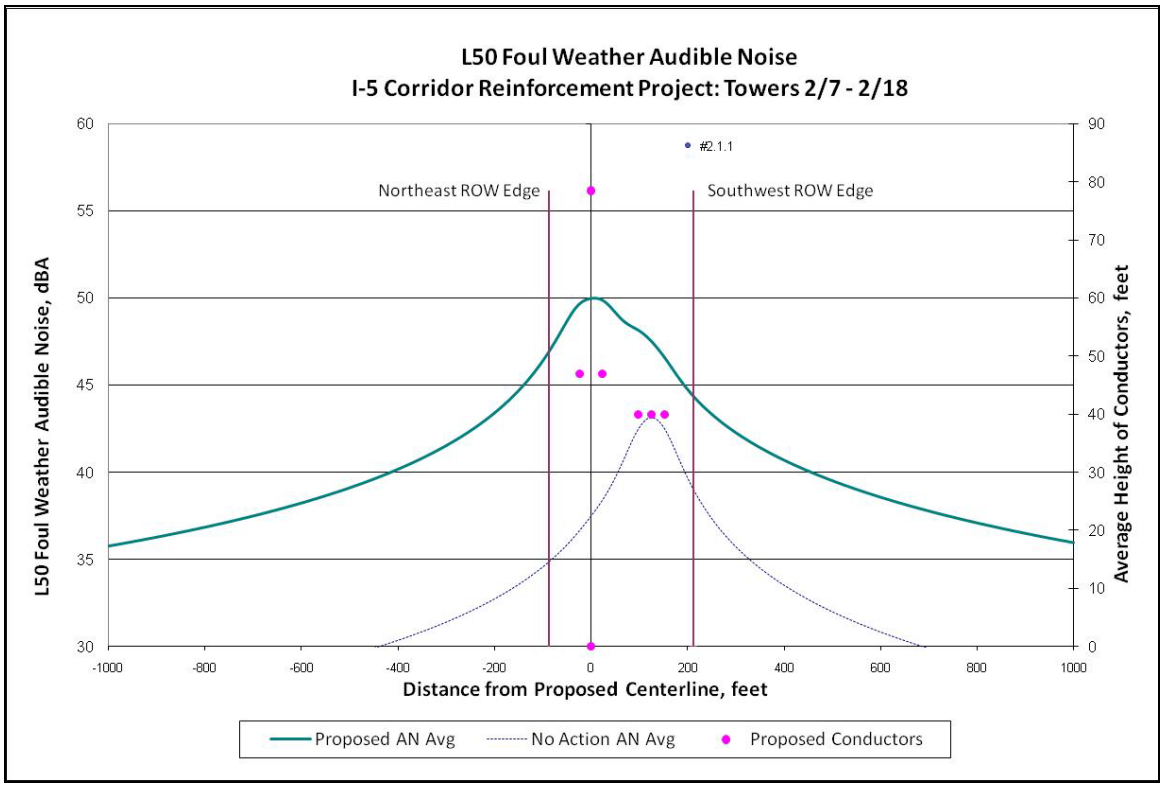


Table 10: Calculation 2.2.0

Calculation 2.2.0 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
2	2/18 - 2/24	1.38				

Calculation 2.2.0 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.3	2.0	0.0	0.4	3.7
	Proposed	1.6	0.3	5.6	1.6	0.4	9.0
Magnetic Field, mG	No Action	2	1	36	4	3	153
	Proposed	9	1	38	34	4	193
Audible Noise, dBA Foul weather L50	No Action	34.9	35.3	Not Applicable			
	Proposed	46.7	41.4				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	18	Not Applicable			
	Proposed	36	24				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	14	1	Not Applicable			
	Proposed	21	2				

Figure 10: Calculation 2.2.0 – Electric Fields

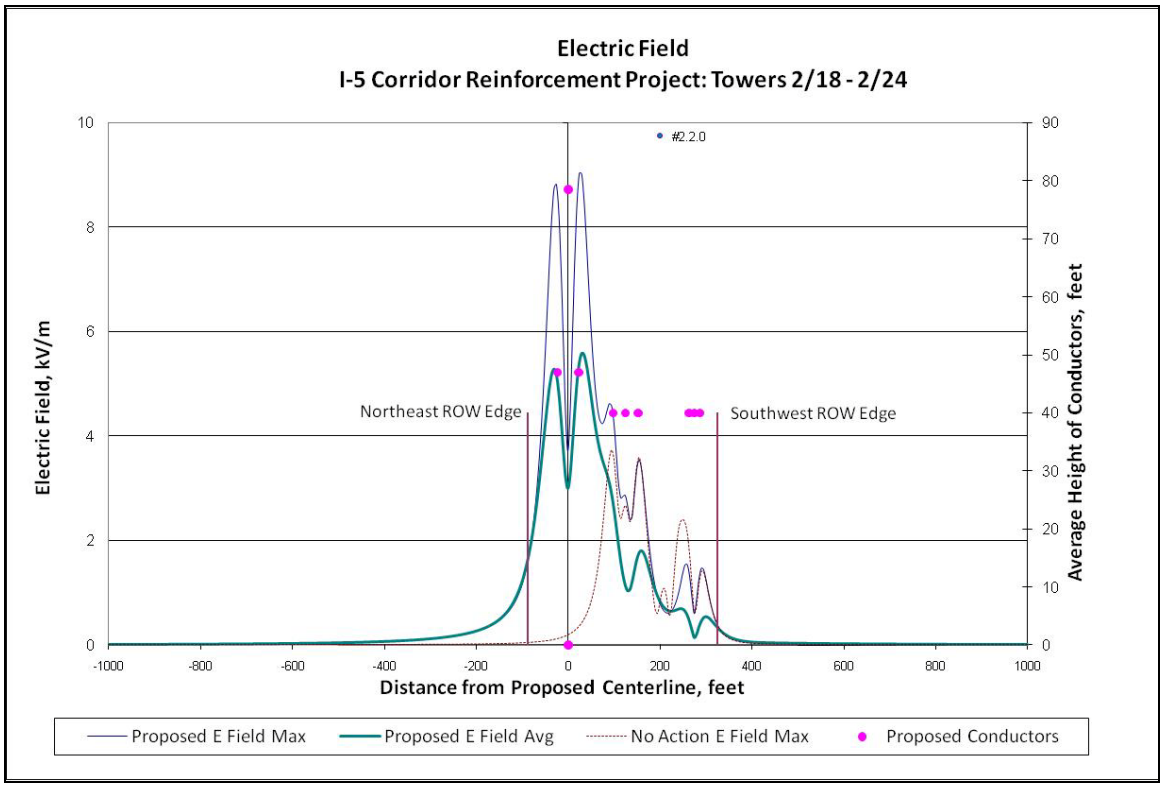


Figure 11: Calculation 2.2.0 – Magnetic Fields

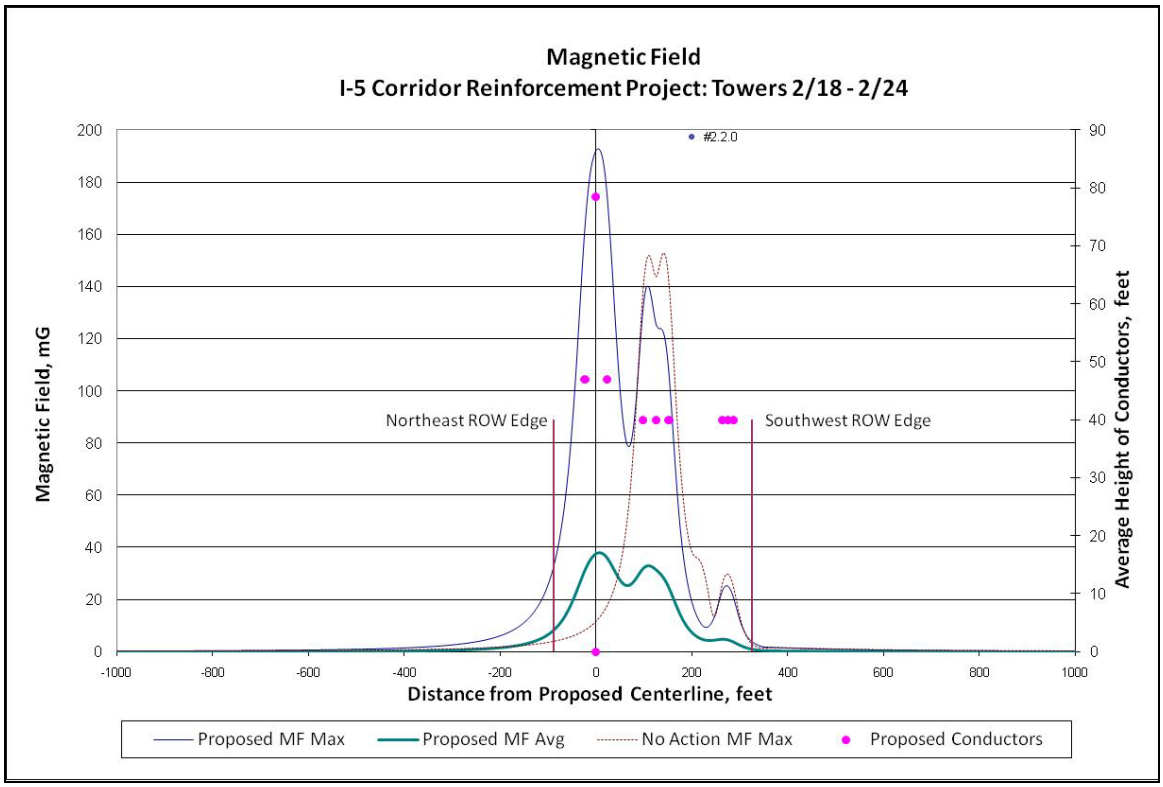


Figure 12: Calculation 2.2.0 – Audible Noise Levels

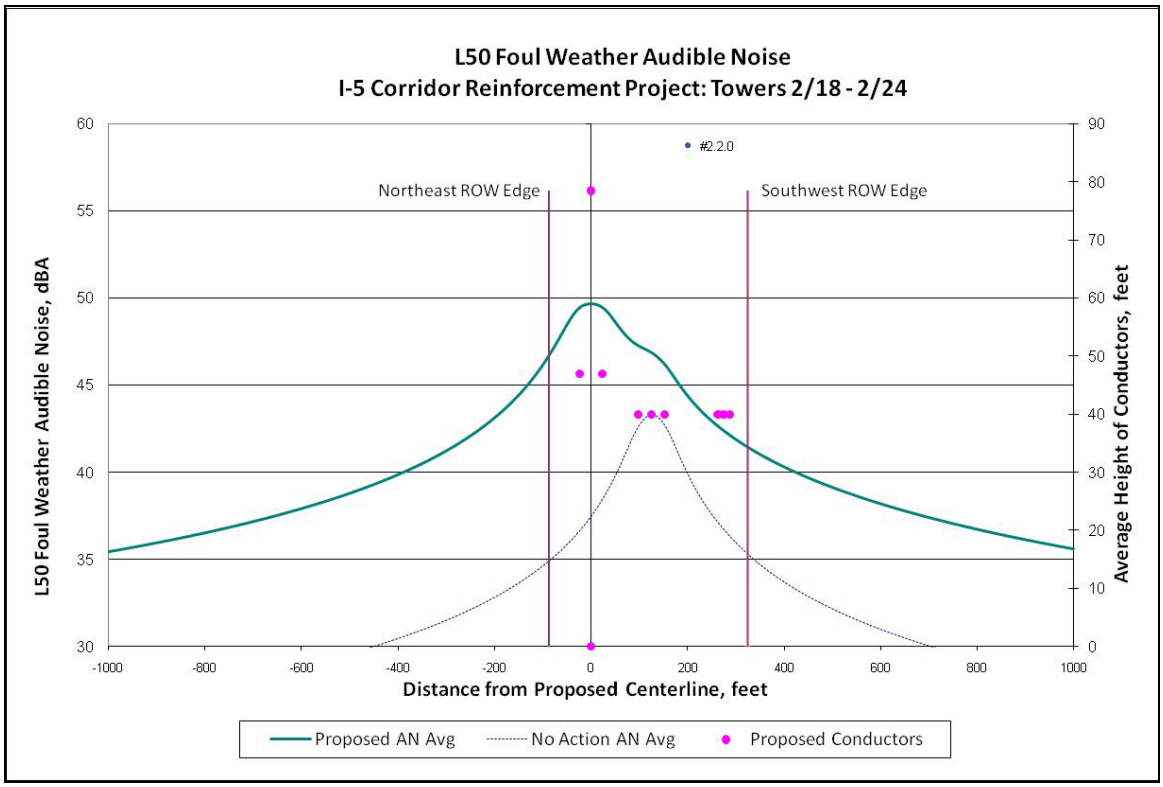


Table 11: Calculation 2.2.1

Calculation 2.2.1 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
2	2/24 - 2/27	0.46				

Calculation 2.2.1 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.4	2.0	0.0	0.5	3.7
	Proposed	1.6	0.4	5.6	1.6	0.4	9.0
Magnetic Field, mG	No Action	2	2	36	4	8	152
	Proposed	9	2	38	33	5	193
Audible Noise, dBA Foul weather L50	No Action	34.9	35.3	Not Applicable			
	Proposed	46.7	41.5				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	18	Not Applicable			
	Proposed	36	24				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	14	1	Not Applicable			
	Proposed	21	2				

Figure 13: Calculation 2.2.1 – Electric Fields

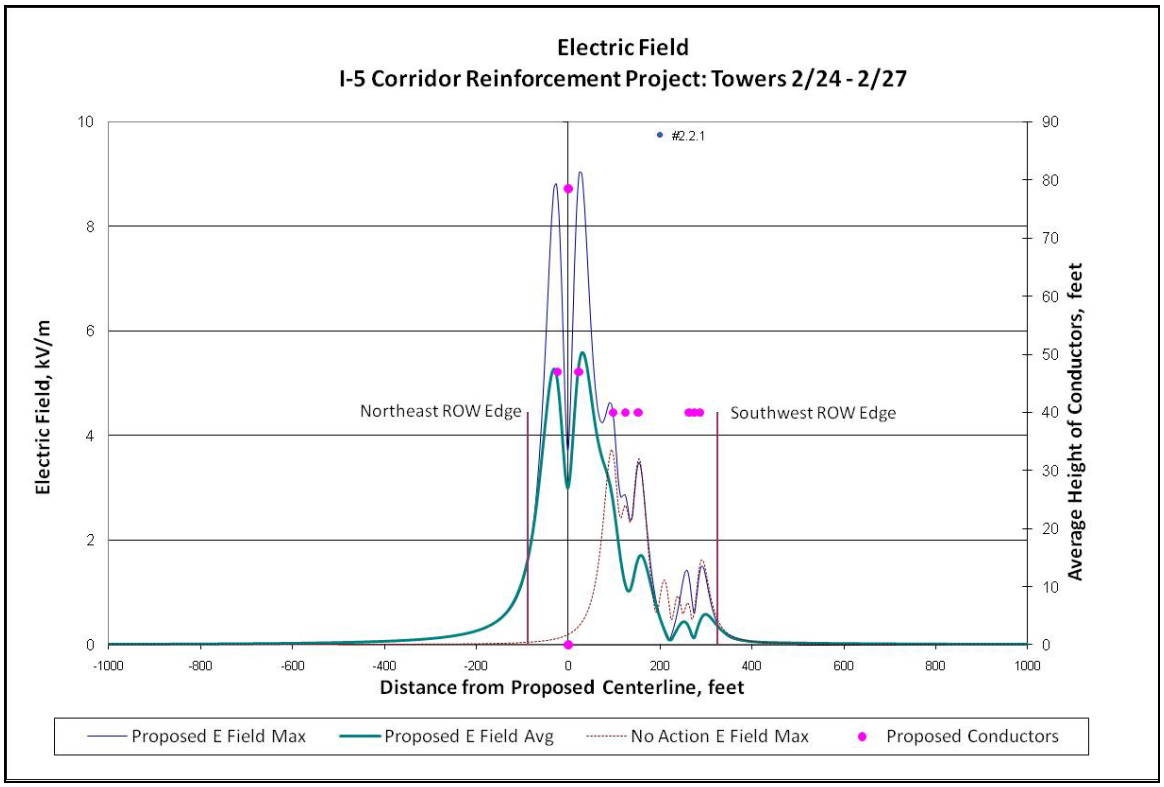


Figure 14: Calculation 2.2.1 – Magnetic Fields

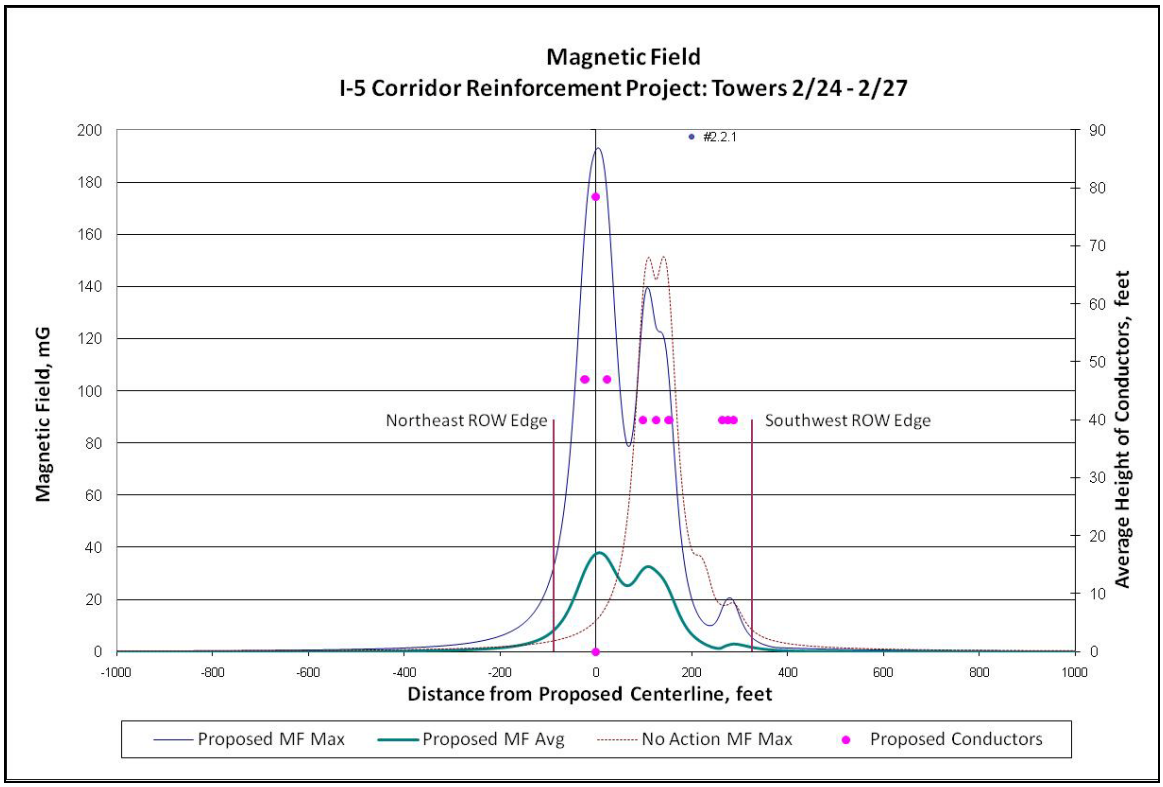


Figure 15: Calculation 2.2.1 – Audible Noise Levels

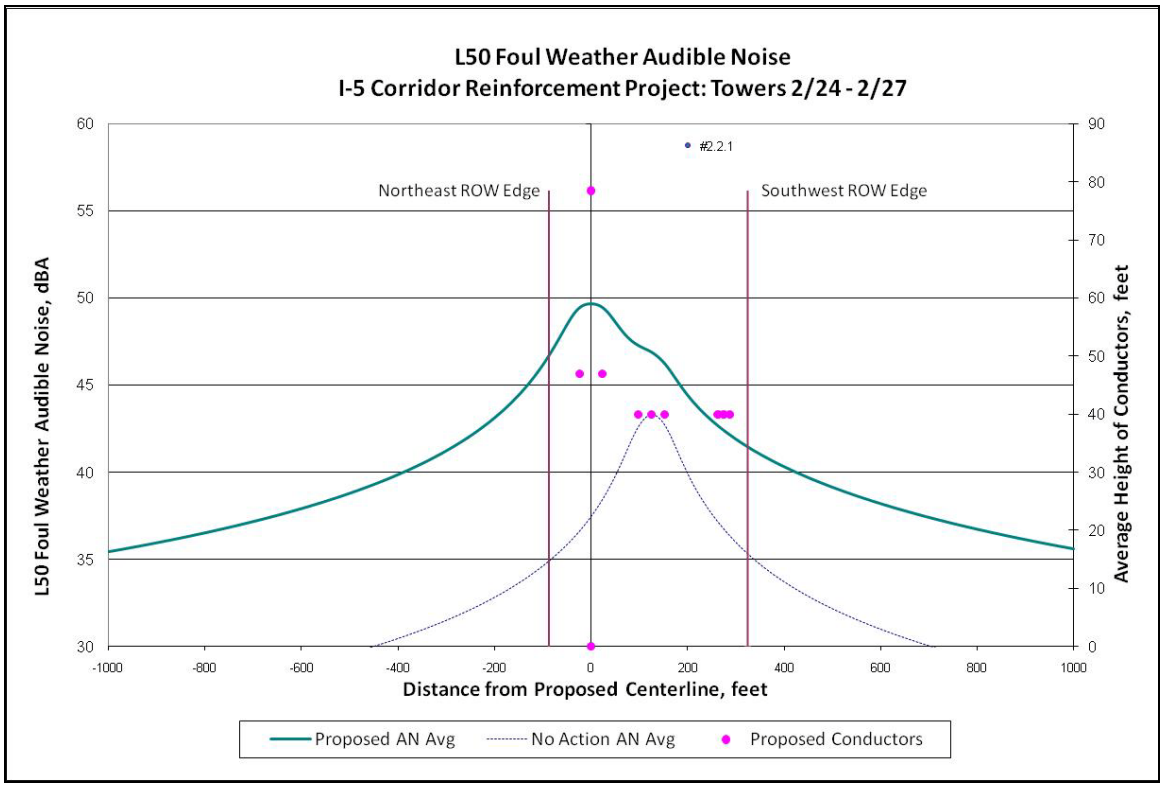


Table 12: Calculation 9.2.0

Calculation 9.2.0 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
4	4/3 - 4/5	0.40		9	9/3 - 9/11	1.61
9	9/1 - 9/3	0.52		9	9/11 - 9/20	1.94

Calculation 9.2.0 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.2	1.2	2.0	0.2	1.3	3.7
	Proposed	2.2	1.0	5.5	2.3	1.1	8.8
Magnetic Field, mG	No Action	1	5	11	5	25	77
	Proposed	12	2	34	46	8	180
Audible Noise, dBA Foul weather L50	No Action	35.5	40.5	Not Applicable			
	Proposed	47.2	45.0				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	20	27	Not Applicable			
	Proposed	36	29				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	4	14	Not Applicable			
	Proposed	21	16				

Figure 16: Calculation 9.2.0 – Electric Fields

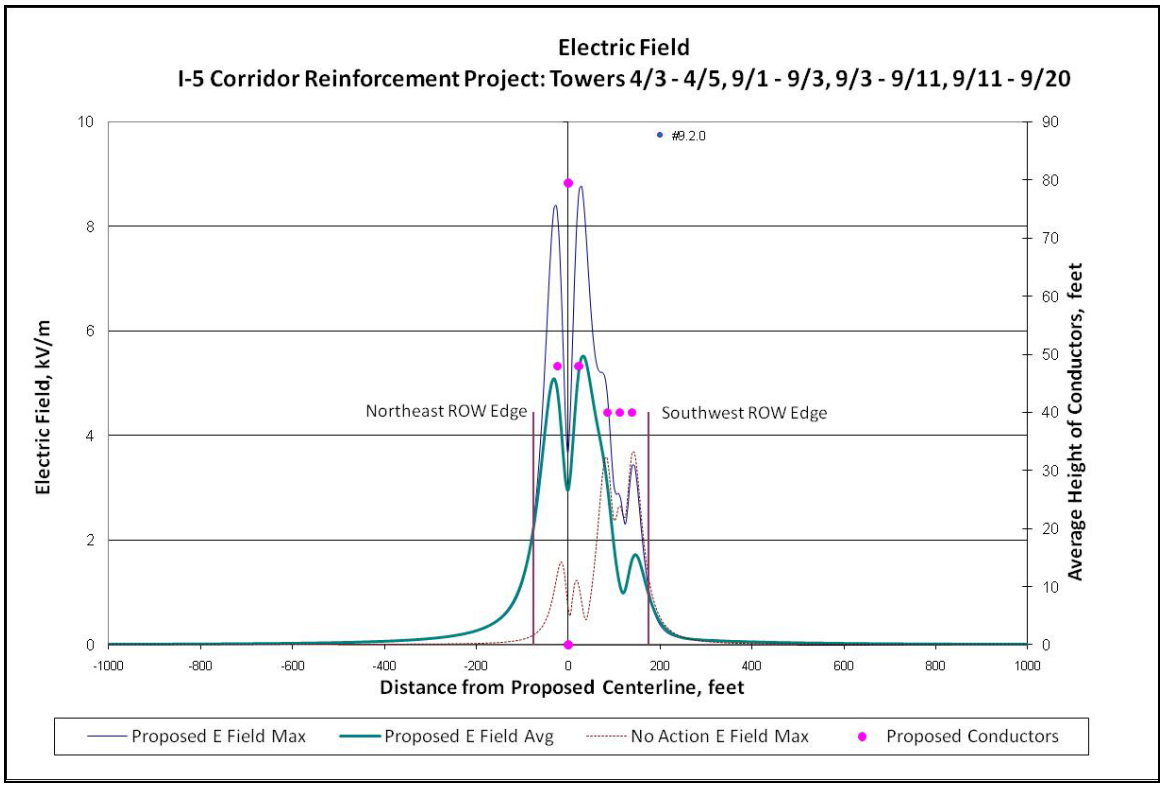


Figure 17: Calculation 9.2.0 – Magnetic Fields

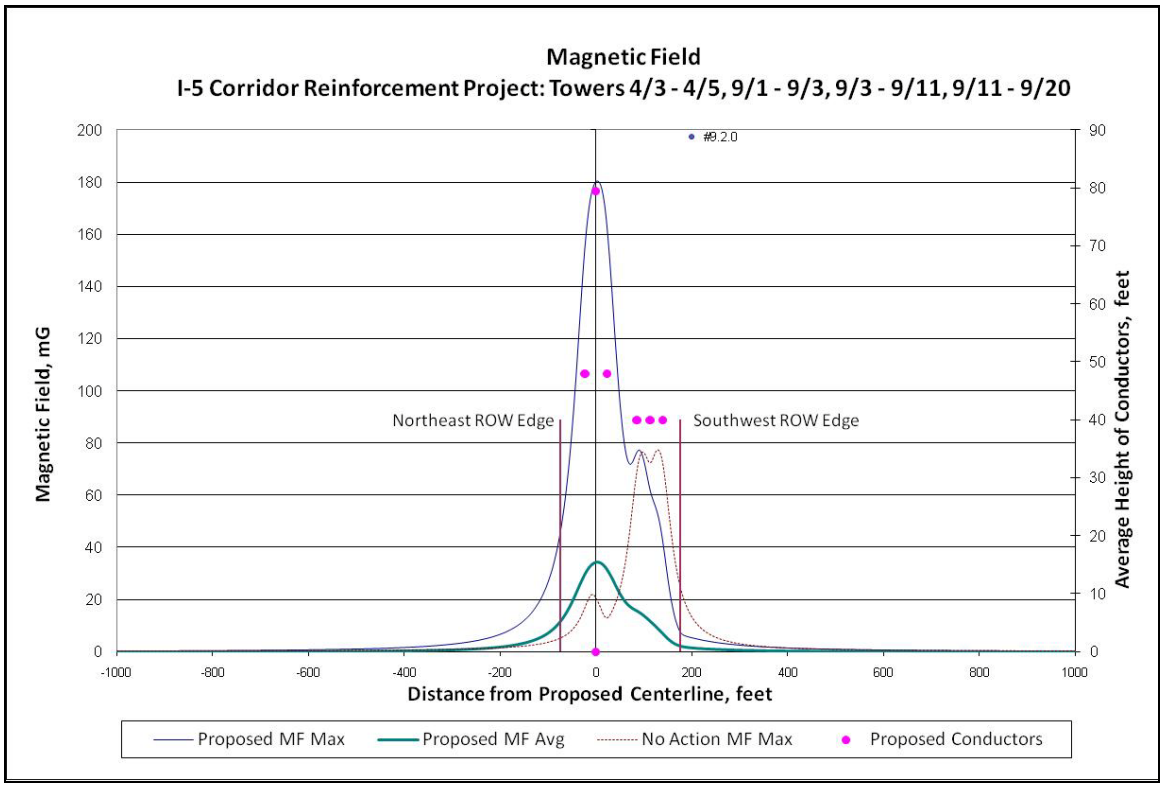


Figure 18: Calculation 9.2.0 – Audible Noise Levels

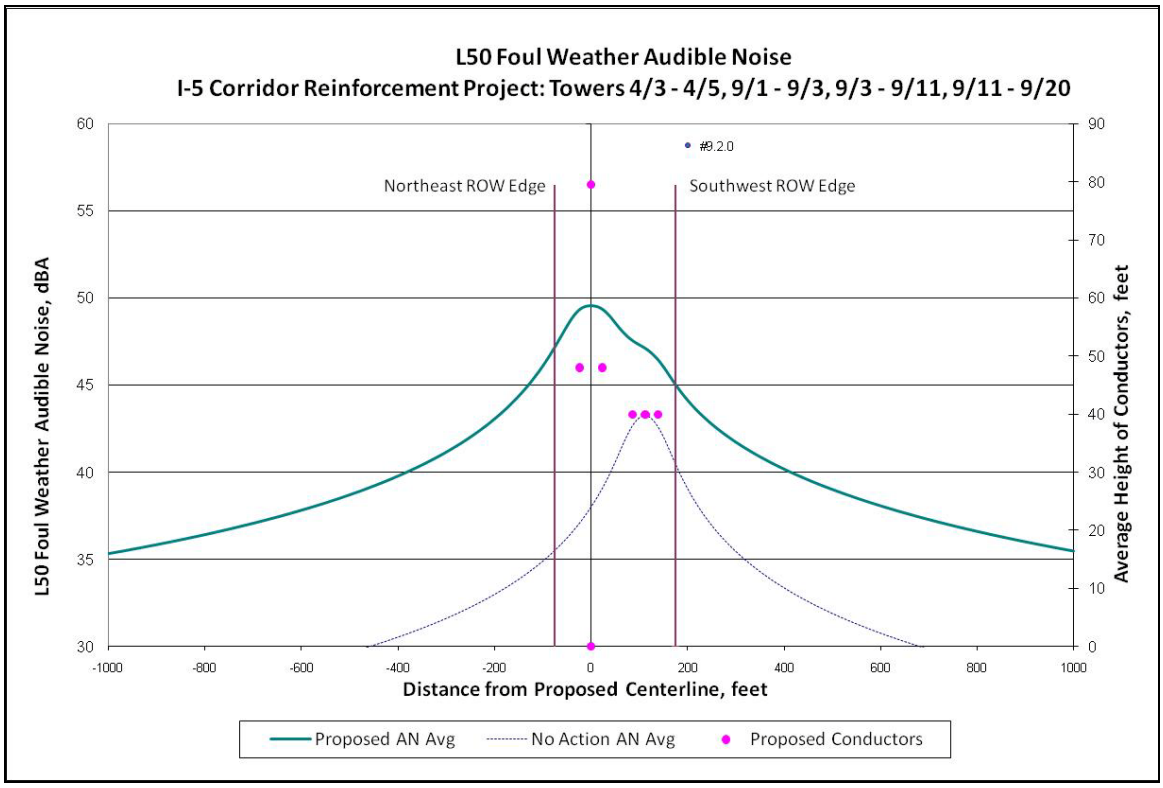


Table 13: Calculation 9.3.0

Calculation 9.3.0 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
9	9/20 - 9/21	0.50				
9	9/21 - 9/28	1.54				

Calculation 9.3.0 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.6	1.9	0.0	0.5	3.7
	Proposed	1.9	0.5	5.6	1.8	0.4	9.0
Magnetic Field, mG	No Action	1	3	11	2	13	78
	Proposed	10	1	35	39	4	187
Audible Noise, dBA Foul weather L50	No Action	34.8	39.0	Not Applicable			
	Proposed	46.9	43.9				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	27	Not Applicable			
	Proposed	36	28				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	14	14	Not Applicable			
	Proposed	21	15				

Figure 19: Calculation 9.3.0 – Electric Fields

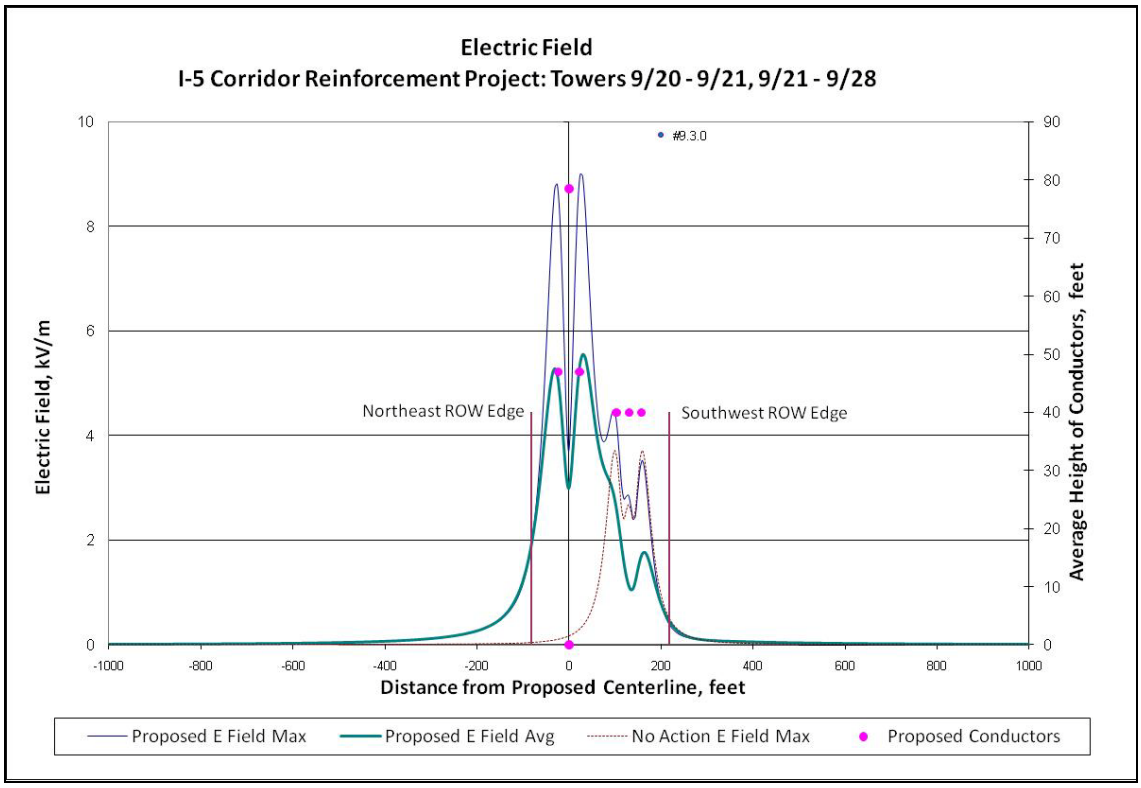


Figure 20: Calculation 9.3.0 – Magnetic Fields

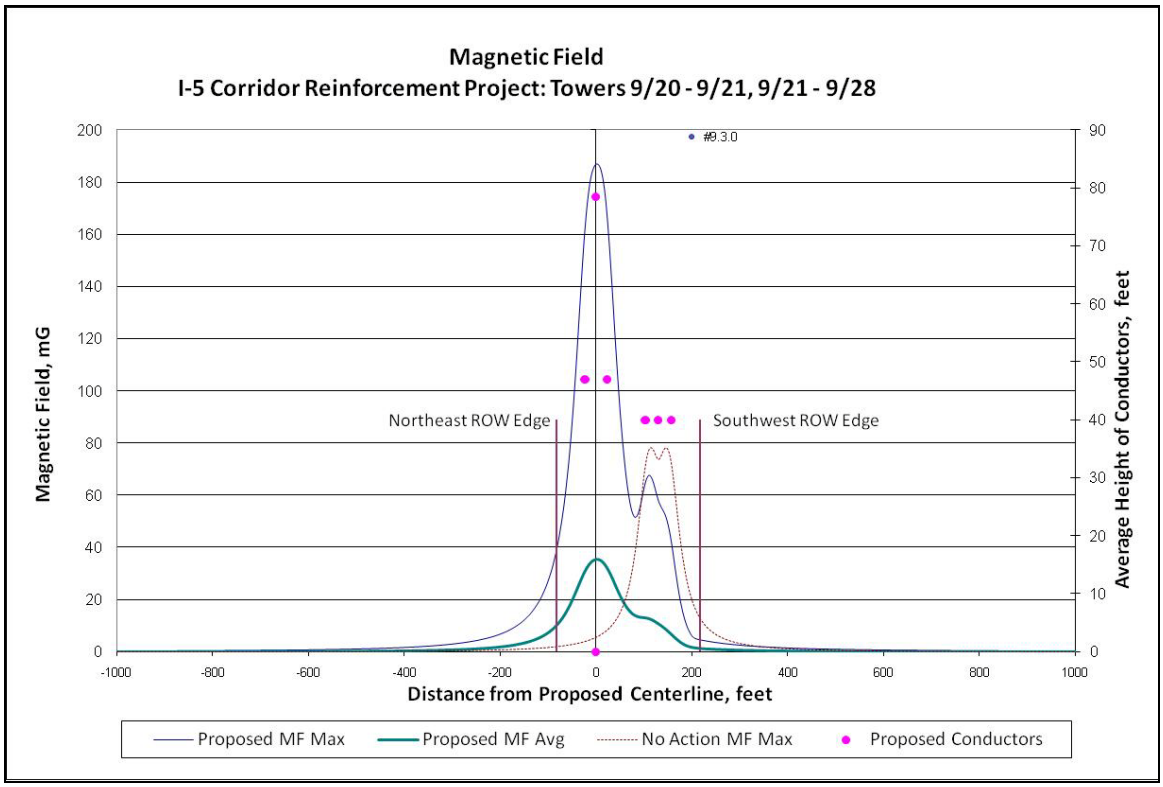


Figure 21: Calculation 9.3.0 – Audible Noise Levels

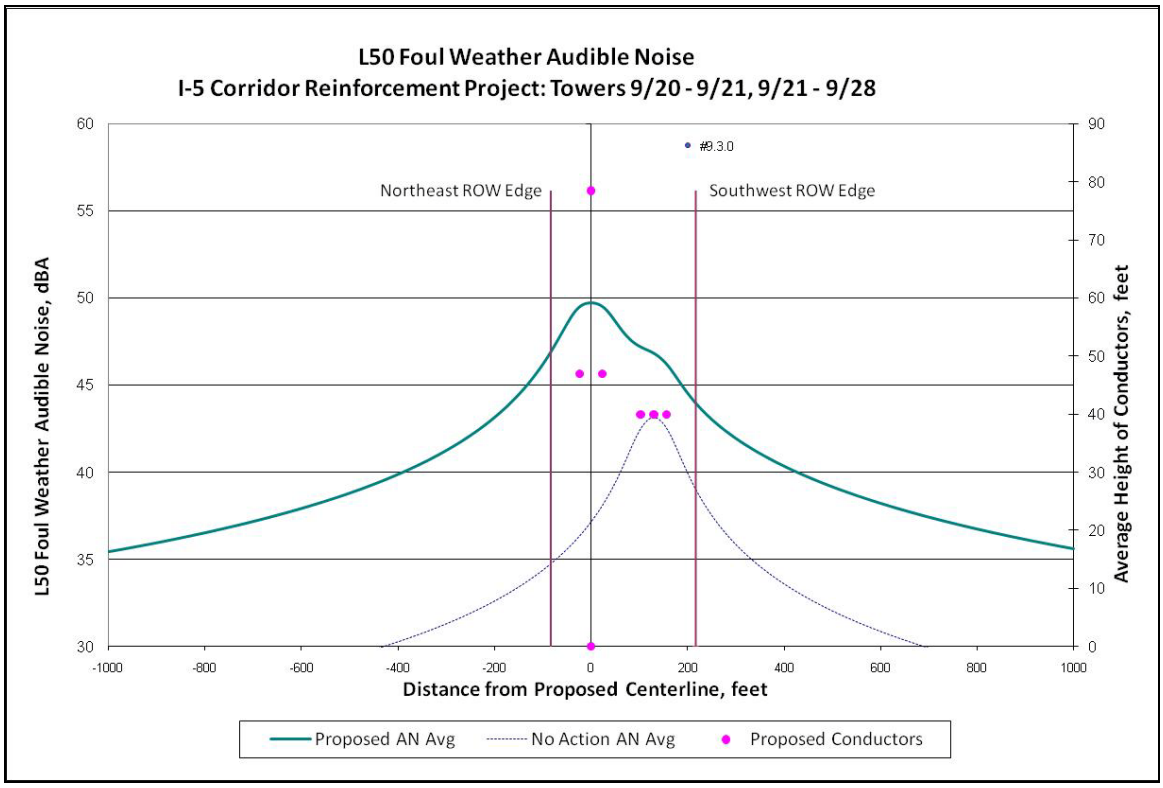


Table 14: Calculation 9.3.1

Calculation 9.3.1 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
9	9/28 - 9/82	12.62				
25	25/1 - 25/7	1.35				

Calculation 9.3.1 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.6	1.9	0.0	0.5	3.7
	Proposed	1.9	0.7	5.3	1.9	0.7	8.9
Magnetic Field, mG	No Action	1	3	11	2	13	78
	Proposed	11	3	34	41	11	182
Audible Noise, dBA Foul weather L50	No Action	34.8	39.0	Not Applicable			
	Proposed	47.1	44.3				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	27	Not Applicable			
	Proposed	36	28				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	14	14	Not Applicable			
	Proposed	21	13				

Figure 22: Calculation 9.3.1 – Electric Fields

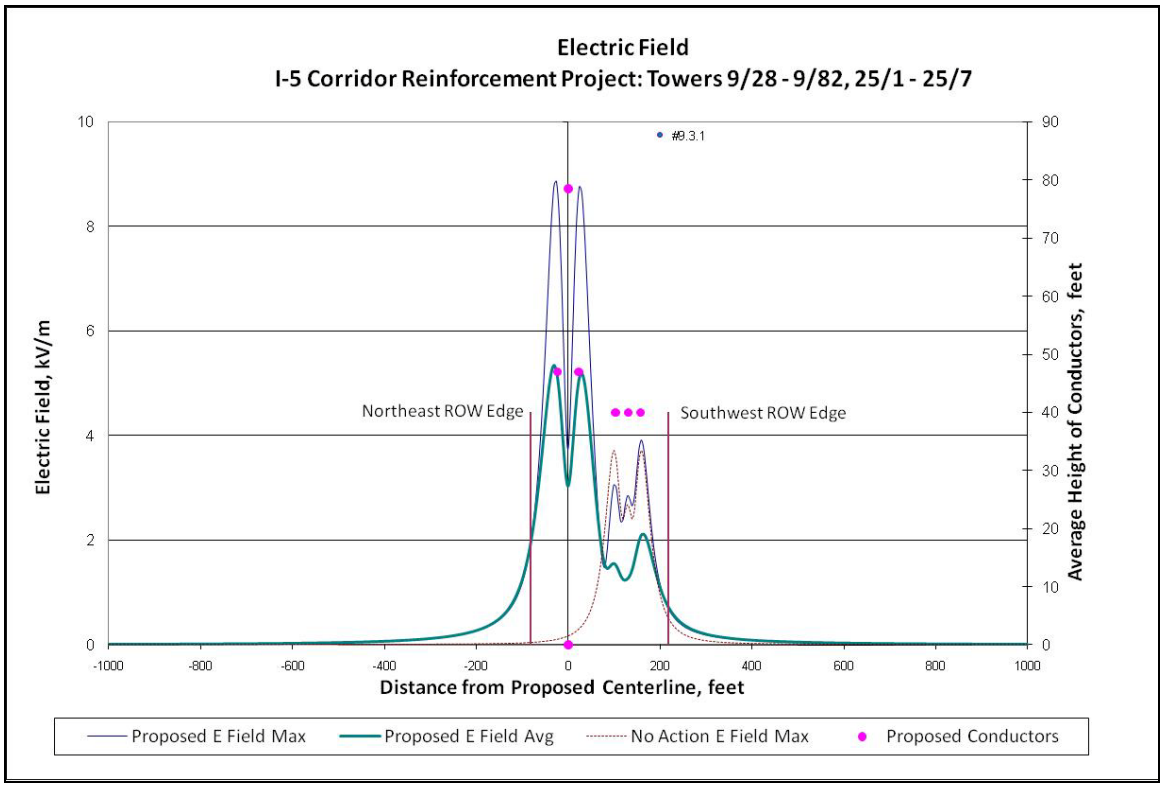


Figure 23: Calculation 9.3.1 – Magnetic Fields

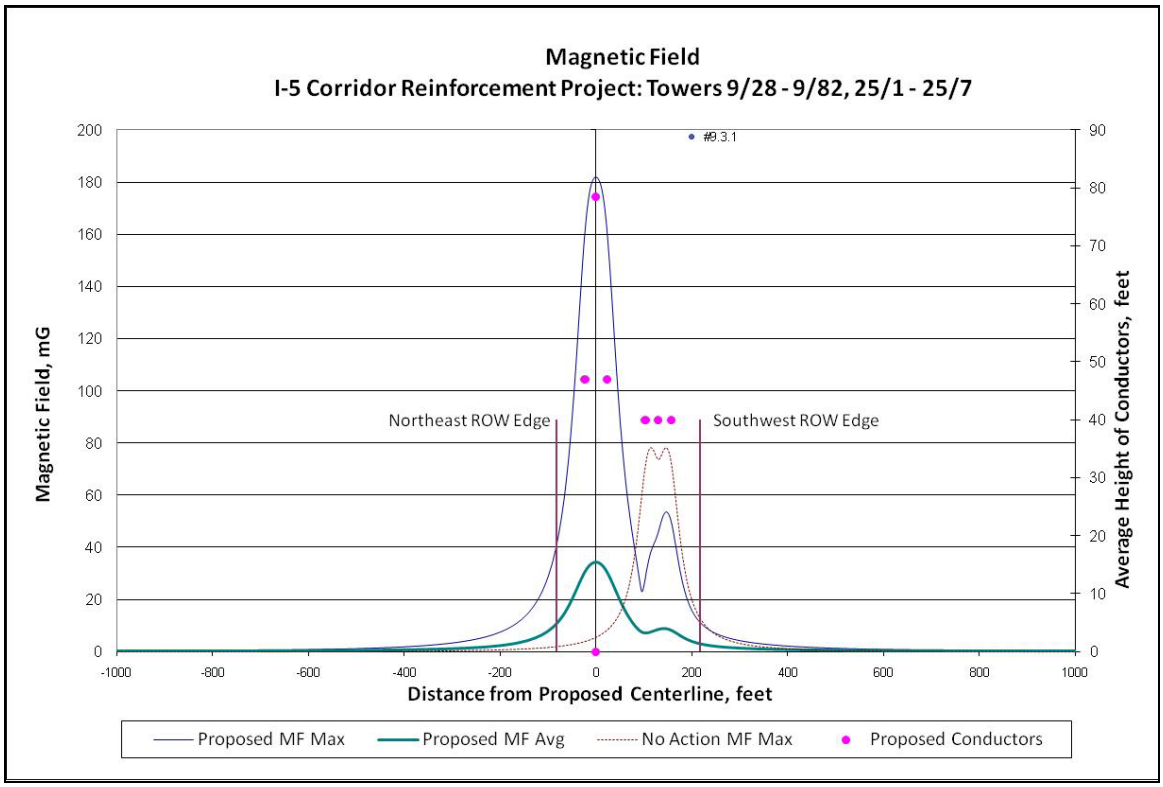


Figure 24: Calculation 9.3.1 – Audible Noise Levels

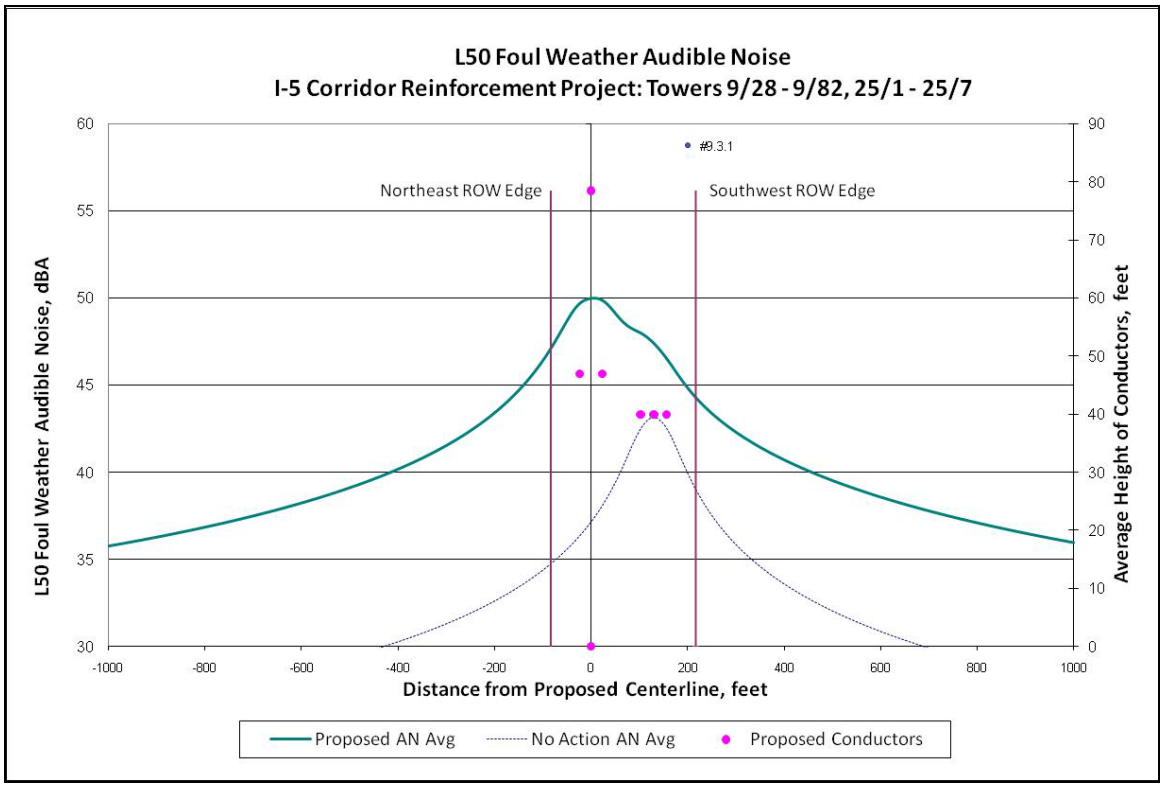


Table 15: Calculation 9.3.2

Calculation 9.3.2 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
25	25/7 - 25/11	0.75				

Calculation 9.3.2 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.6	1.9	0.0	0.5	3.7
	Proposed	1.6	0.6	5.3	1.6	0.5	8.8
Magnetic Field, mG	No Action	1	3	11	2	13	78
	Proposed	10	3	34	36	12	183
Audible Noise, dBA Foul weather L50	No Action	34.8	39.0	Not Applicable			
	Proposed	47.0	44.5				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	27	Not Applicable			
	Proposed	36	28				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	14	14	Not Applicable			
	Proposed	21	15				

Figure 25: Calculation 9.3.2 – Electric Fields

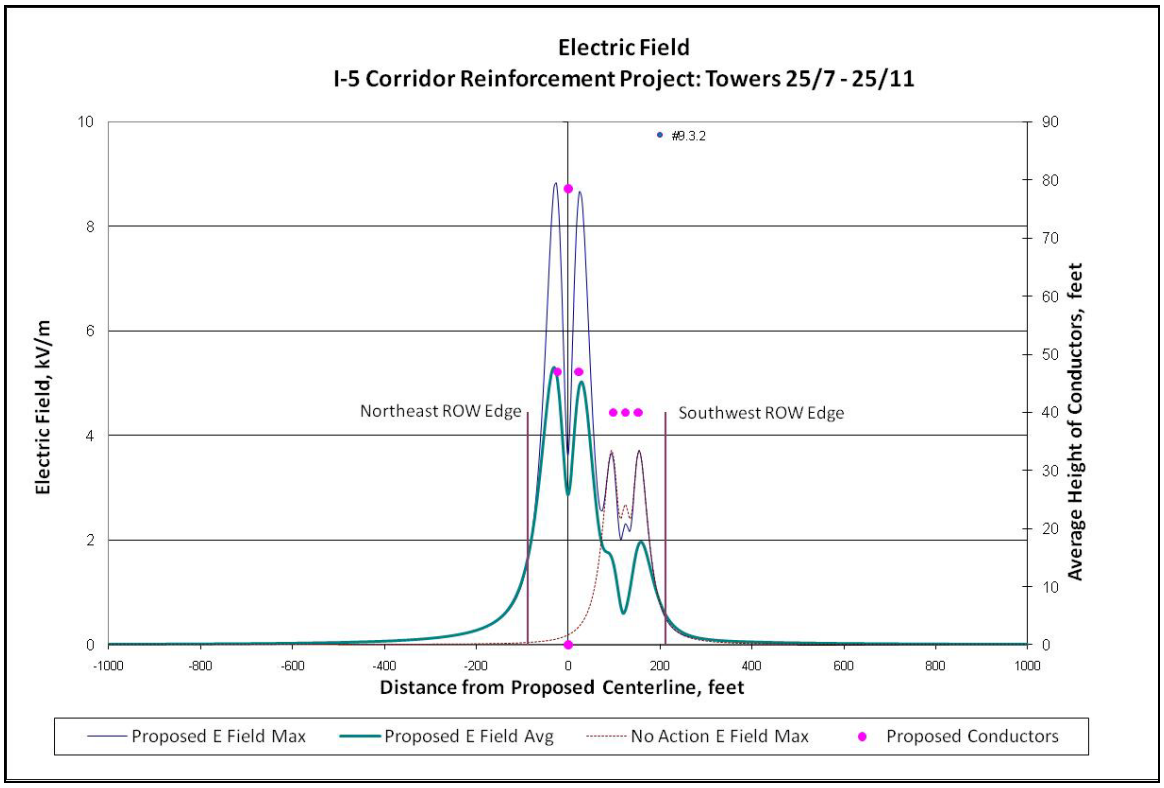


Figure 26: Calculation 9.3.2 – Magnetic Fields

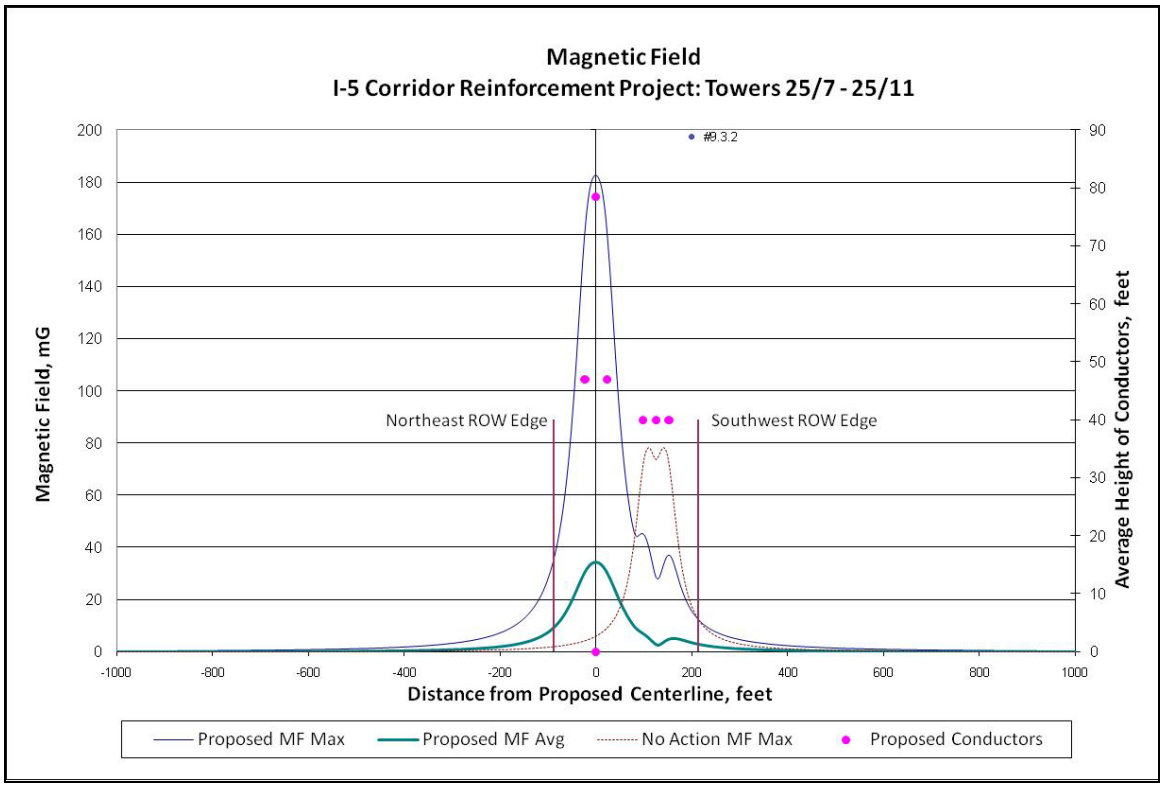


Figure 27: Calculation 9.3.2 – Audible Noise Levels

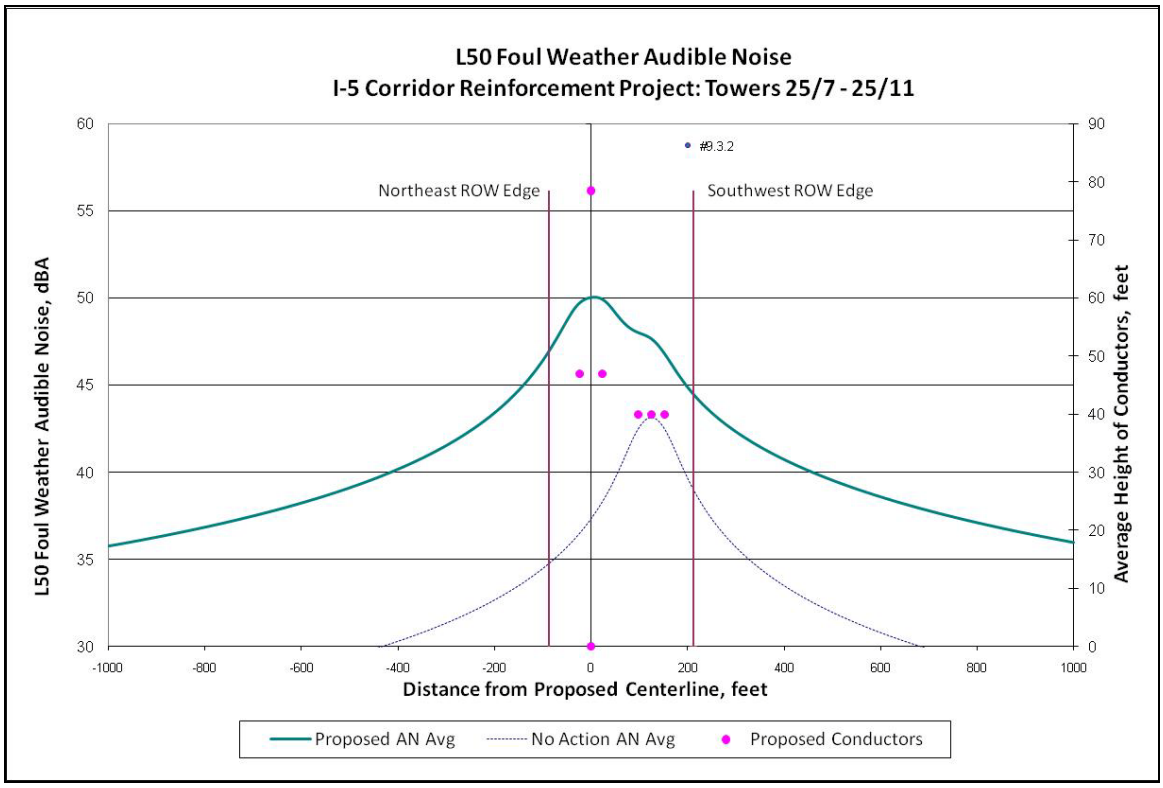


Table 16: Calculation 25.2.0

Calculation 25.2.0 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
25	25/11 - 25/18	1.64				
25	25/19 - 25/72	11.00				

Calculation 25.2.0 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	1.2	1.9	0.1	1.3	3.7
	Proposed	2.3	1.2	5.3	2.3	1.3	8.8
Magnetic Field, mG	No Action	2	15	35	8	76	242
	Proposed	12	14	33	49	71	196
Audible Noise, dBA Foul weather L50	No Action	35.4	40.4	Not Applicable			
	Proposed	47.6	45.7				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	27	Not Applicable			
	Proposed	36	29				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	14	14	Not Applicable			
	Proposed	21	16				

Figure 28: Calculation 25.2.0 – Electric Fields

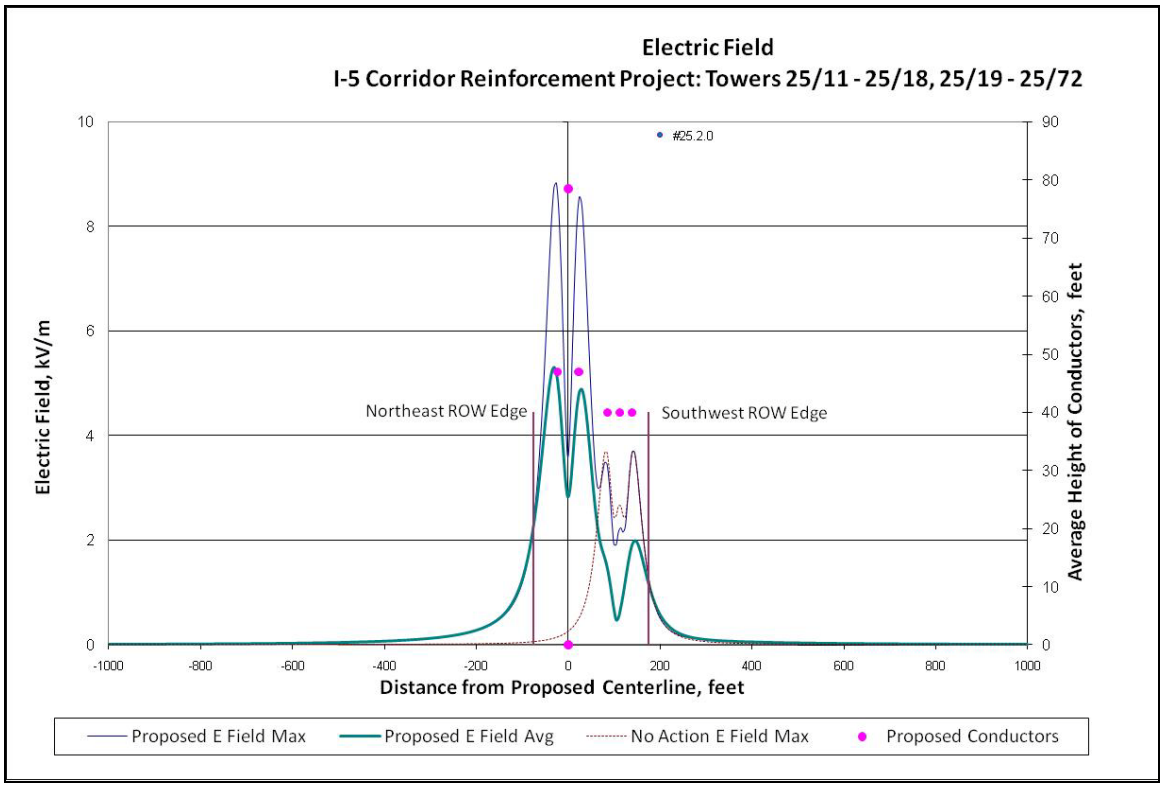


Figure 29: Calculation 25.2.0 – Magnetic Fields

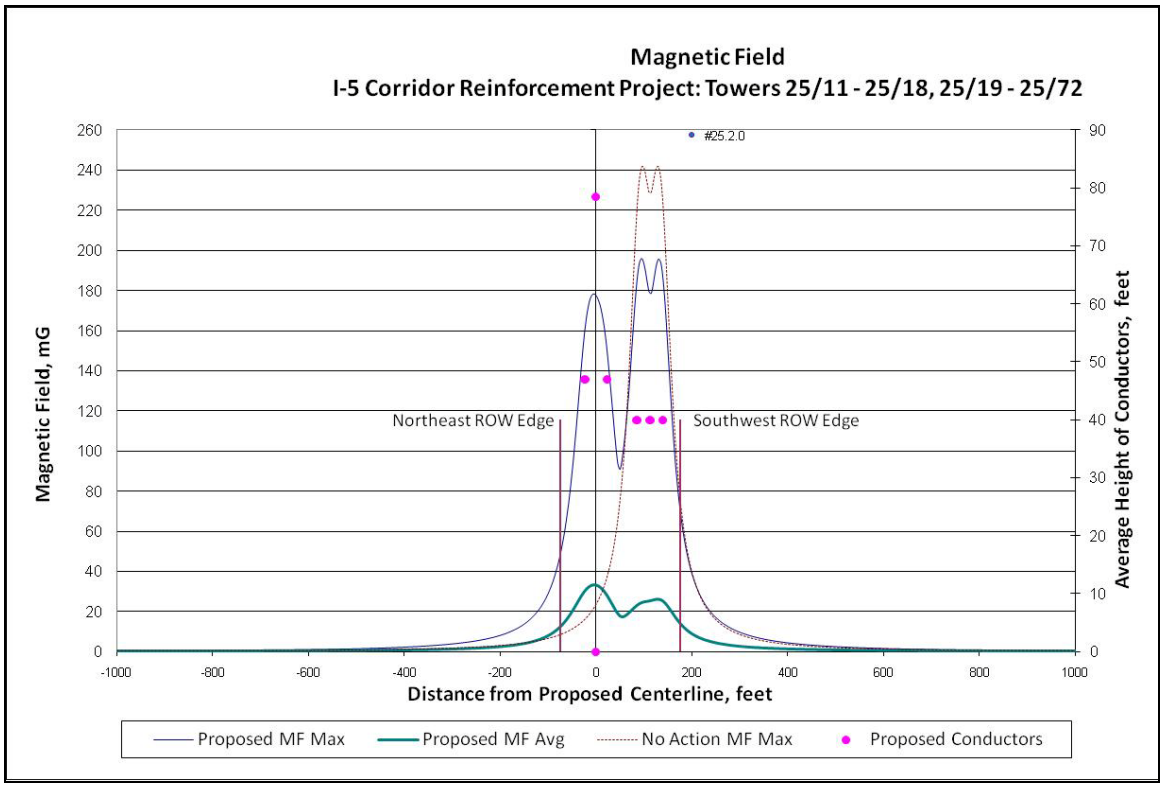


Figure 30: Calculation 25.2.0 – Audible Noise Levels

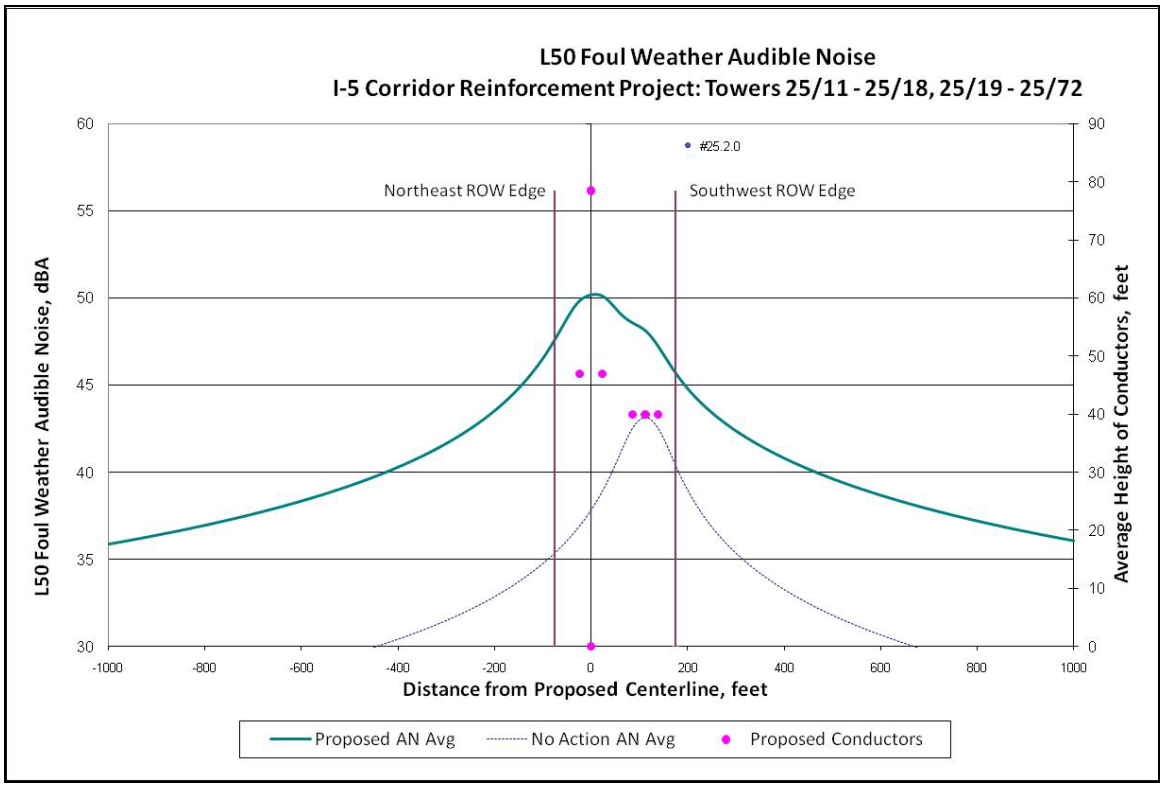


Table 17: Calculation 25.2.1

Calculation 25.2.1 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
25	25/72 - 25/106	6.47				

Calculation 25.2.1 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	1.2	1.9	0.1	1.3	3.7
	Proposed	2.2	1.0	5.5	2.3	1.1	8.8
Magnetic Field, mG	No Action	2	15	35	8	76	242
	Proposed	11	11	38	41	58	240
Audible Noise, dBA Foul weather L50	No Action	35.4	40.4	Not Applicable			
	Proposed	47.2	45.0				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	27	Not Applicable			
	Proposed	36	29				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	14	14	Not Applicable			
	Proposed	21	16				

Figure 31: Calculation 25.2.1 – Electric Fields

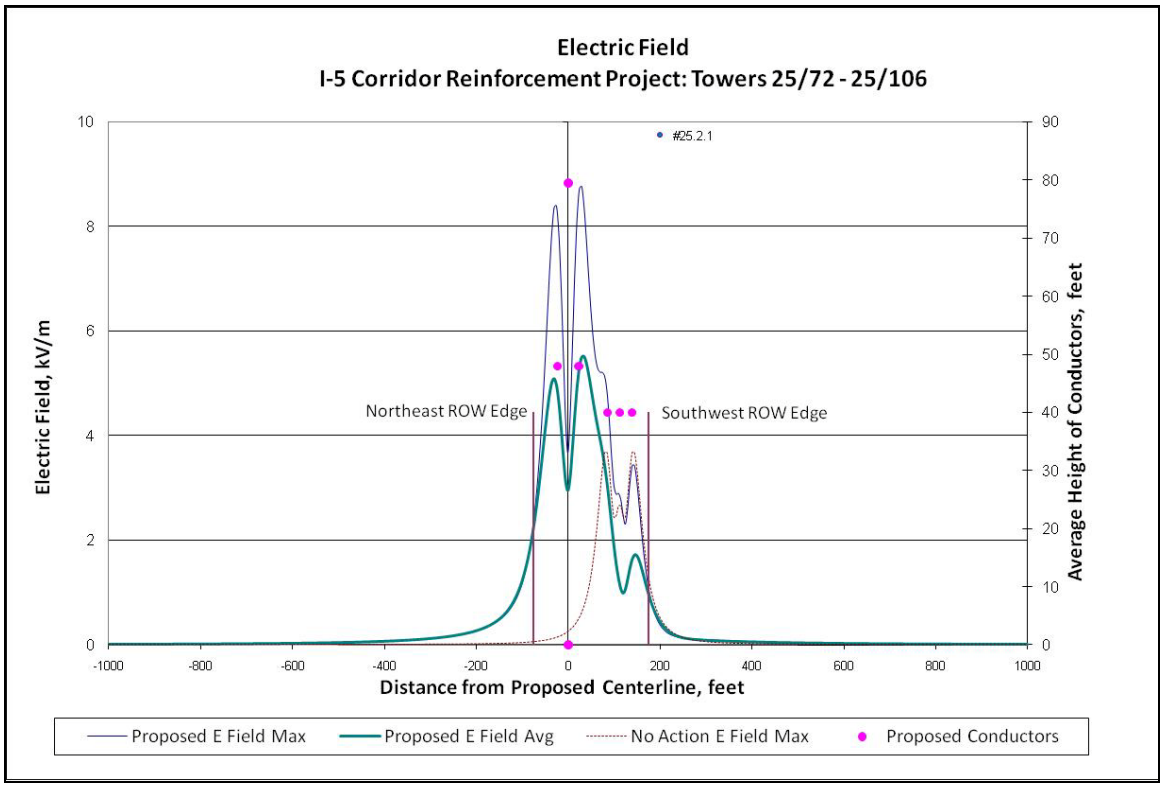


Figure 32: Calculation 25.2.1 – Magnetic Fields

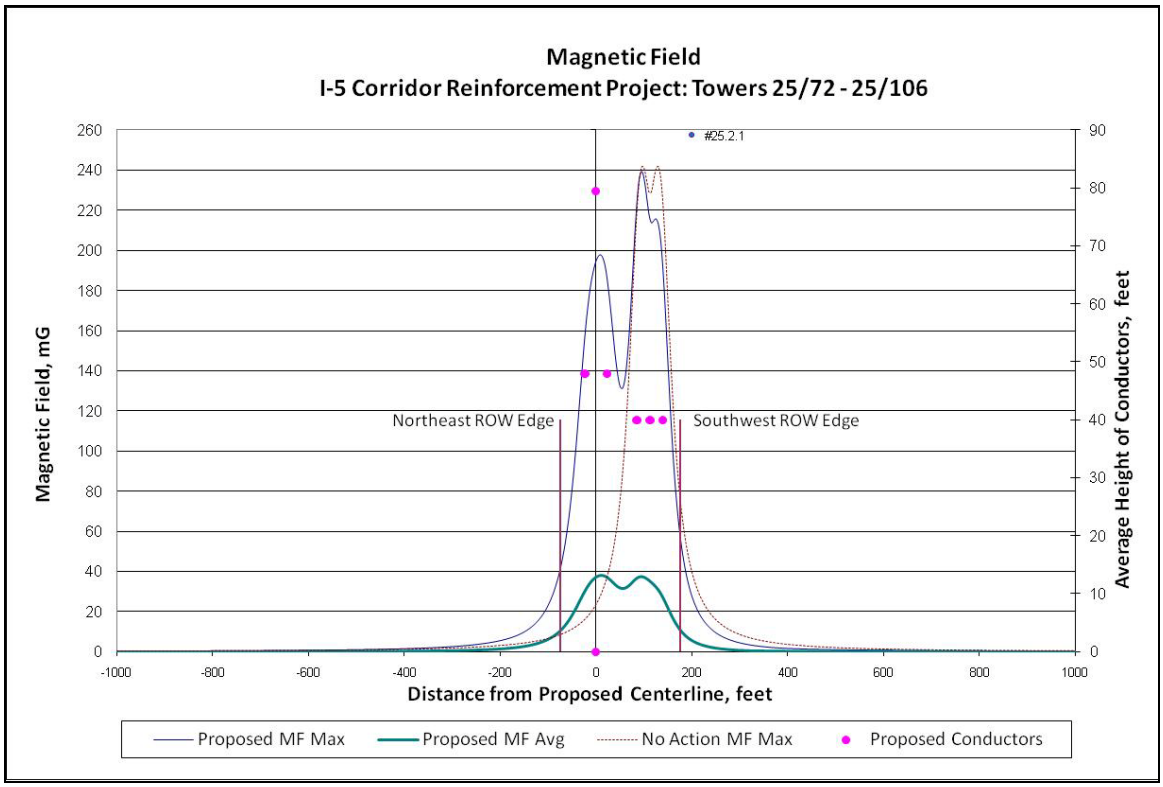


Figure 33: Calculation 25.2.1 – Audible Noise Levels

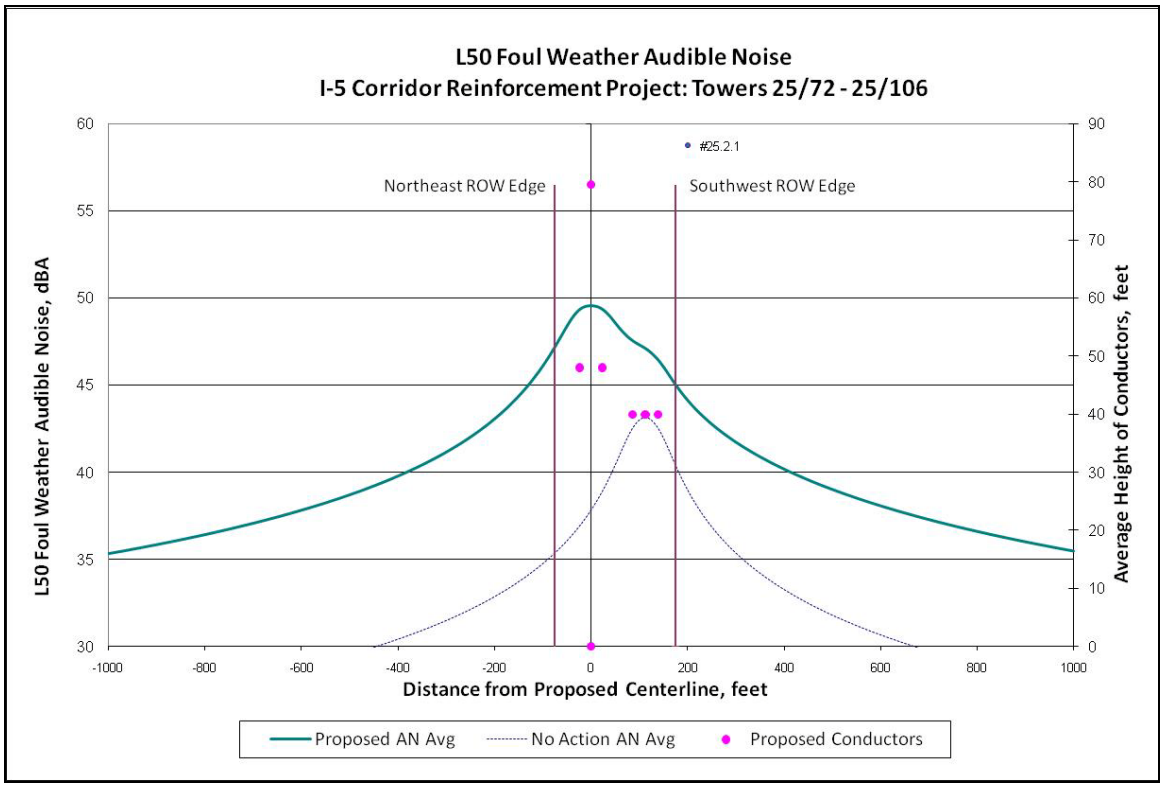


Table 18: Calculation 25.3.0

Calculation 25.3.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
25	25/106 - 25/110	0.63				

Calculation 25.3.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northwest Edge	Southeast Edge	Peak On ROW	Northwest Edge	Southeast Edge	Peak On ROW
Electric Field, kV/m	No Action	0.0	0.7	1.2	0.0	0.9	2.4
	Proposed	0.9	0.6	5.3	0.9	0.8	8.8
Magnetic Field, mG	No Action	0	5	5	1	40	52
	Proposed	6	3	35	22	25	184
Audible Noise, dBA Foul weather L50	No Action	11.7	20.0	Not Applicable			
	Proposed	45.5	43.2				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	10	10	Not Applicable			
	Proposed	36	27				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	-7	-7	Not Applicable			
	Proposed	21	8				

Figure 34: Calculation 25.3.0 – Electric Fields

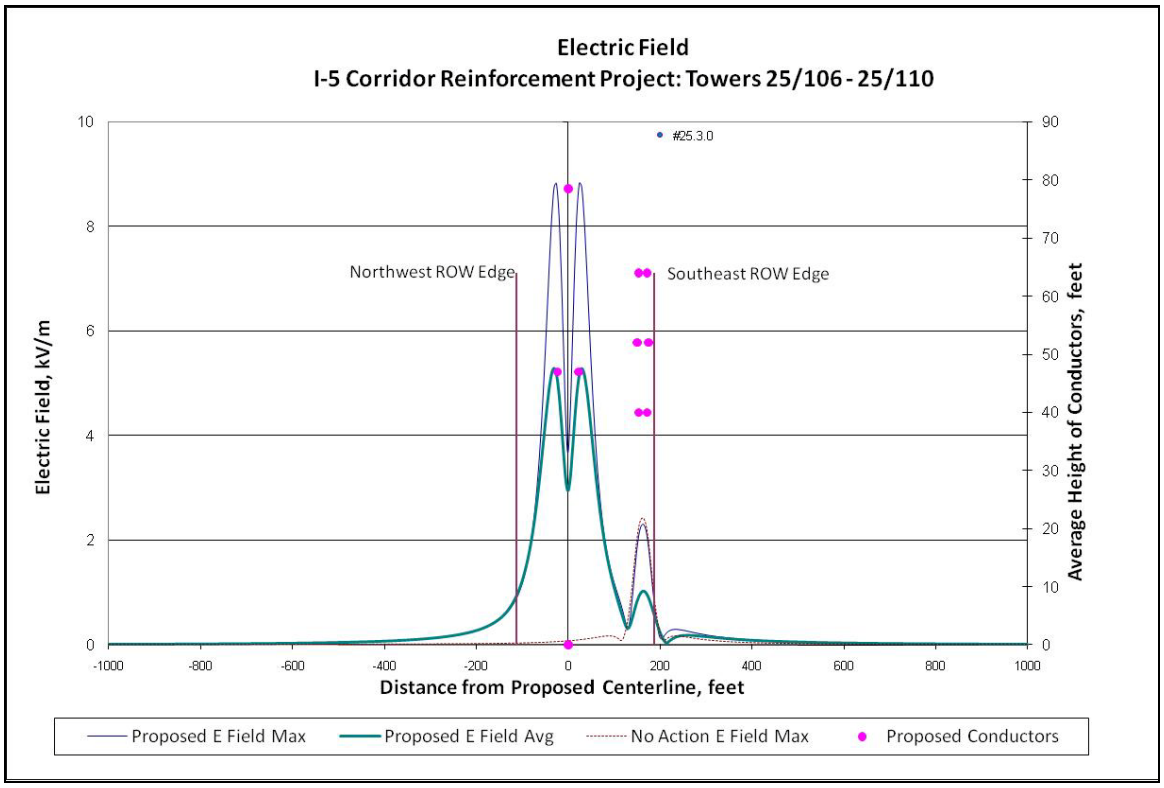


Figure 35: Calculation 25.3.0 – Magnetic Fields

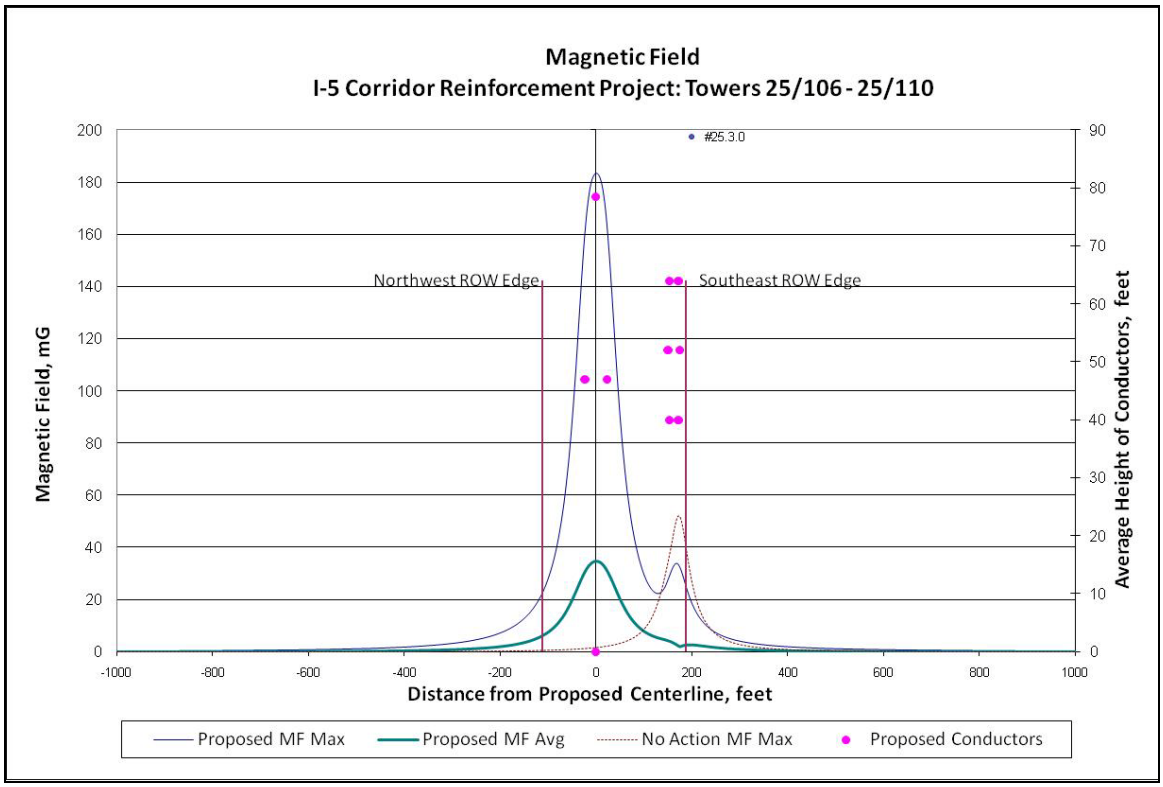


Figure 36: Calculation 25.3.0 – Audible Noise Levels

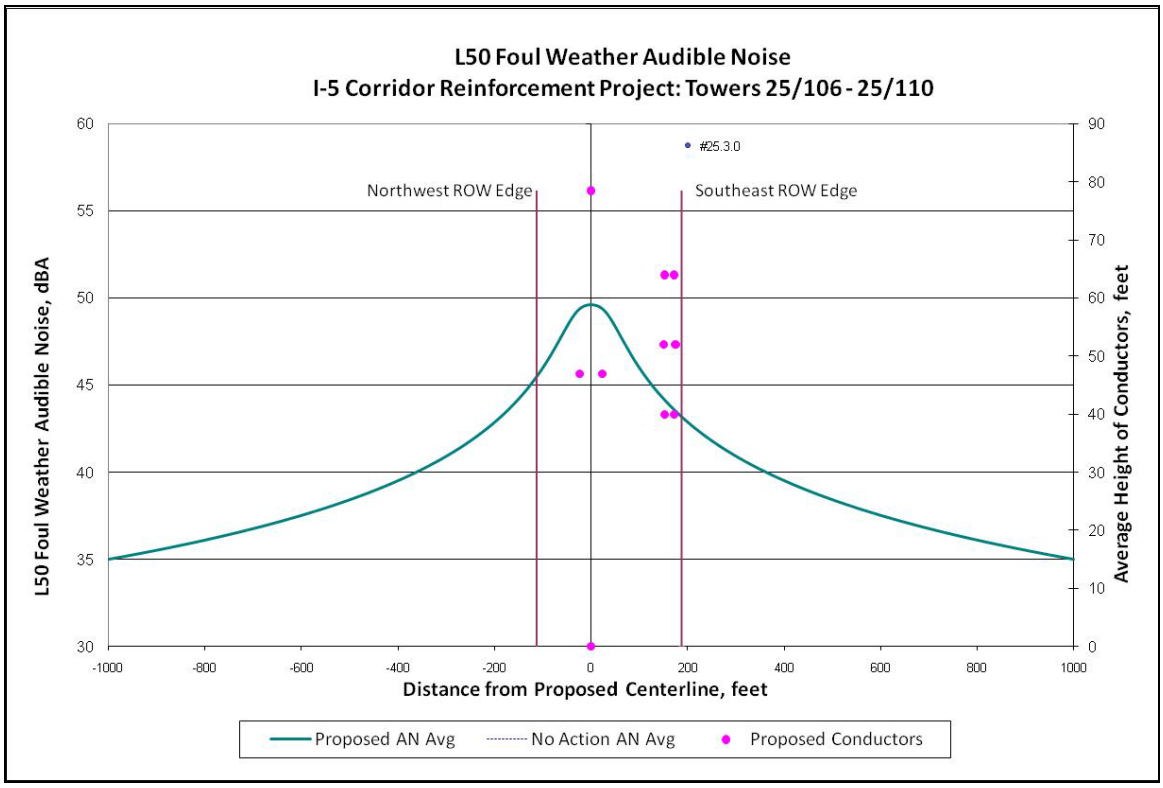


Table 19: Calculation 25.4.0

Calculation 25.4.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
25	25/110 - 25/141	5.67				

Calculation 25.4.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northwest Edge	Southeast Edge	Peak On ROW	Northwest Edge	Southeast Edge	Peak On ROW
Electric Field, kV/m	No Action	0.2	0.8	2.9	0.2	1.0	5.3
	Proposed	2.2	0.7	5.5	2.3	0.9	8.7
Magnetic Field, mG	No Action	5	5	49	9	32	136
	Proposed	14	4	32	50	22	170
Audible Noise, dBA Foul weather L50	No Action	48.4	49.3	Not Applicable			
	Proposed	50.7	51.3				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	37	30	Not Applicable			
	Proposed	36	34				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	23	14	Not Applicable			
	Proposed	21	18				

Figure 37: Calculation 25.4.0 – Electric Fields

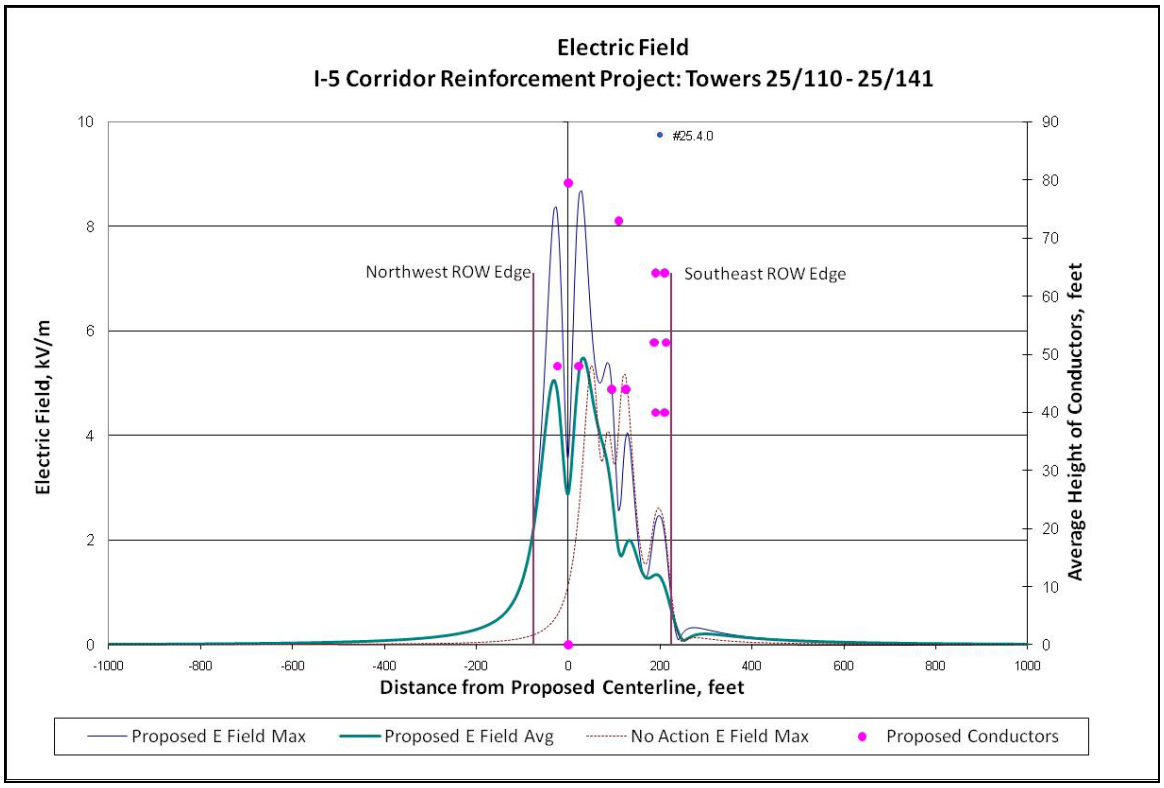


Figure 38: Calculation 25.4.0 – Magnetic Fields

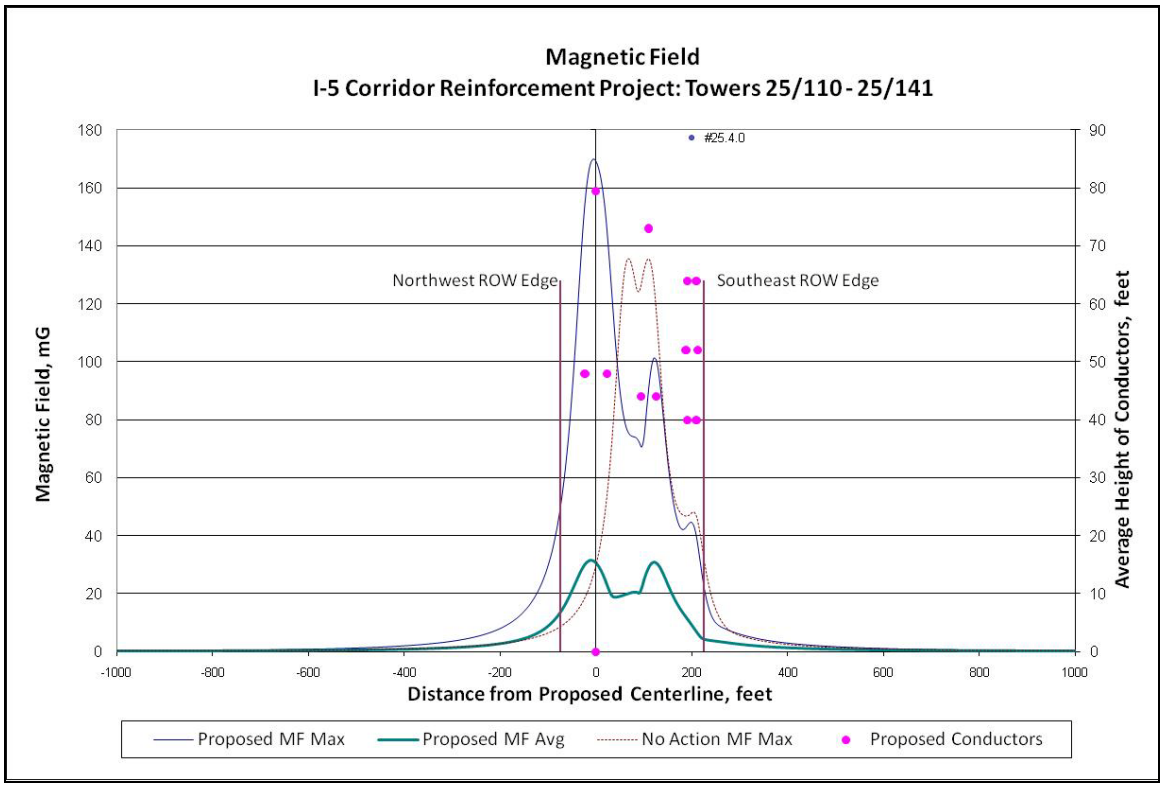


Figure 39: Calculation 25.4.0 – Audible Noise Levels

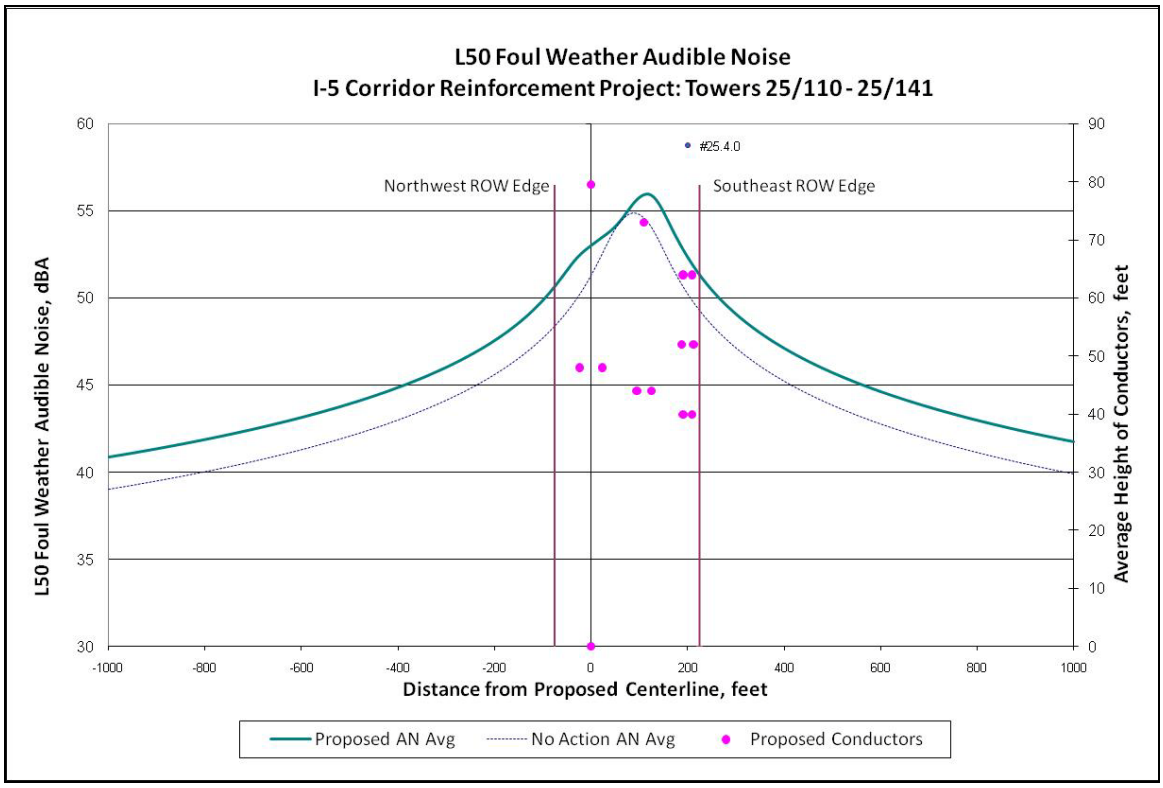


Table 20: Calculation 25.5.0

Calculation 25.5.0 : Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
25	25/141 - 25/151	1.71				
25	25/151 - 25/152	0.18				

Calculation 25.5.0 : Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northwest Edge	Southeast Edge	Peak On ROW	Northwest Edge	Southeast Edge	Peak On ROW
Electric Field, kV/m	No Action	0.3	0.6	2.9	0.2	0.9	5.4
	Proposed	2.2	0.6	5.8	2.3	0.9	8.8
Magnetic Field, mG	No Action	5	3	49	9	26	136
	Proposed	15	5	46	51	15	158
Audible Noise, dBA Foul weather L50	No Action	48.4	49.3	Not Applicable			
	Proposed	49.8	49.6				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	37	30	Not Applicable			
	Proposed	36	30				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	23	14	Not Applicable			
	Proposed	21	15				

Figure 40: Calculation 25.5.0 – Electric Fields

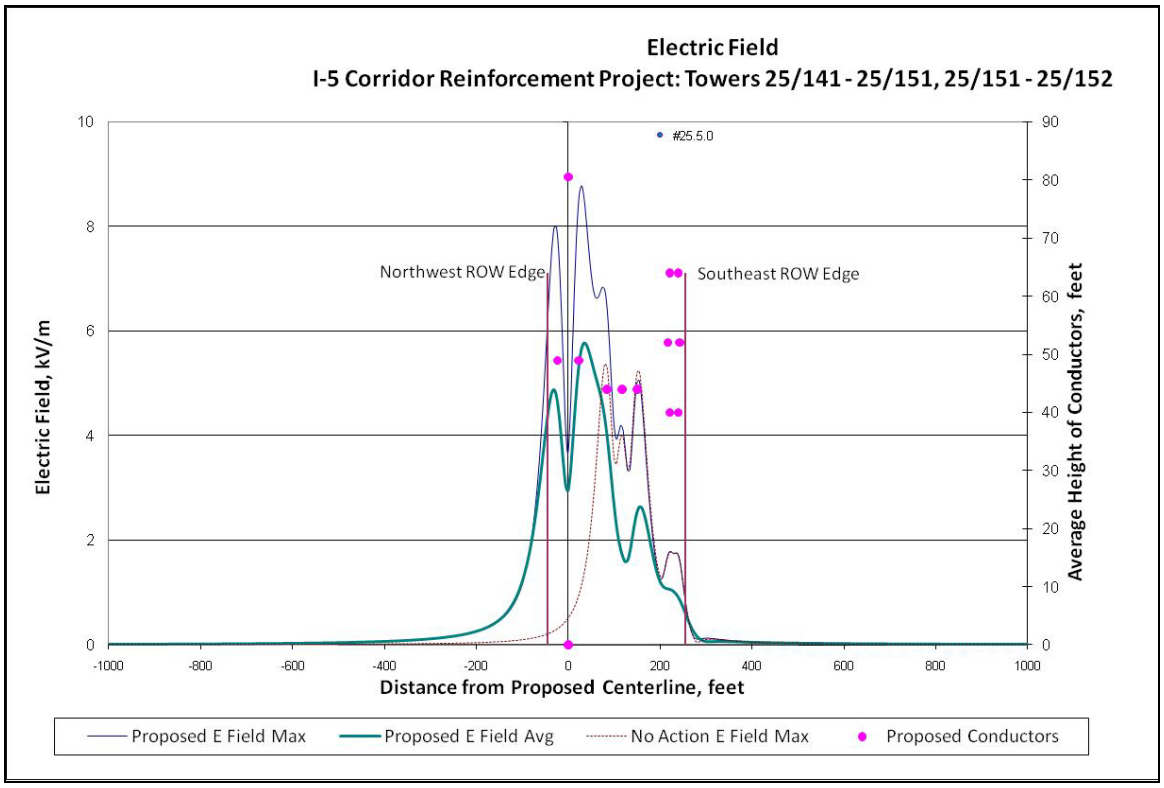


Figure 41: Calculation 25.5.0 – Magnetic Fields

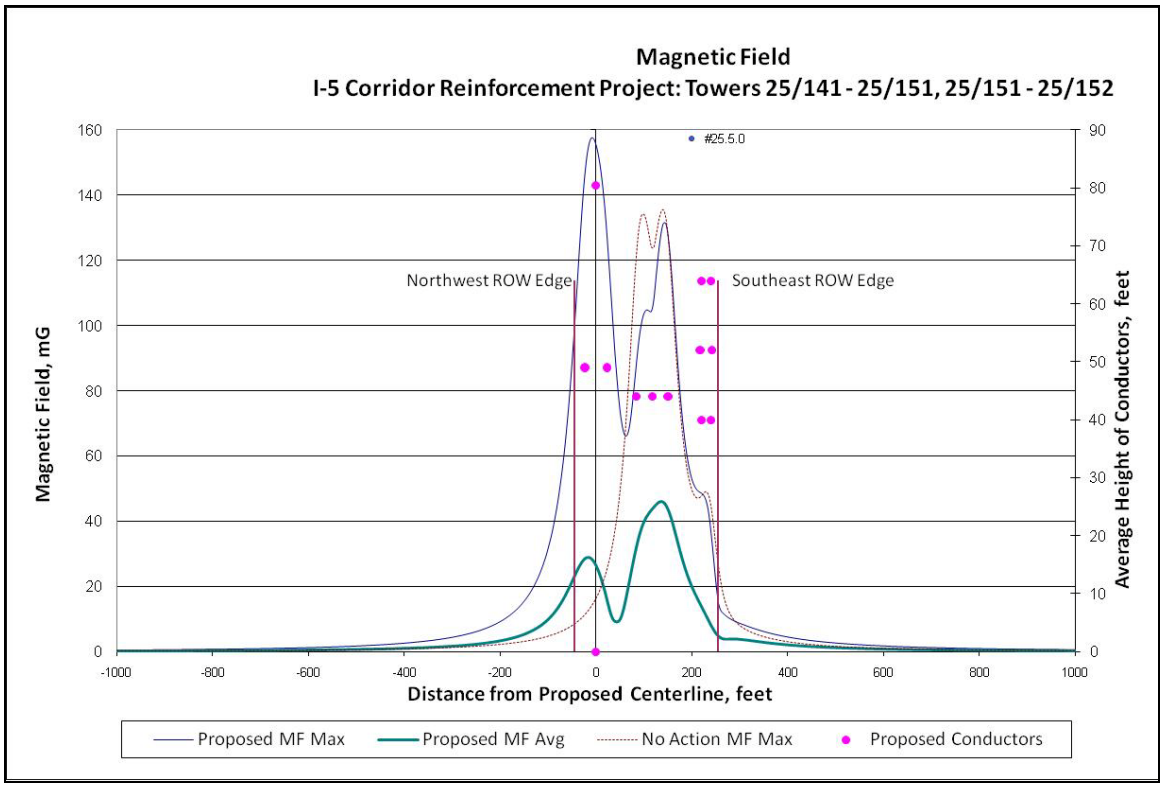


Figure 42: Calculation 25.5.0 – Audible Noise Levels

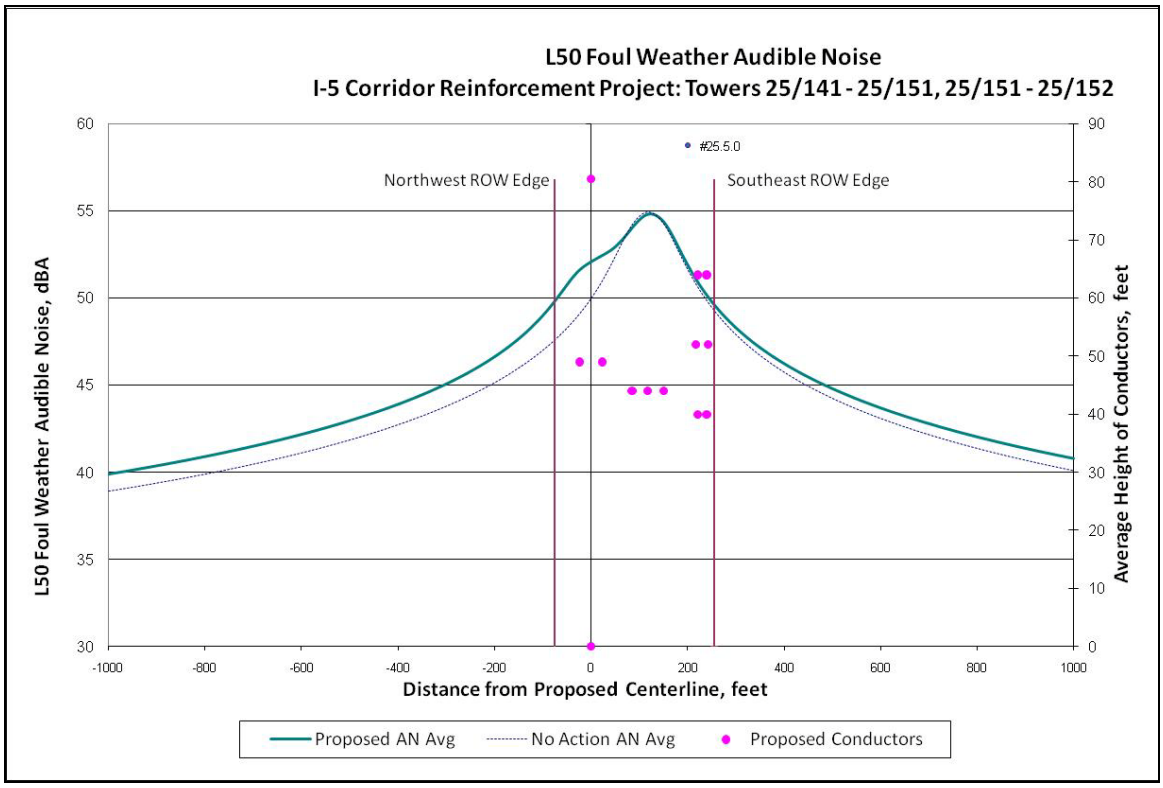


Table 21: Calculation 36A.1.0

Calculation 36A.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
36	36/1 - 36/2	0.22				
36A	36A/1 - 36A/5	0.80				

Calculation 36A.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		North Edge	South Edge	Peak On ROW	North Edge	South Edge	Peak On ROW
Electric Field, kV/m	No Action	0.3	0.6	2.9	0.2	0.9	5.4
	Proposed	2.2	0.6	5.8	2.3	0.9	8.8
Magnetic Field, mG	No Action	5	4	49	9	15	136
	Proposed	15	6	46	51	12	158
Audible Noise, dBA Foul weather L50	No Action	48.4	49.3	Not Applicable			
	Proposed	49.8	49.6				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	37	30	Not Applicable			
	Proposed	36	30				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	23	14	Not Applicable			
	Proposed	21	15				

Figure 43: Calculation 36A.1.0 – Electric Fields

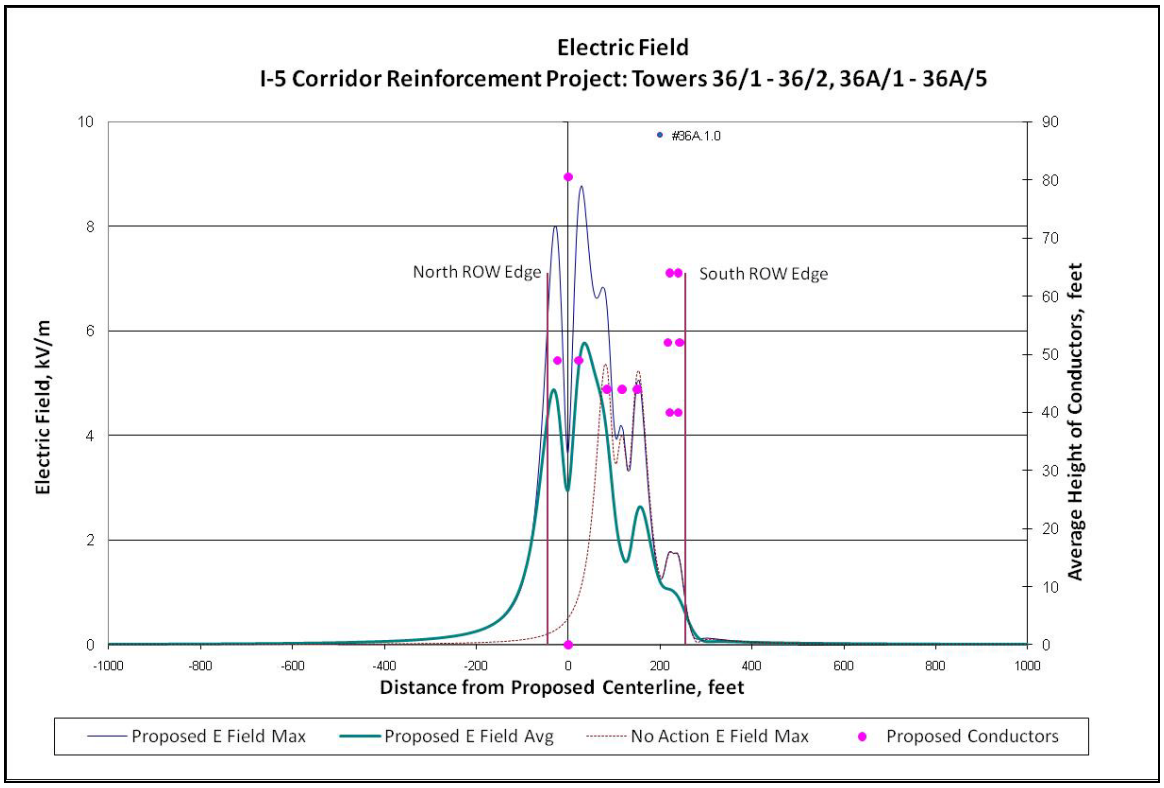


Figure 44: Calculation 36A.1.0 – Magnetic Fields

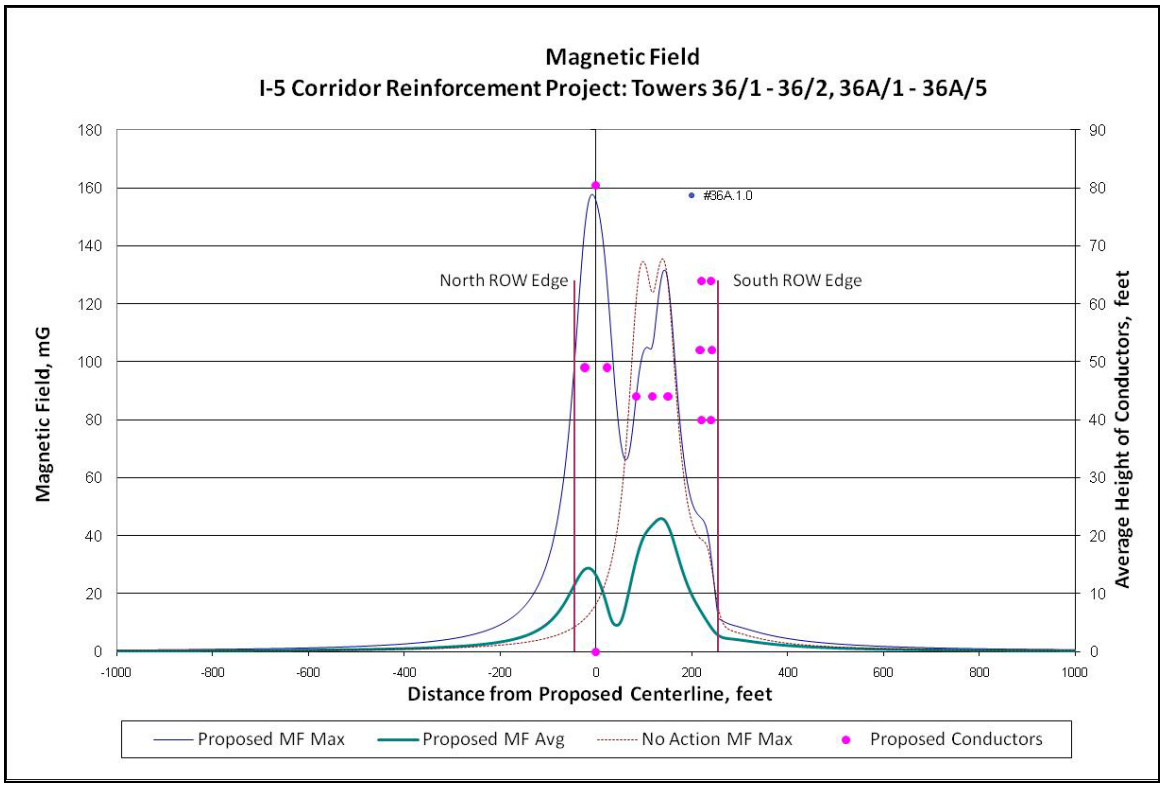


Figure 45: Calculation 36A.1.0 – Audible Noise Levels

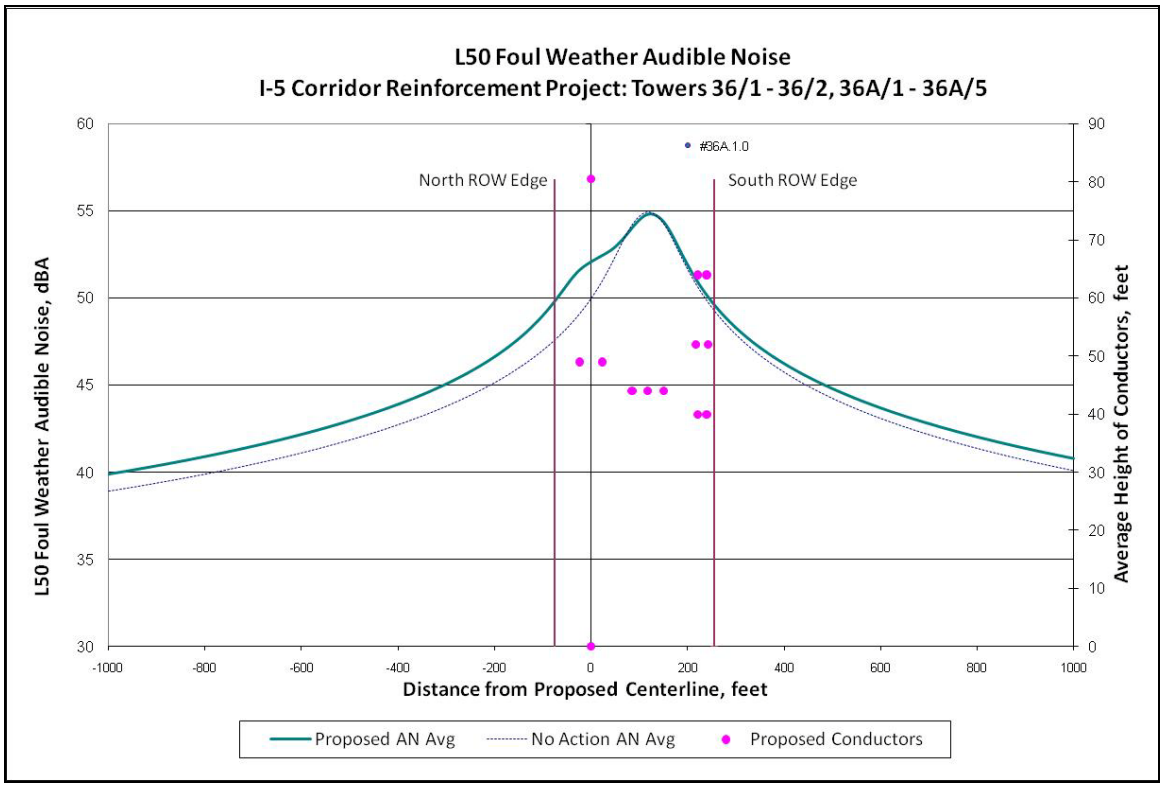


Table 22: Calculation 36A.2.0

Calculation 36A.2.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
36A	36A/5 - 36A/6	0.23				
37	37/1 - 37/2	0.21				

Calculation 36A.2.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		North Edge	South Edge	Peak On ROW	North Edge	South Edge	Peak On ROW
Electric Field, kV/m	No Action	0.3	0.6	2.9	0.2	0.9	5.4
	Proposed	2.2	0.6	5.5	2.3	0.9	8.7
Magnetic Field, mG	No Action	5	4	49	9	15	136
	Proposed	13	4	32	50	15	170
Audible Noise, dBA Foul weather L50	No Action	48.4	49.3	Not Applicable			
	Proposed	50.7	51.3				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	37	30	Not Applicable			
	Proposed	36	34				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	23	14	Not Applicable			
	Proposed	21	18				

Figure 46: Calculation 36A.2.0 – Electric Fields

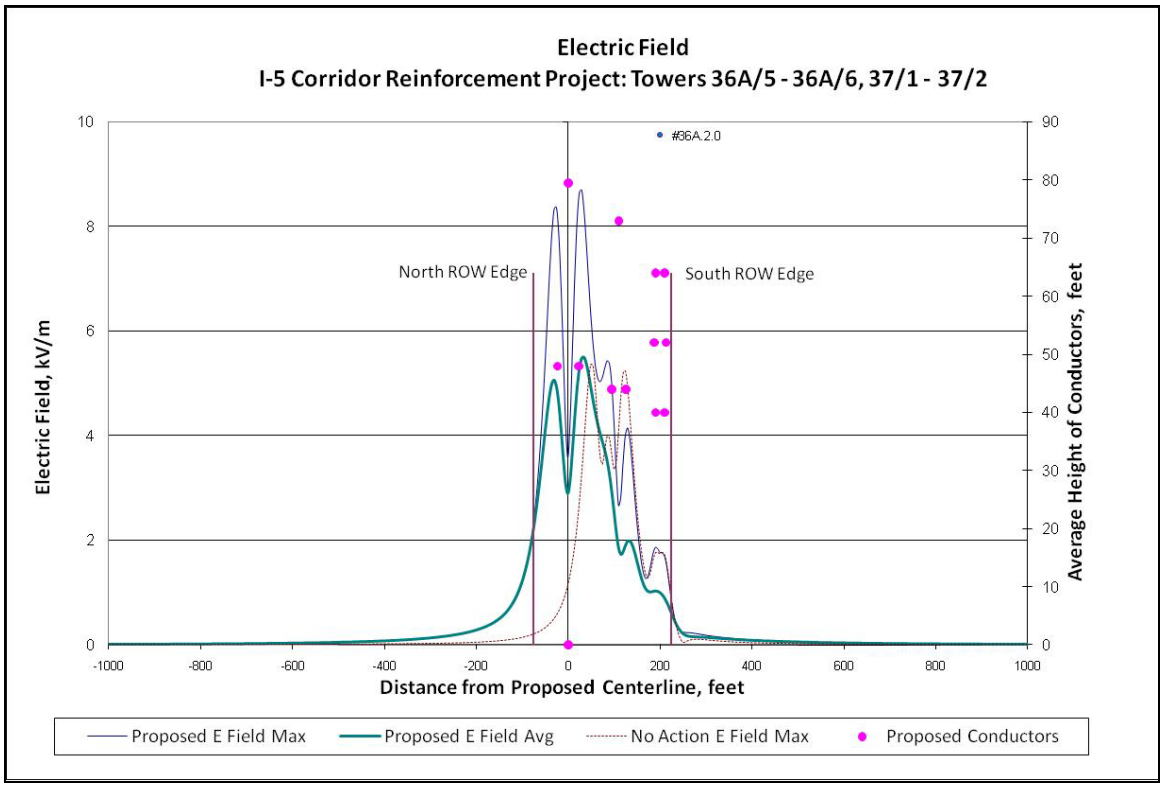


Figure 47: Calculation 36A.2.0 – Magnetic Fields

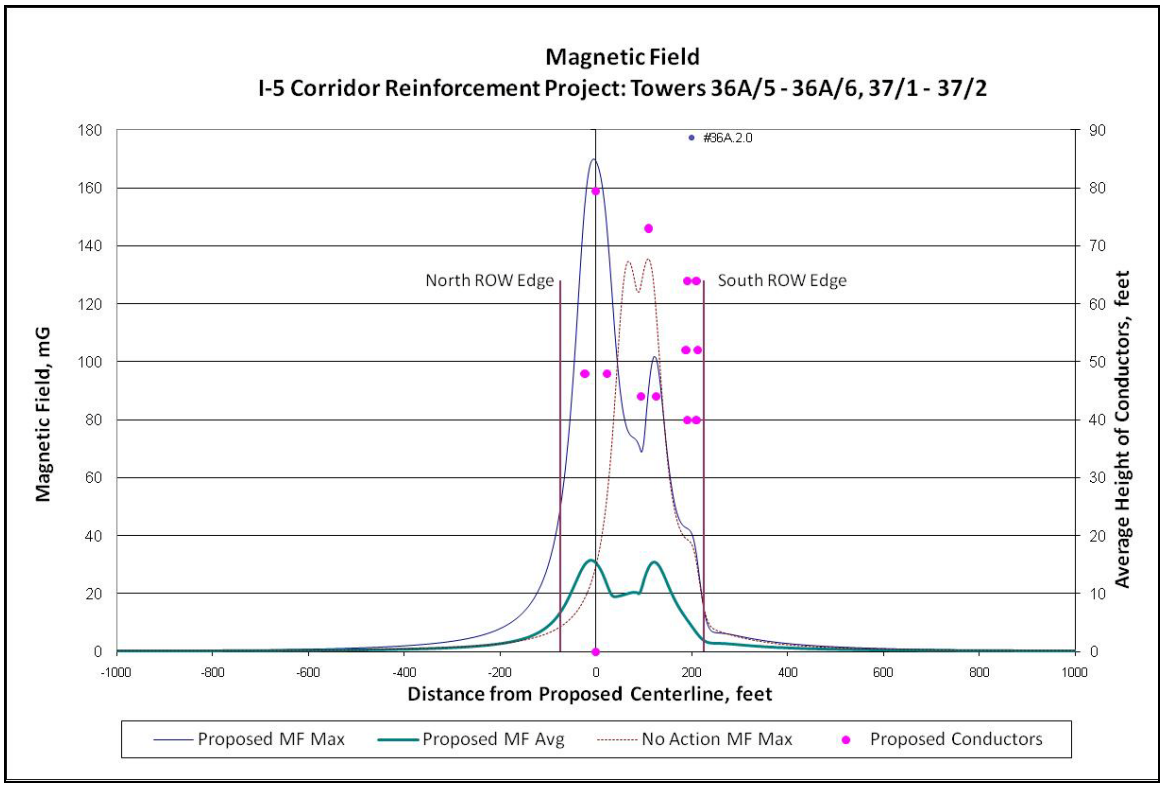


Figure 48: Calculation 36A.2.0 – Audible Noise Levels

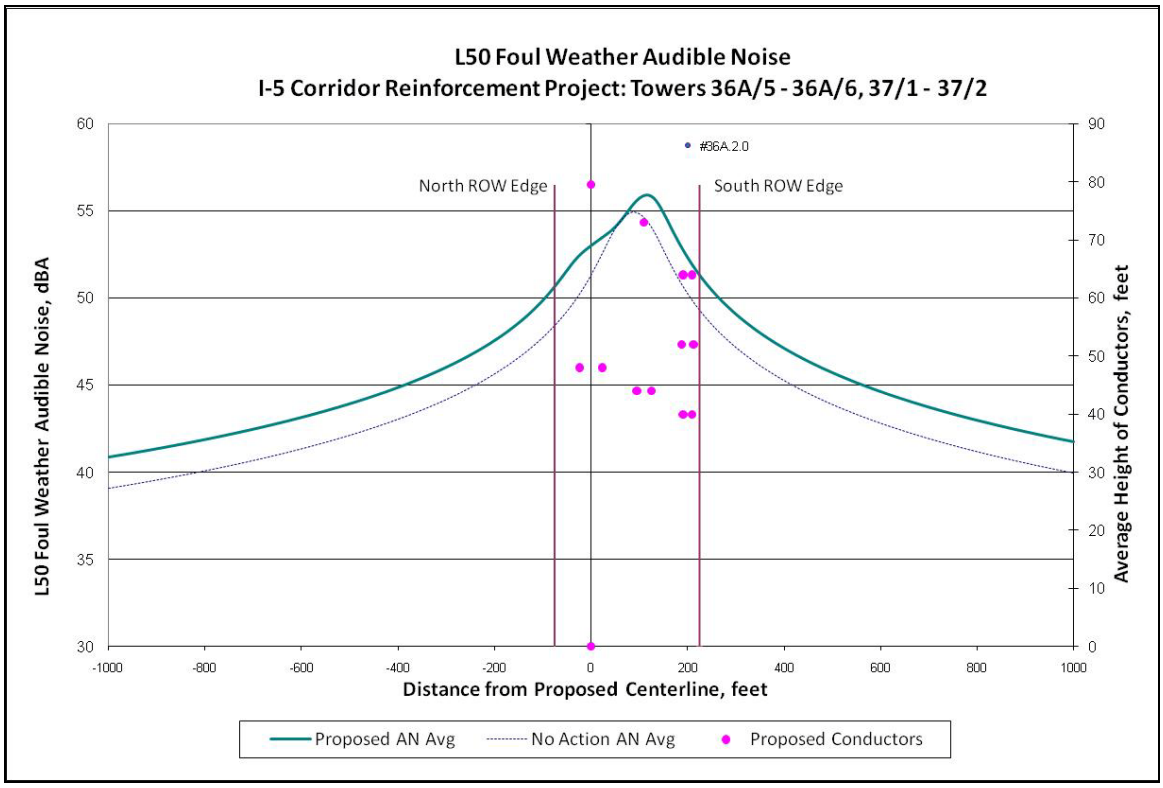


Table 23: Calculation 36B.1.0

Calculation 36B.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
36B	36B/2 - 36B/7	1.04				

Calculation 36B.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		North Edge	South Edge	Peak On ROW	North Edge	South Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.0	2.9	0.0	0.1	5.4
	Proposed	0.1	0.5	5.3	0.1	0.5	8.9
Magnetic Field, mG	No Action	2	1	49	4	2	136
	Proposed	3	5	46	5	14	181
Audible Noise, dBA Foul weather L50	No Action	46.6	44.5	Not Applicable			
	Proposed	47.2	47.3				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	37	30	Not Applicable			
	Proposed	37	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	23	14	Not Applicable			
	Proposed	23	21				

Figure 49: Calculation 36B.1.0 – Electric Fields

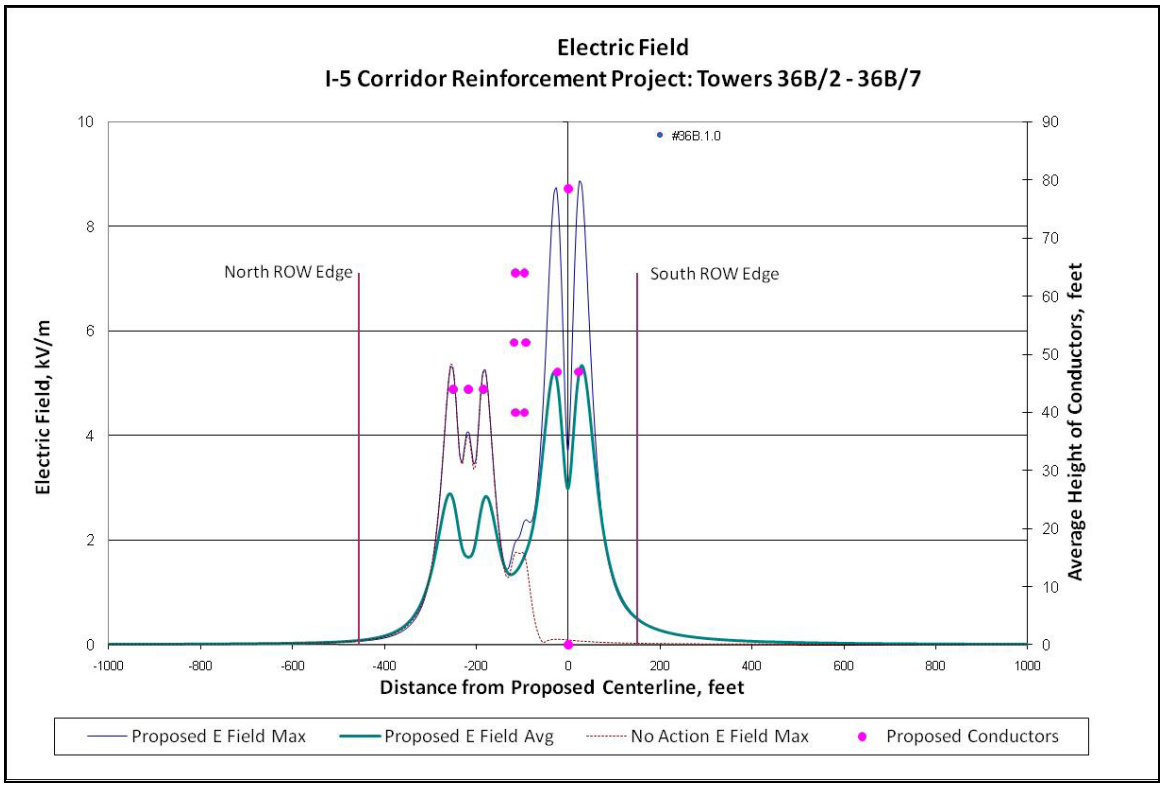


Figure 50: Calculation 36B.1.0 – Magnetic Fields

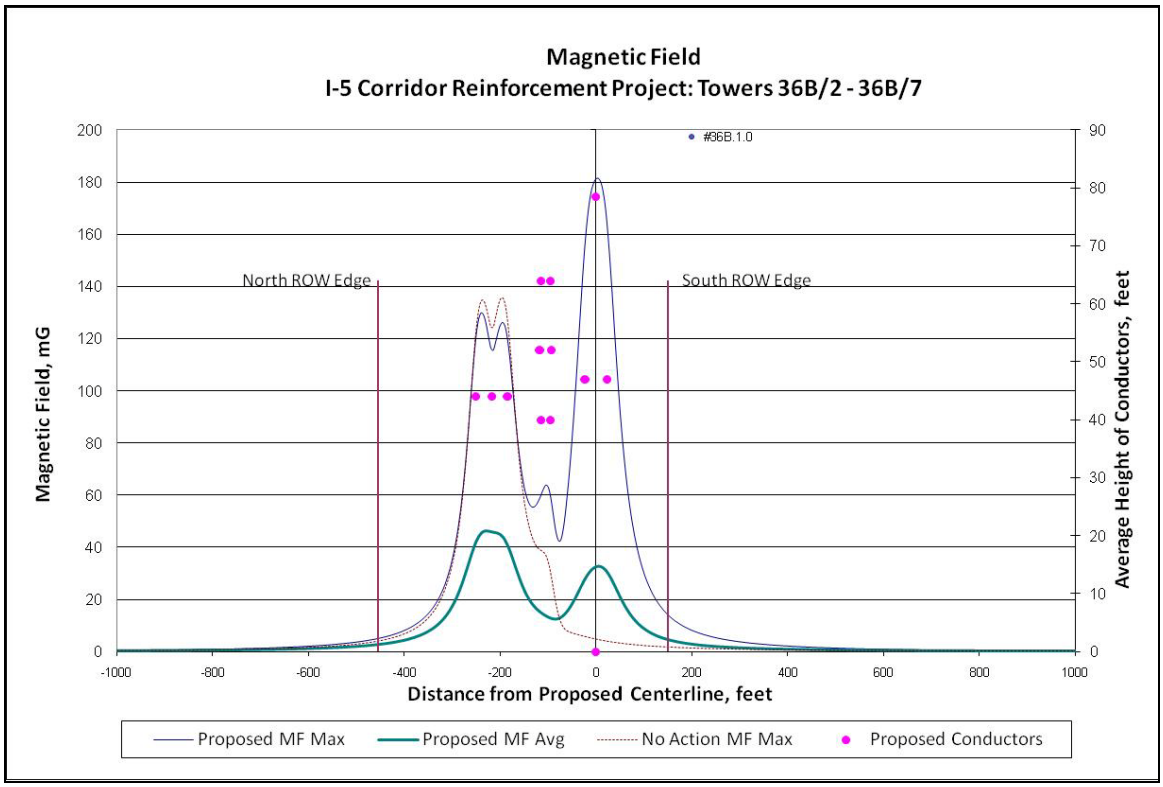


Figure 51: Calculation 36B.1.0 – Audible Noise Levels

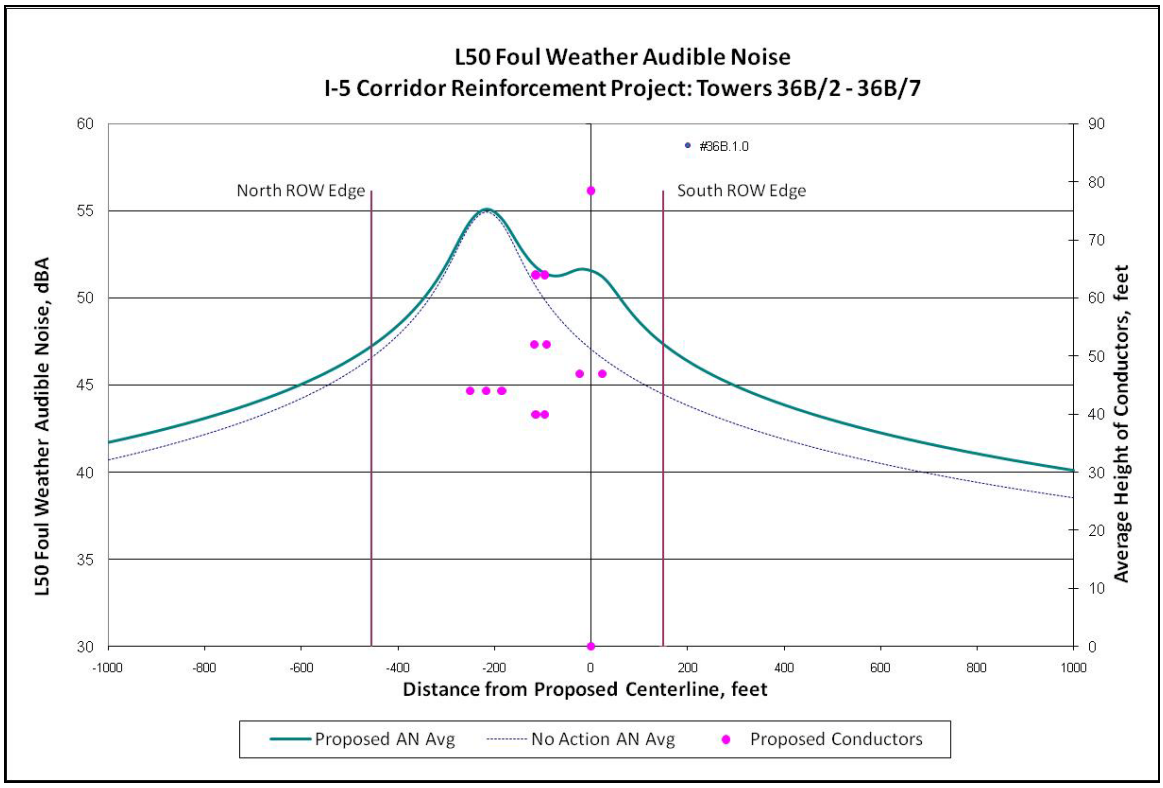


Table 24: Calculation 37.2.0

Calculation 37.2.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
37	37/2 - 37/4	0.46		39	39/1 - 39/20	4.05
38	38/1 - 38/5	0.66				

Calculation 37.2.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		North Edge	South Edge	Peak On ROW	North Edge	South Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	1.1	2.9	0.1	1.1	5.3
	Proposed	1.4	1.0	5.7	1.3	1.0	8.8
Magnetic Field, mG	No Action	3	16	49	5	30	136
	Proposed	11	17	46	35	36	158
Audible Noise, dBA Foul weather L50	No Action	47.1	51.3	Not Applicable			
	Proposed	49.1	51.5				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	37	37	Not Applicable			
	Proposed	36	38				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	23	23	Not Applicable			
	Proposed	21	24				

Figure 52: Calculation 37.2.0 – Electric Fields

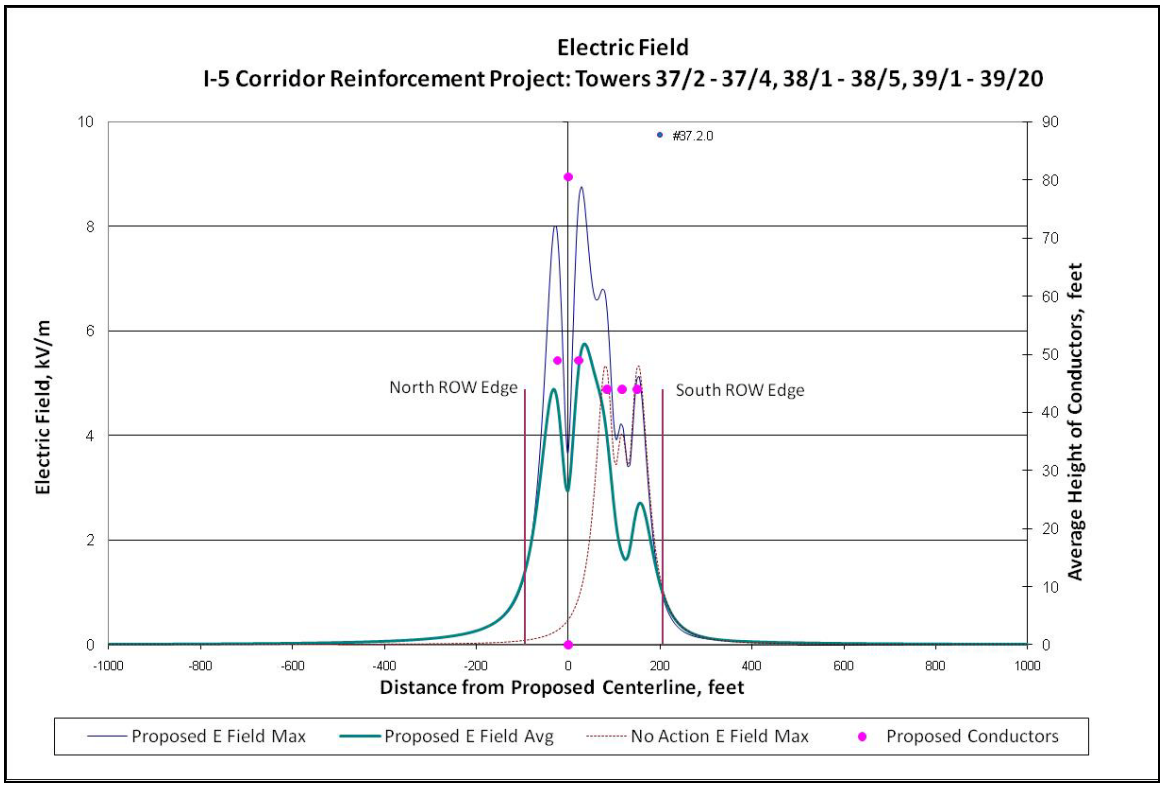


Figure 53: Calculation 37.2.0 – Magnetic Fields

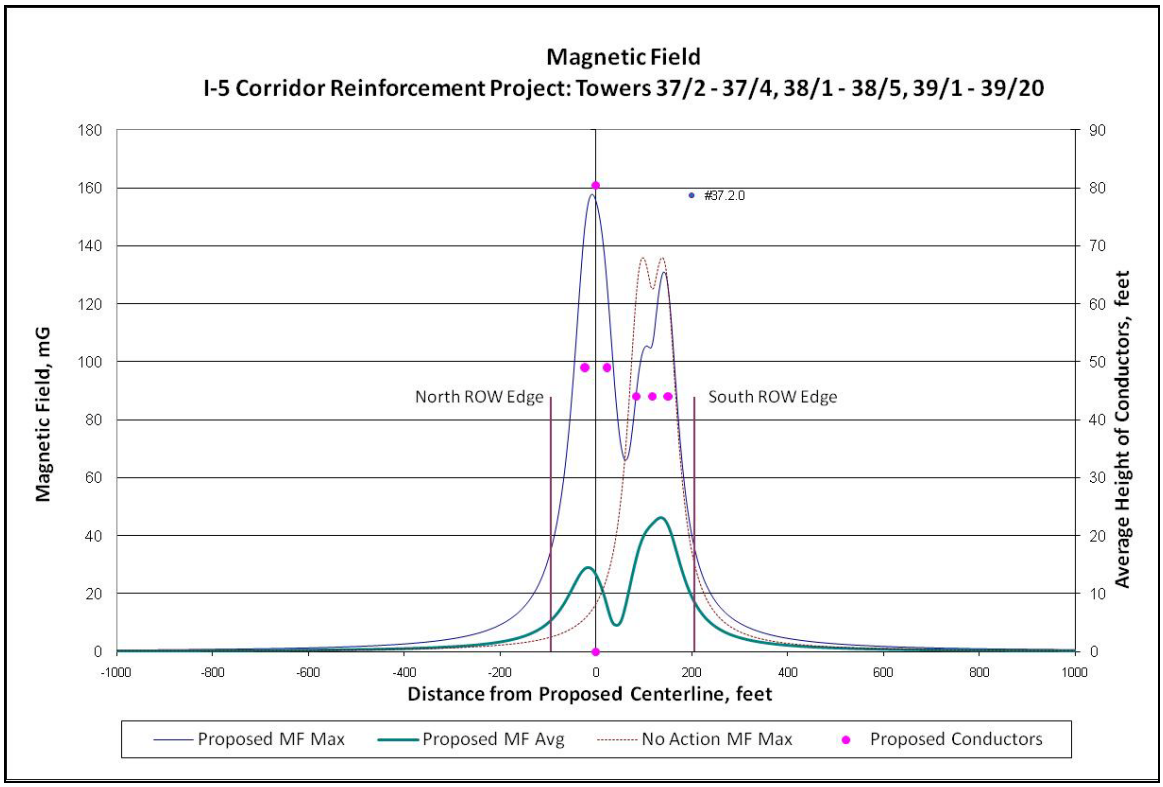


Figure 54: Calculation 37.2.0 – Audible Noise Levels

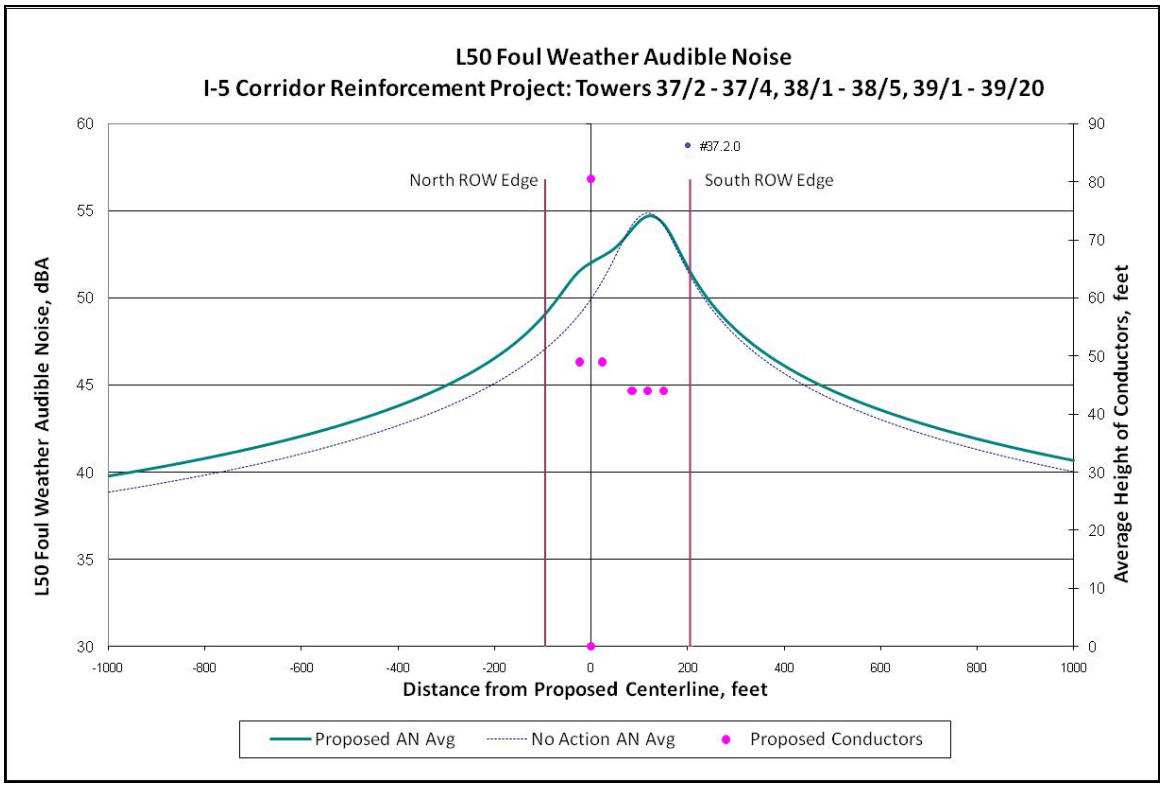


Table 25: Calculation 39.2.0

Calculation 39.2.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
39	39/20 - 39/23	0.62				

Calculation 39.2.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		North Edge	South Edge	Peak On ROW	North Edge	South Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.1	2.9	0.1	0.1	5.3
	Proposed	0.1	2.2	5.7	0.1	2.3	8.8
Magnetic Field, mG	No Action	3	4	49	5	6	136
	Proposed	4	15	46	7	51	158
Audible Noise, dBA Foul weather L50	No Action	47.1	47.6	Not Applicable			
	Proposed	47.5	49.8				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	37	37	Not Applicable			
	Proposed	38	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	23	23	Not Applicable			
	Proposed	24	21				

Figure 55: Calculation 39.2.0 – Electric Fields

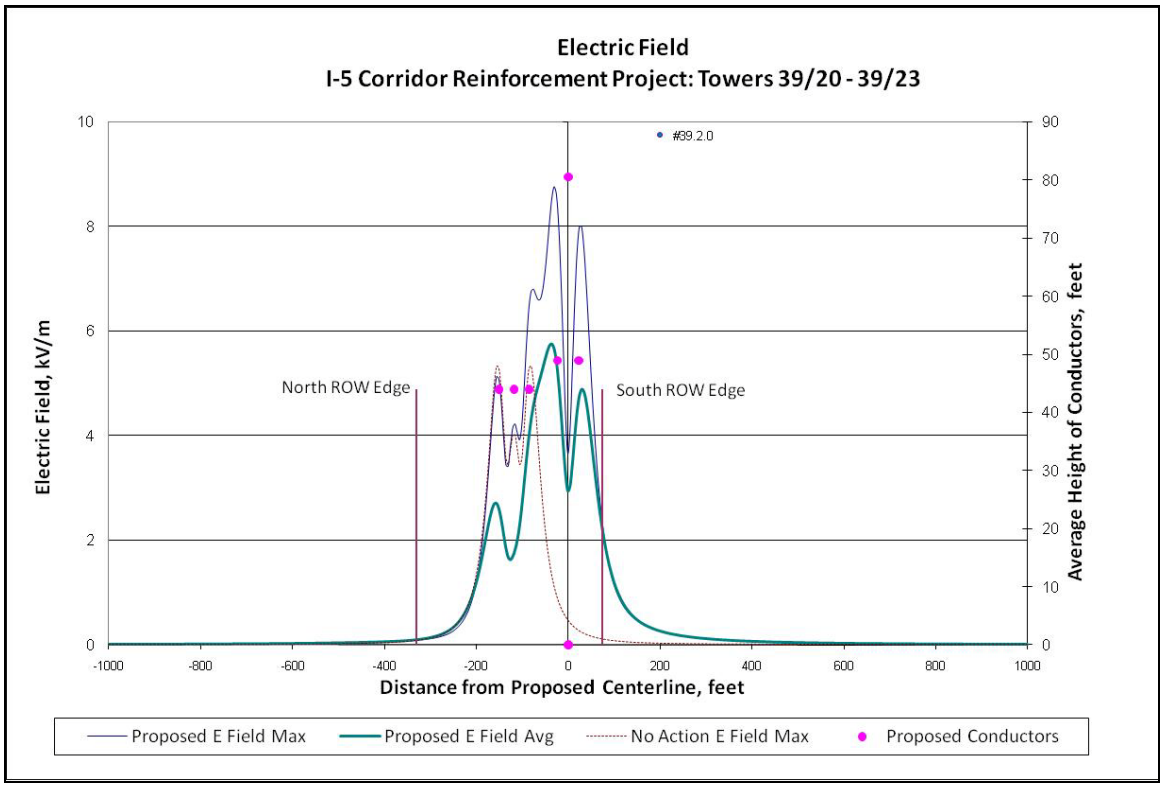


Figure 56: Calculation 39.2.0 – Magnetic Fields

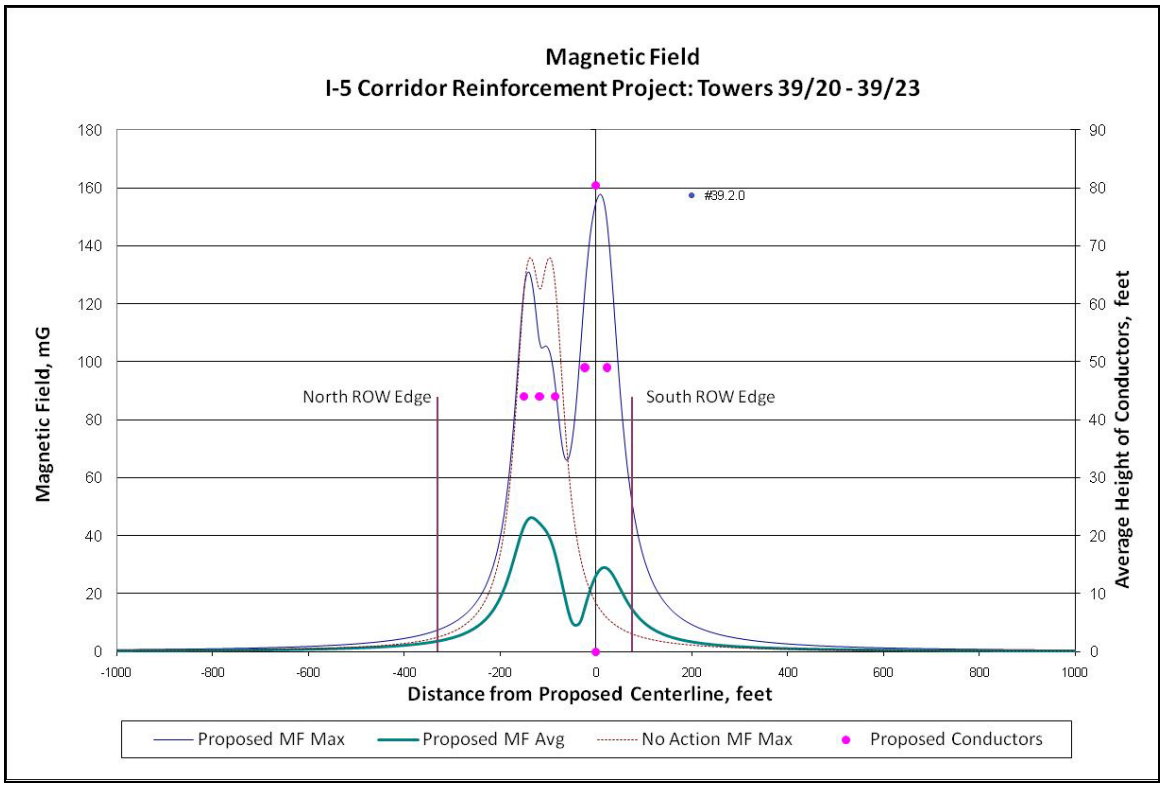


Figure 57: Calculation 39.2.0 – Audible Noise Levels

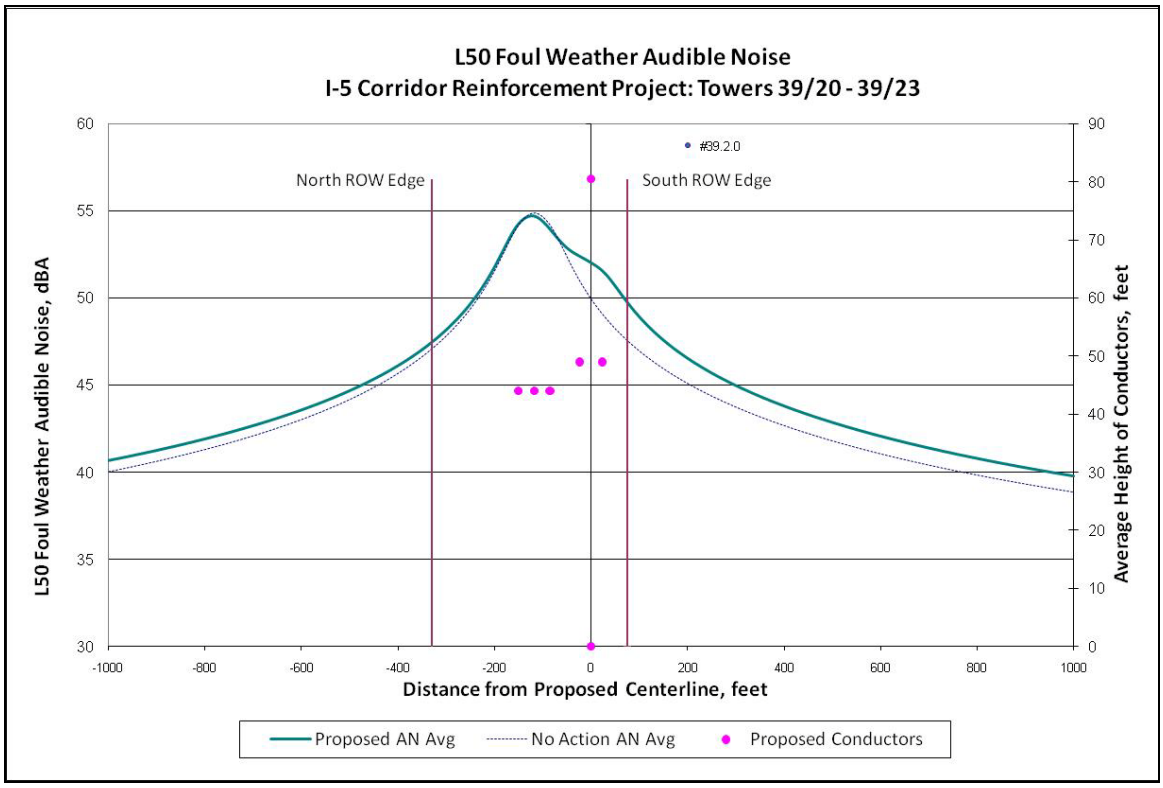


Table 26: Calculation 39.3.0

Calculation 39.3.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
39	39/23 - 39/27	0.68				

Calculation 39.3.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		North Edge	South Edge	Peak On ROW	North Edge	South Edge	Peak On ROW
Electric Field, kV/m	No Action	1.2	0.1	2.9	0.1	1.2	5.4
	Proposed	1.2	2.3	5.4	1.2	2.4	8.9
Magnetic Field, mG	No Action	16	2	51	31	6	142
	Proposed	16	13	49	32	49	174
Audible Noise, dBA Foul weather L50	No Action	51.4	45.6	Not Applicable			
	Proposed	51.7	49.5				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	37	29	Not Applicable			
	Proposed	37	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	23	12	Not Applicable			
	Proposed	23	21				

Figure 58: Calculation 39.3.0 – Electric Fields

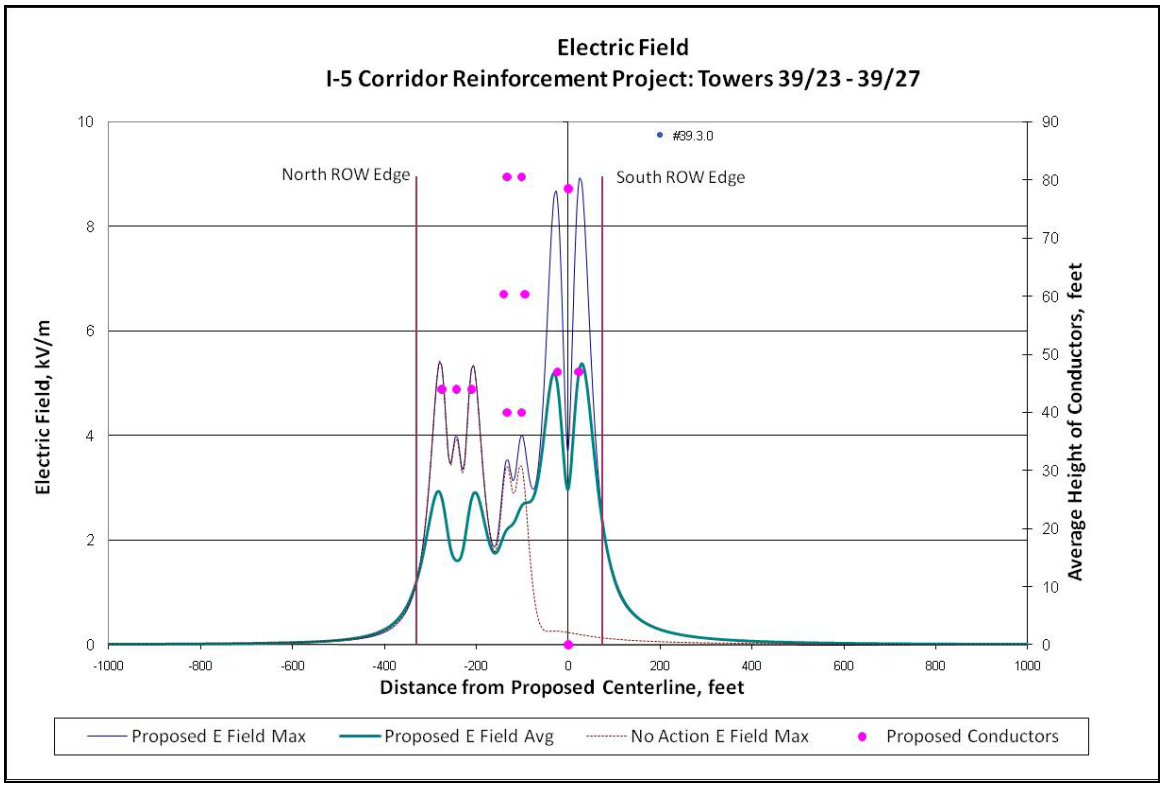


Figure 59: Calculation 39.3.0 – Magnetic Fields

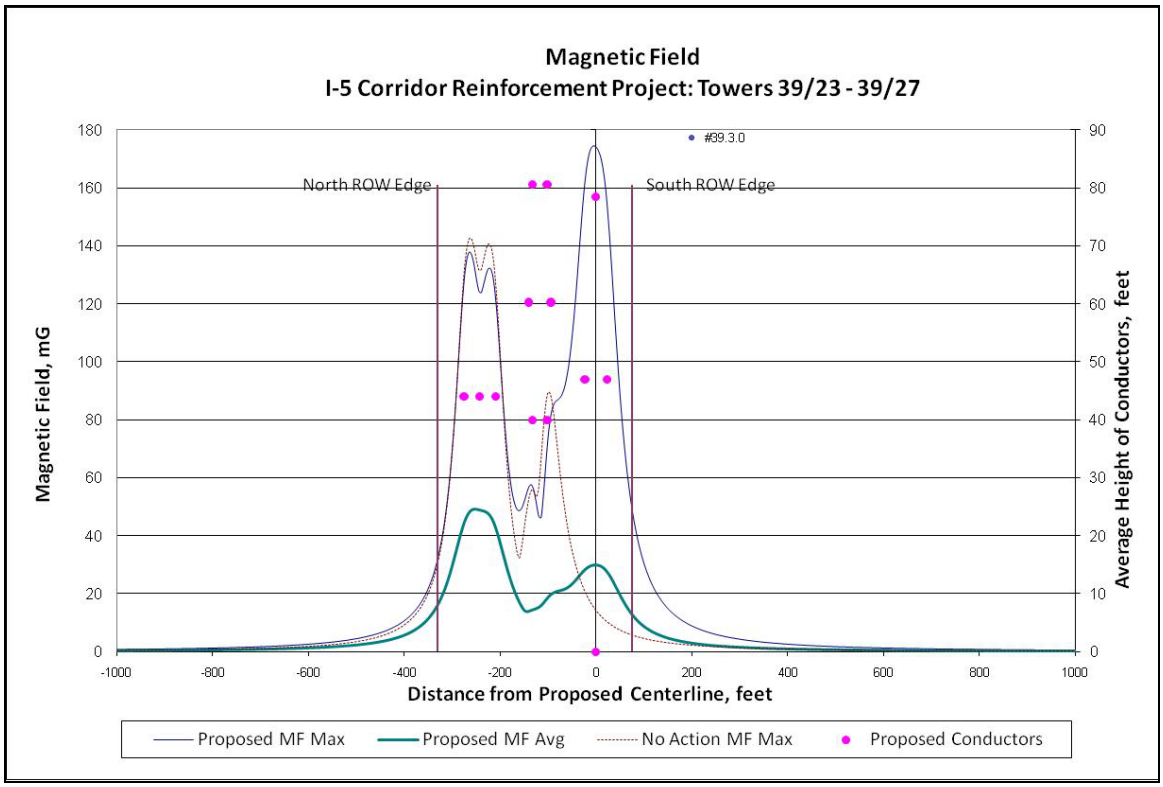


Figure 60: Calculation 39.3.0 – Audible Noise Levels

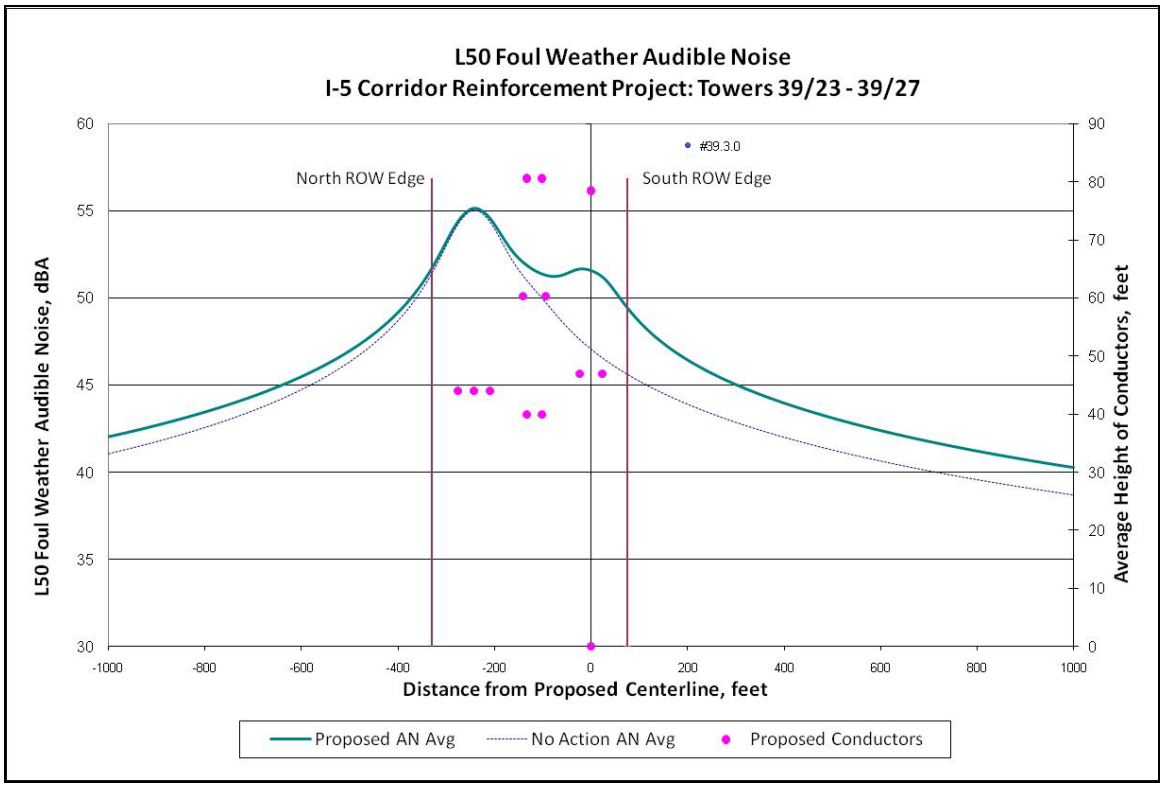


Table 27: Calculation 40.1.0

Calculation 40.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
40	40/11 - 40/14	0.68		47	47/1 - 47/4	
43	43/9 - 43/10			48	48/1 - 48/14	
46	46/1 - 46/3					

Calculation 40.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		North Edge	South Edge	Peak On ROW	North Edge	South Edge	Peak On ROW
Electric Field, kV/m	No Action	0.6	0.6	2.3	0.5	0.5	4.0
	Proposed	0.5	0.8	5.6	0.4	0.8	8.9
Magnetic Field, mG	No Action	4	3	19	13	13	94
	Proposed	6	13	28	19	50	139
Audible Noise, dBA Foul weather L50	No Action	39.8	39.8	Not Applicable			
	Proposed	43.8	47.1				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	26	26	Not Applicable			
	Proposed	30	40				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	13	13	Not Applicable			
	Proposed	14	20				

Figure 61: Calculation 40.1.0 – Electric Fields

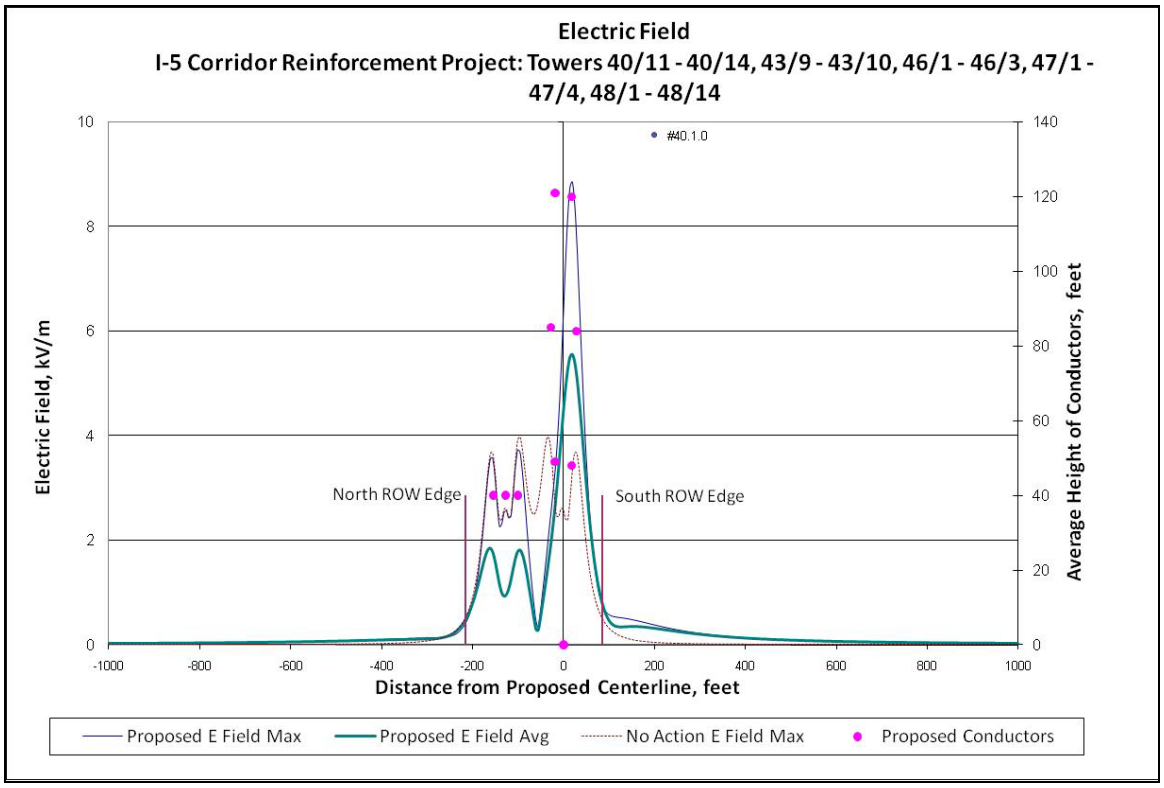


Figure 62: Calculation 40.1.0 – Magnetic Fields

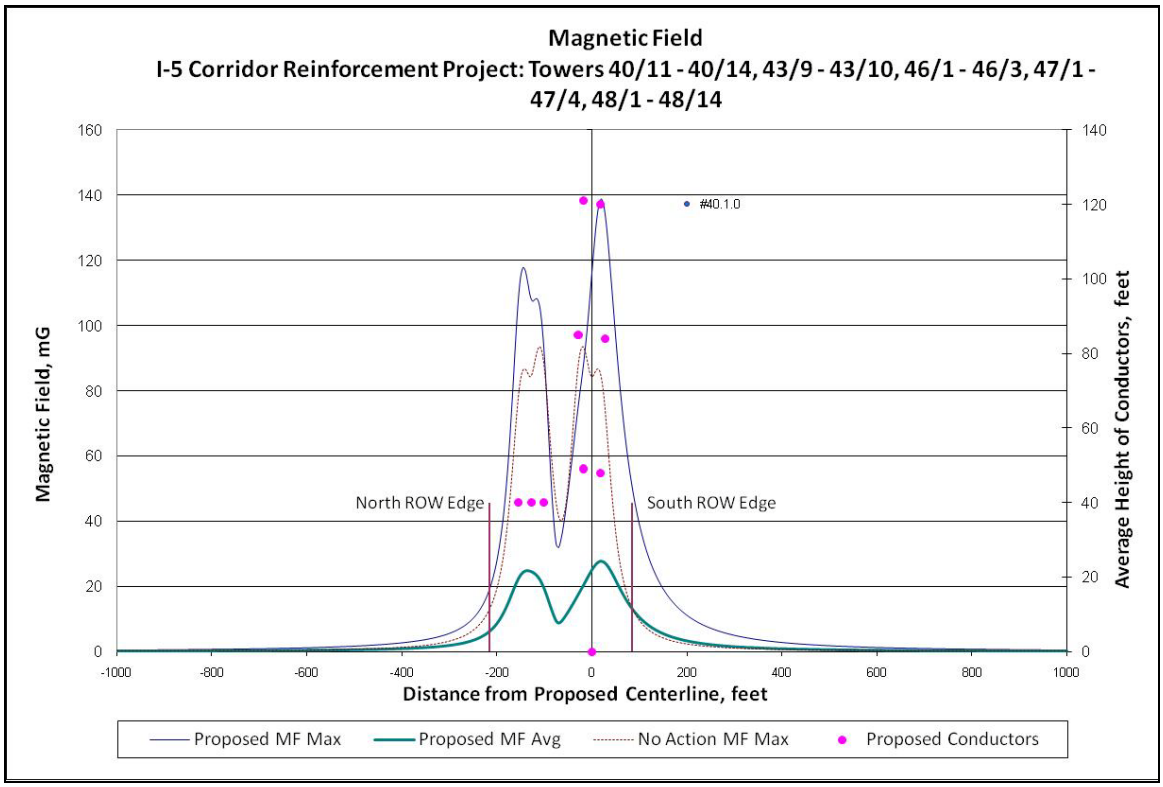


Figure 63: Calculation 40.1.0 – Audible Noise Levels

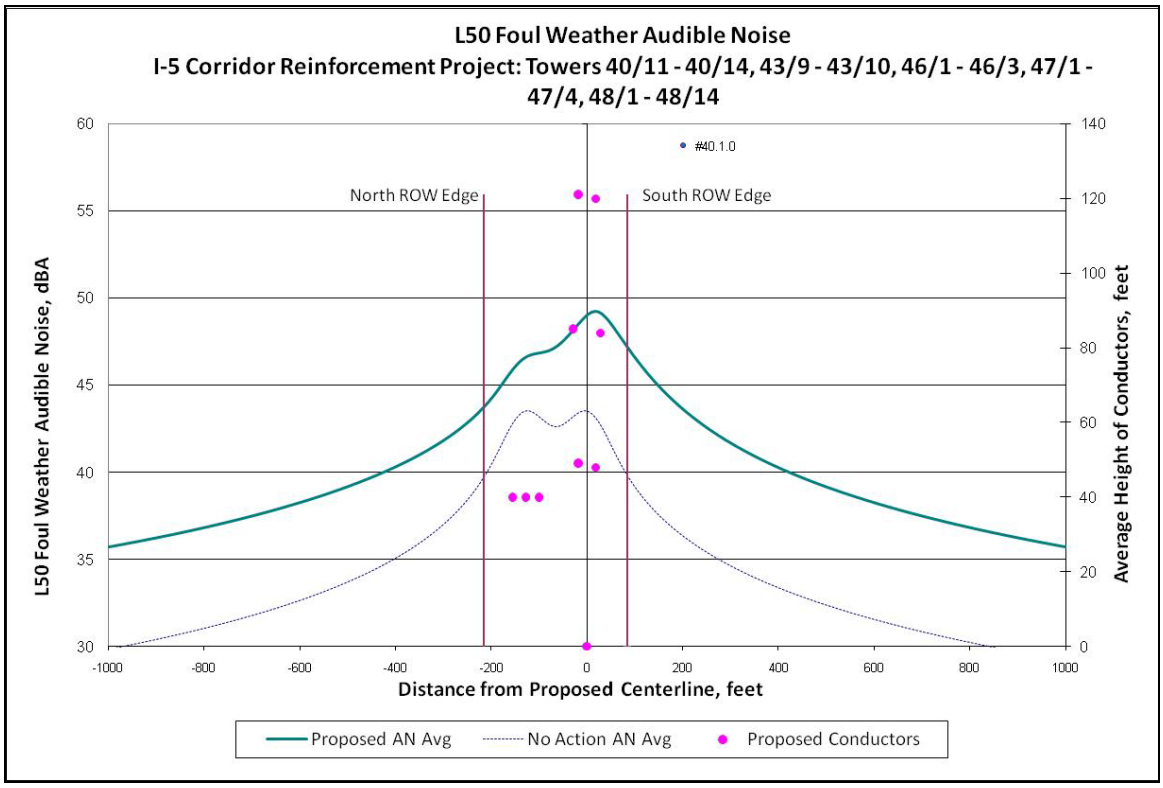


Table 28: Calculation 41.1.0

Calculation 41.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
41	41/1 - 41/2	0.14		45	45/1 - 45/3	0.35
41	41/2 - 41/8	1.13		50	50/13 - 50/21	1.16

Calculation 41.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		Northeast Edge	Southwest Edge	Peak On ROW	Northeast Edge	Southwest Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.1	0.8	0.1	0.1	1.6
	Proposed	0.1	1.3	5.6	0.4	1.2	8.8
Magnetic Field, mG	No Action	1	1	3	4	6	35
	Proposed	8	14	25	31	55	130
Audible Noise, dBA Foul weather L50	No Action	18.4	18.4	Not Applicable			
	Proposed	45.5	47.2				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	10	10	Not Applicable			
	Proposed	35	40				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	-7	-7	Not Applicable			
	Proposed	16	20				

Figure 64: Calculation 41.1.0 – Electric Fields

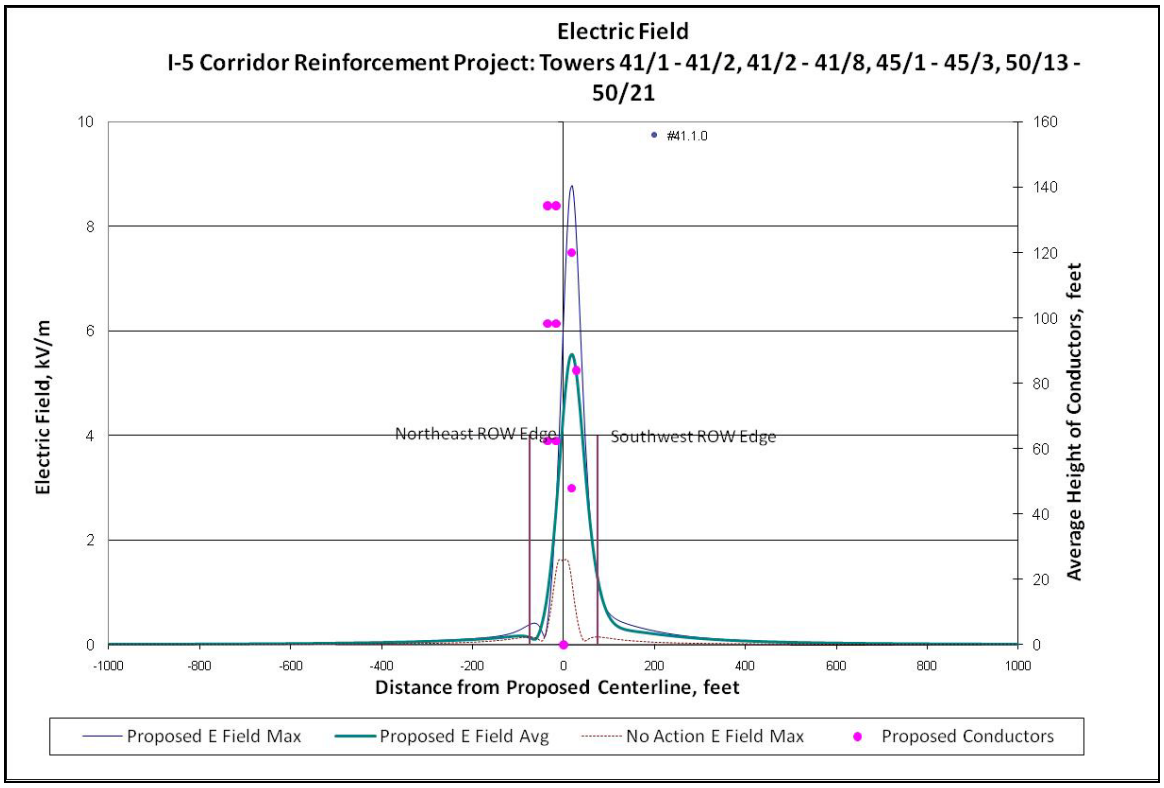


Figure 65: Calculation 41.1.0 – Magnetic Fields

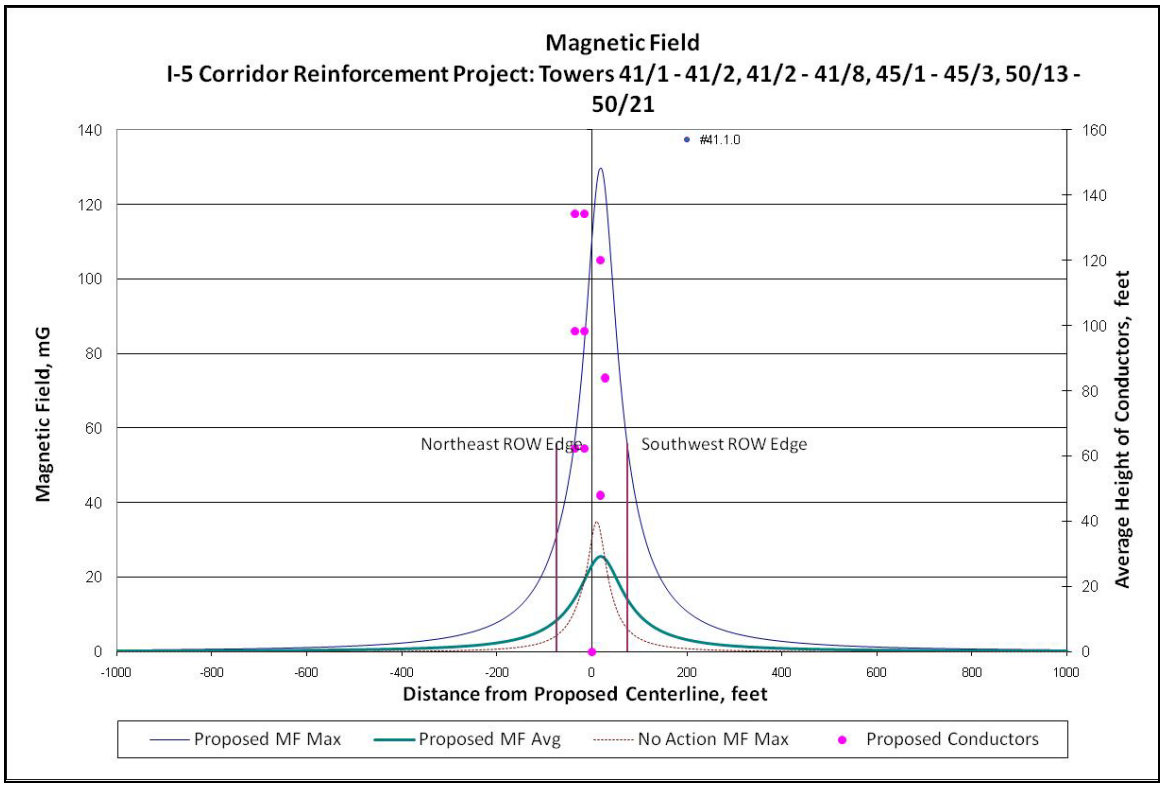


Figure 66: Calculation 41.1.0 – Audible Noise Levels

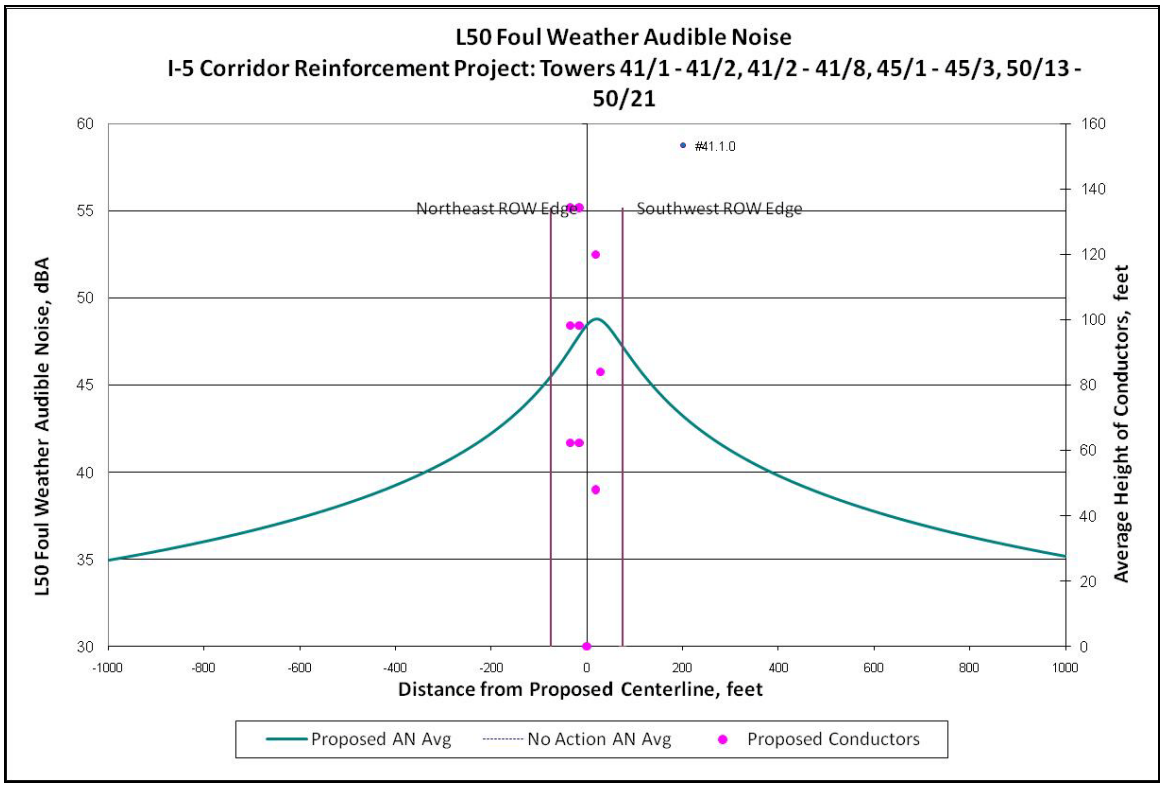


Table 29: Calculation 49.1.0

Calculation 49.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
49	49/7 - 49/10	0.69				

Calculation 49.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		South Edge	North Edge	Peak On ROW	South Edge	North Edge	Peak On ROW
Electric Field, kV/m	No Action	0.6	0.1	2.3	0.0	0.5	4.0
	Proposed	0.5	2.3	5.4	0.5	2.4	8.9
Magnetic Field, mG	No Action	7	1	33	21	3	141
	Proposed	6	13	33	18	50	178
Audible Noise, dBA Foul weather L50	No Action	39.8	36.6	Not Applicable			
	Proposed	43.4	47.6				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	26	26	Not Applicable			
	Proposed	26	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	13	13	Not Applicable			
	Proposed	13	21				

Figure 67: Calculation 49.1.0 – Electric Fields

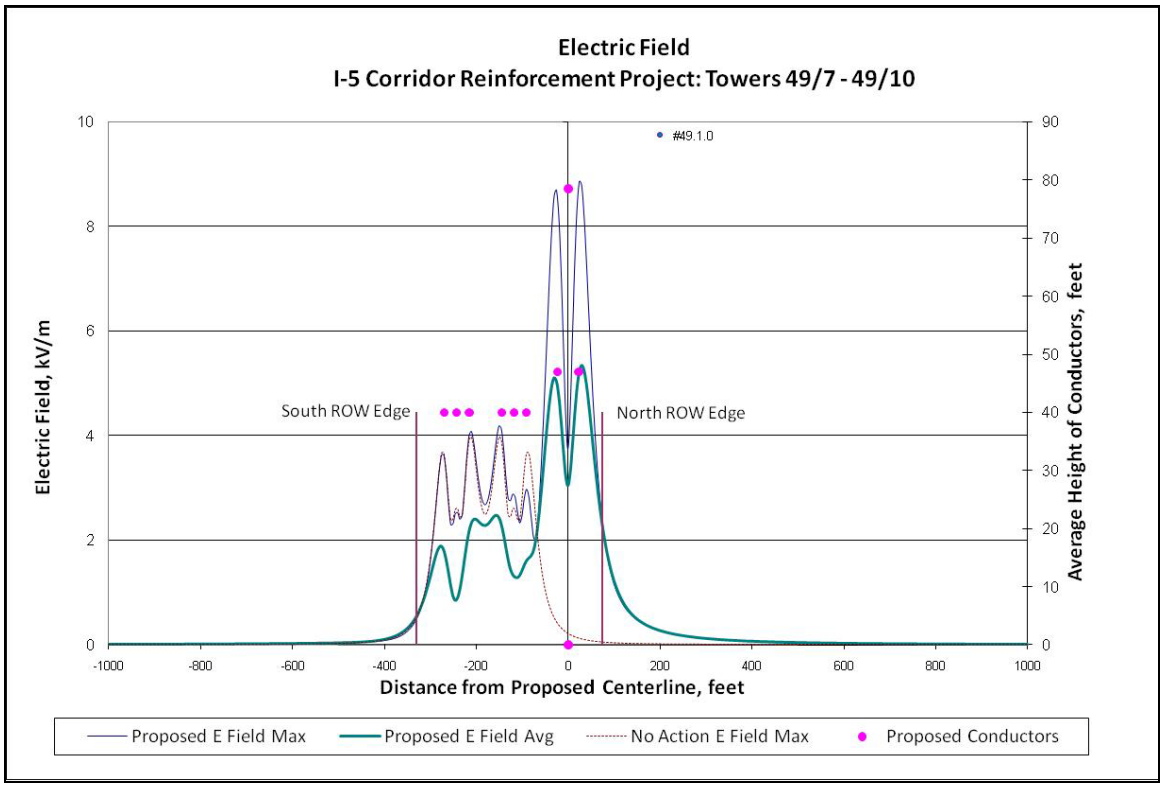


Figure 68: Calculation 49.1.0 – Magnetic Fields

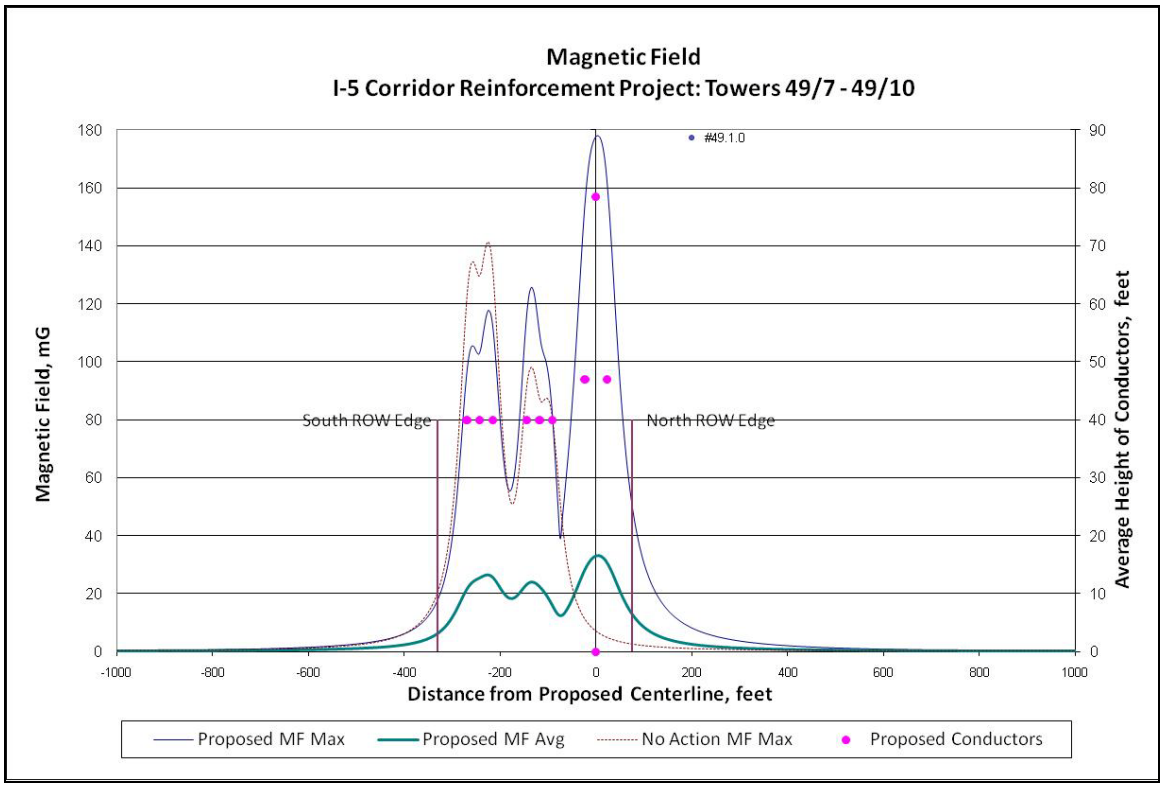


Figure 69: Calculation 49.1.0 – Audible Noise Levels

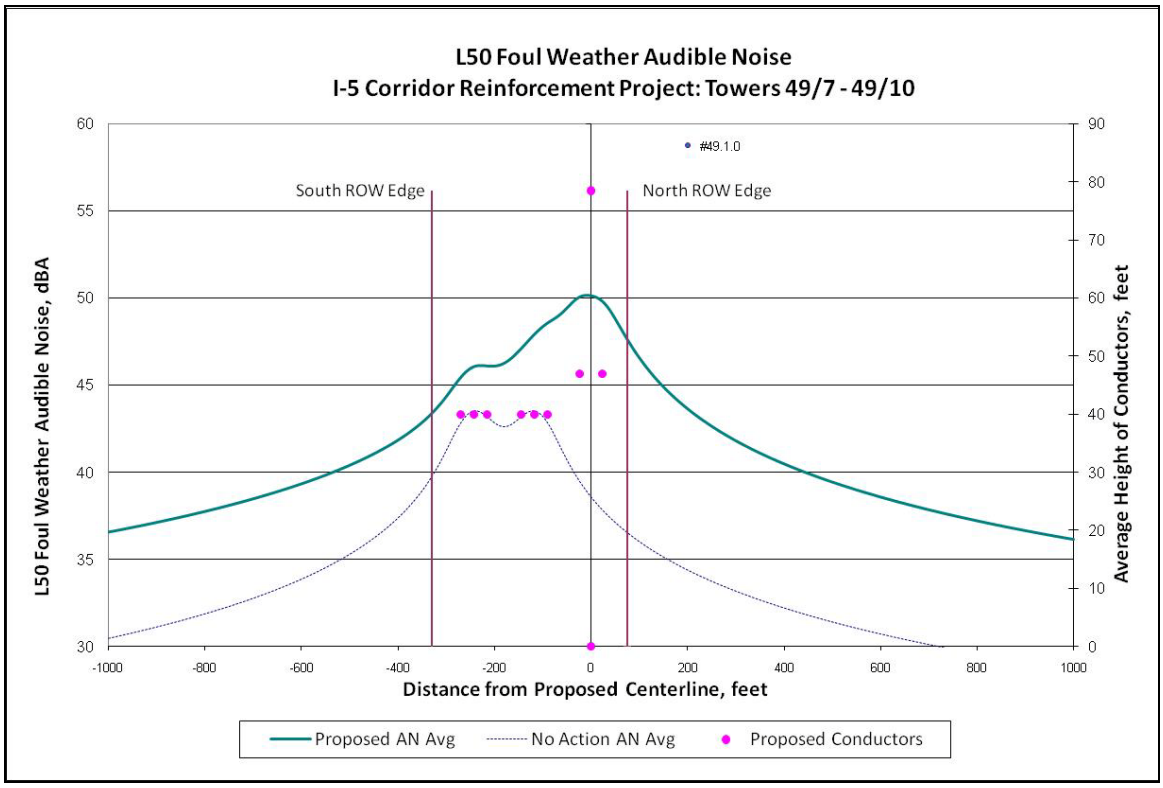


Table 30: Calculation 49.1.1

Calculation 49.1.1: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
49	49/7 - 49/10	0.69				

Calculation 49.1.1: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		South Edge	North Edge	Peak On ROW	South Edge	North Edge	Peak On ROW
Electric Field, kV/m	No Action	0.6	0.1	2.3	0.0	0.5	4.0
	Proposed	0.5	2.2	5.5	0.4	2.3	8.7
Magnetic Field, mG	No Action	7	1	33	21	3	141
	Proposed	5	11	35	15	45	183
Audible Noise, dBA Foul weather L50	No Action	39.8	36.6	Not Applicable			
	Proposed	43.1	47.3				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	26	26	Not Applicable			
	Proposed	26	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	13	13	Not Applicable			
	Proposed	14	21				

Figure 70: Calculation 49.1.1 – Electric Fields

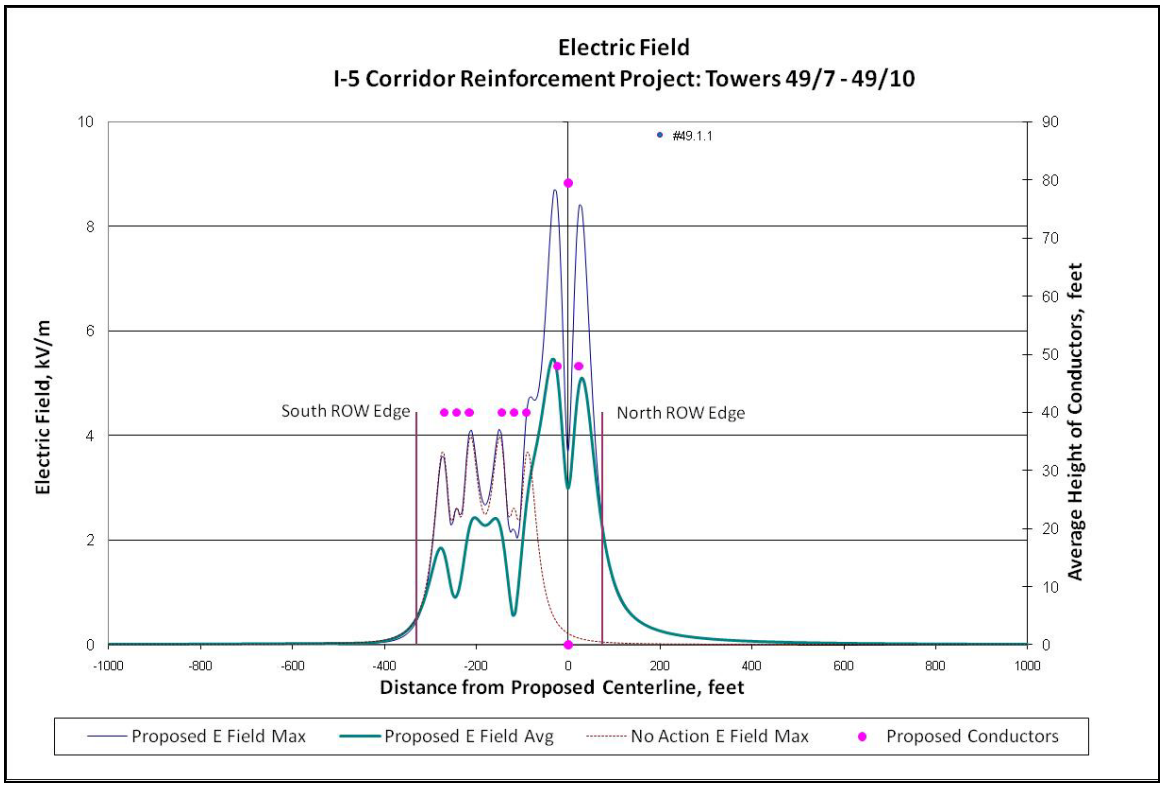


Figure 71: Calculation 49.1.1 – Magnetic Fields

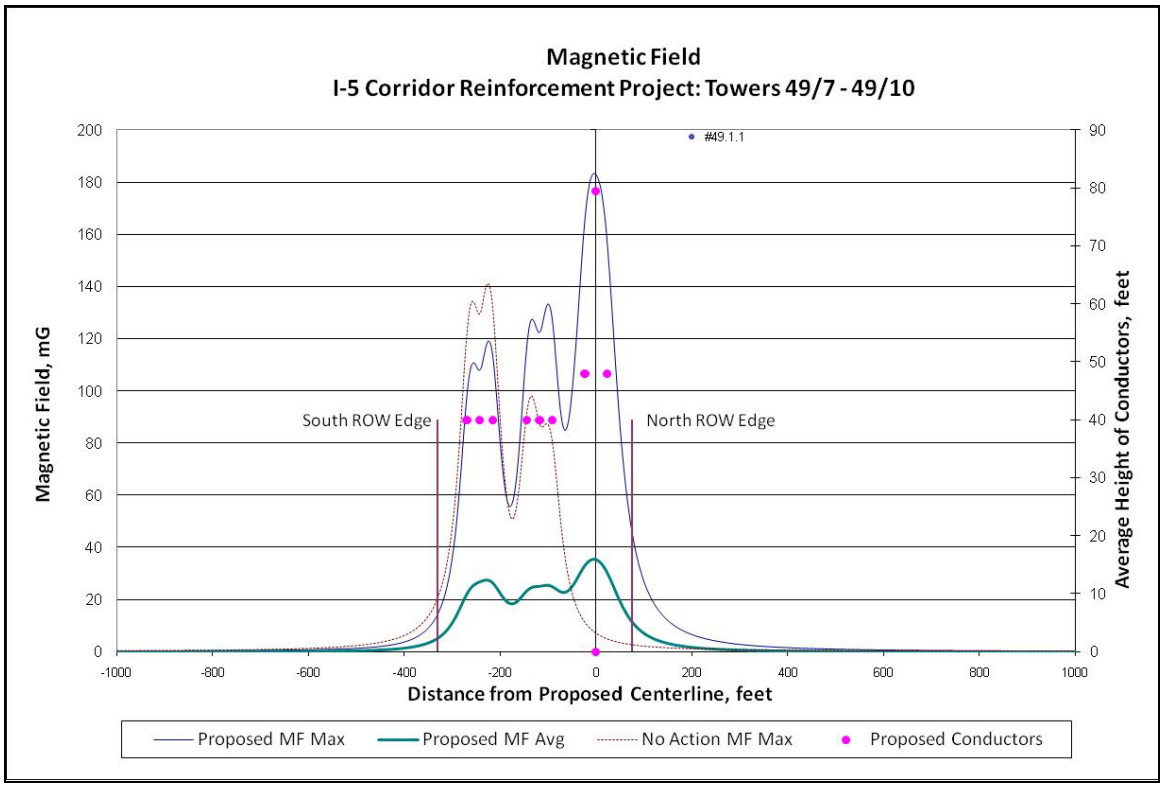


Figure 72: Calculation 49.1.1 – Audible Noise Levels

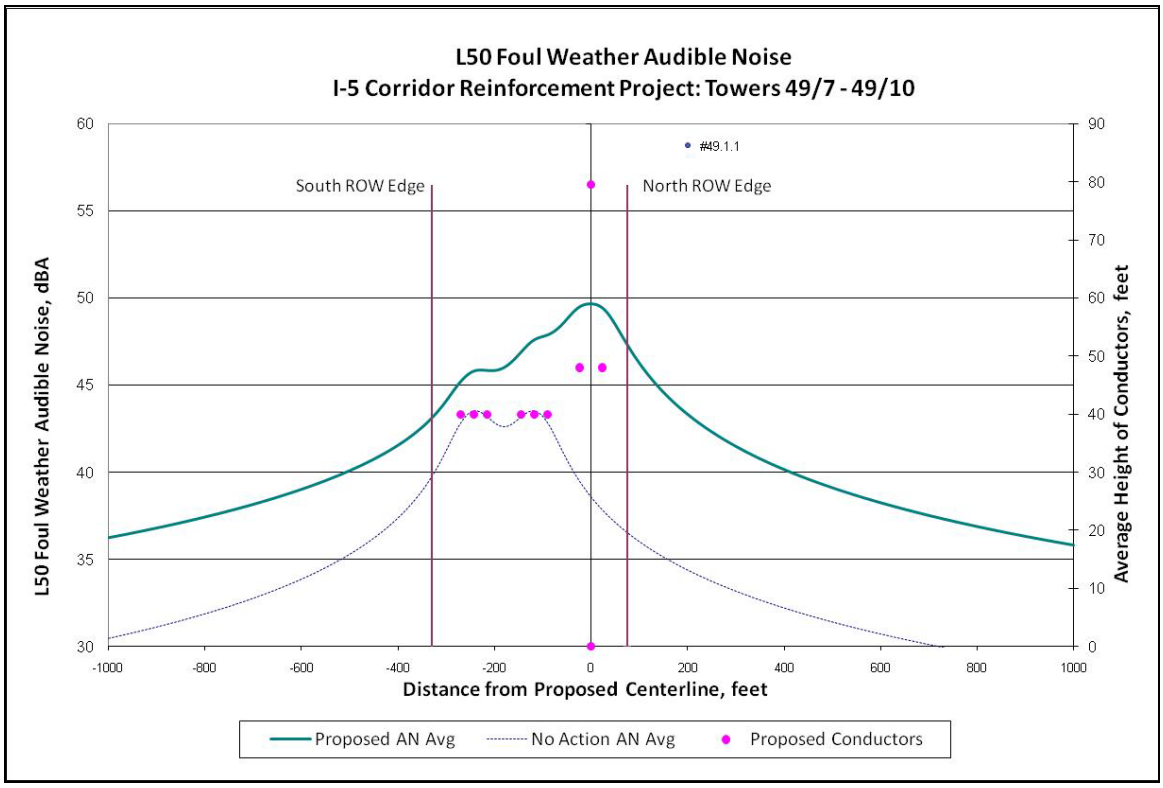


Table 31: Calculation 49.2.0

Calculation 49.2.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
49	49/10 - 49/15	0.80				

Calculation 49.2.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		South Edge	North Edge	Peak On ROW	South Edge	North Edge	Peak On ROW
Electric Field, kV/m	No Action	0.6	0.6	2.3	0.5	0.5	4.0
	Proposed	0.5	0.9	5.6	0.4	0.9	8.9
Magnetic Field, mG	No Action	7	3	33	21	13	141
	Proposed	7	13	26	20	51	133
Audible Noise, dBA Foul weather L50	No Action	39.8	39.8	Not Applicable			
	Proposed	43.7	47.2				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	26	26	Not Applicable			
	Proposed	30	40				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	13	13	Not Applicable			
	Proposed	14	20				

Figure 73: Calculation 49.2.0 – Electric Fields

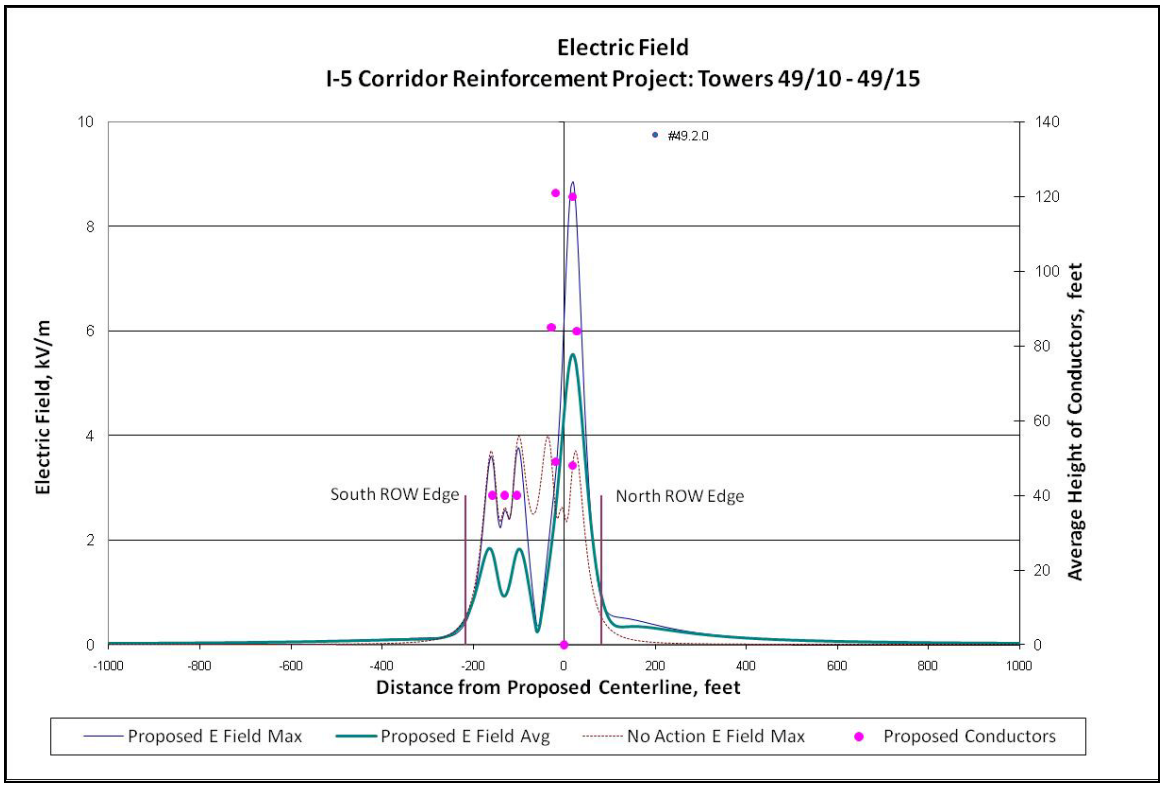


Figure 74: Calculation 49.2.0 – Magnetic Fields

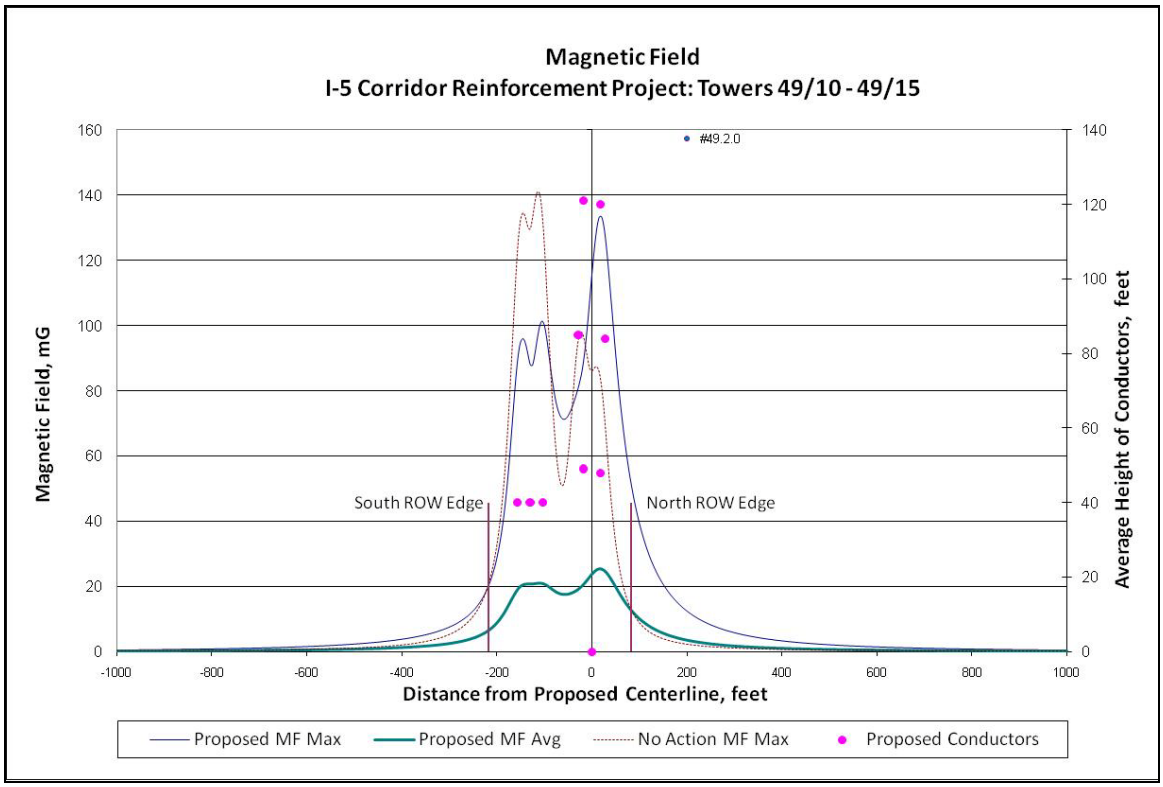


Figure 75: Calculation 49.2.0 – Audible Noise Levels

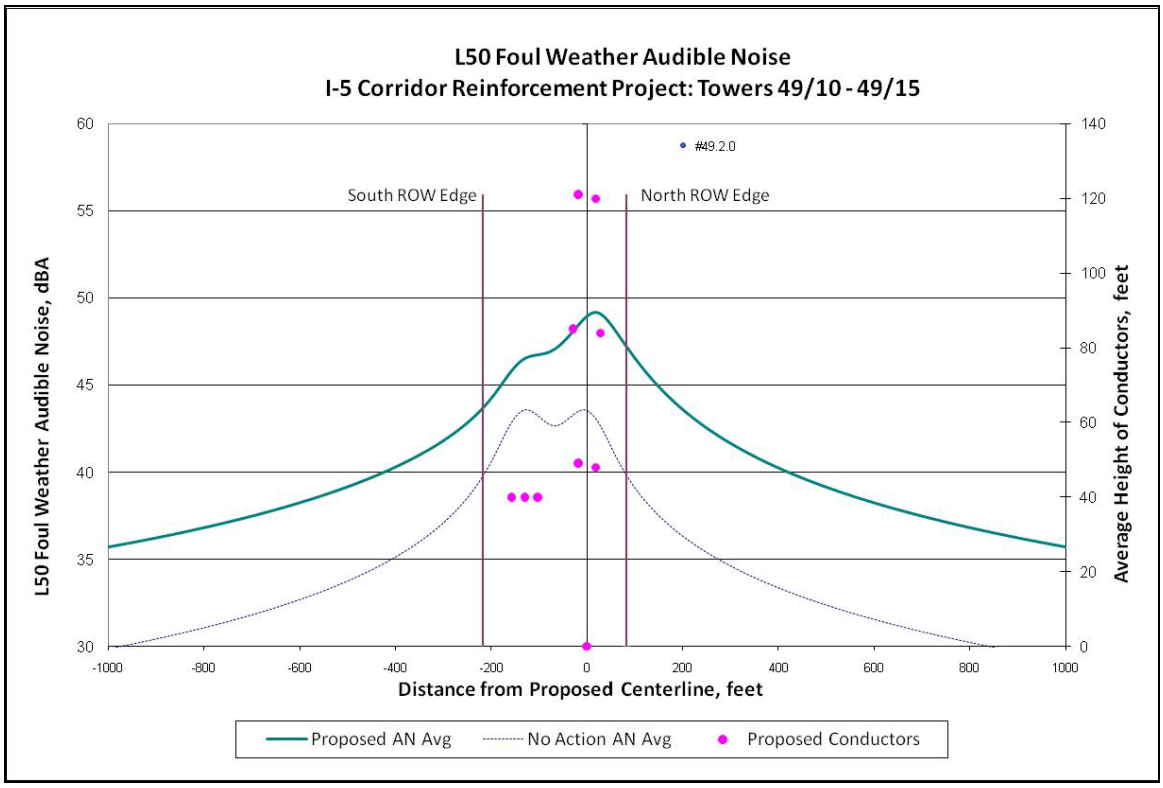


Table 32: Calculation 49.2.1

Calculation 49.2.1: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
49	49/10 - 49/15	0.80				

Calculation 49.2.1: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		South Edge	North Edge	Peak On ROW	South Edge	North Edge	Peak On ROW
Electric Field, kV/m	No Action	0.6	0.6	2.3	0.5	0.5	4.0
	Proposed	0.6	0.9	5.9	0.5	0.9	8.8
Magnetic Field, mG	No Action	7	3	33	21	13	141
	Proposed	6	15	28	19	59	136
Audible Noise, dBA Foul weather L50	No Action	39.8	39.8	Not Applicable			
	Proposed	43.0	46.1				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	26	26	Not Applicable			
	Proposed	30	40				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	13	13	Not Applicable			
	Proposed	13	18				

Figure 76: Calculation 49.2.1 – Electric Fields

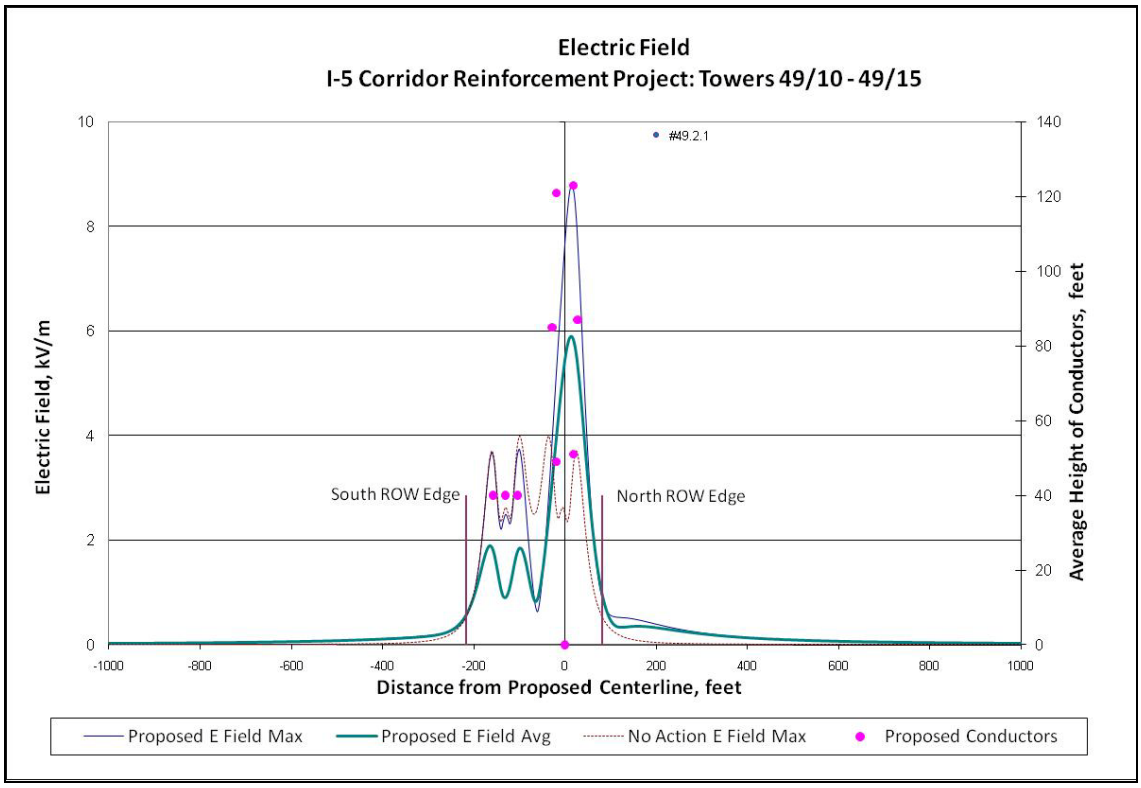


Figure 77: Calculation 49.2.1 – Magnetic Fields

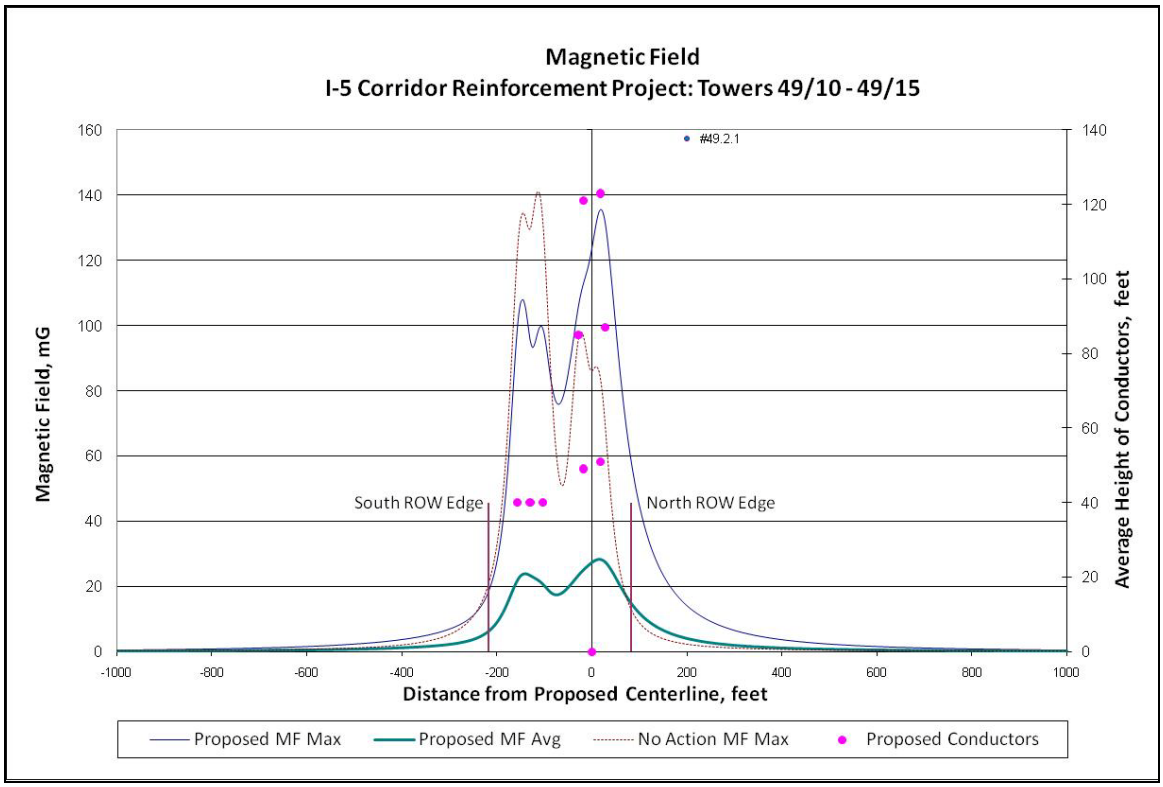


Figure 78: Calculation 49.2.1 – Audible Noise Levels

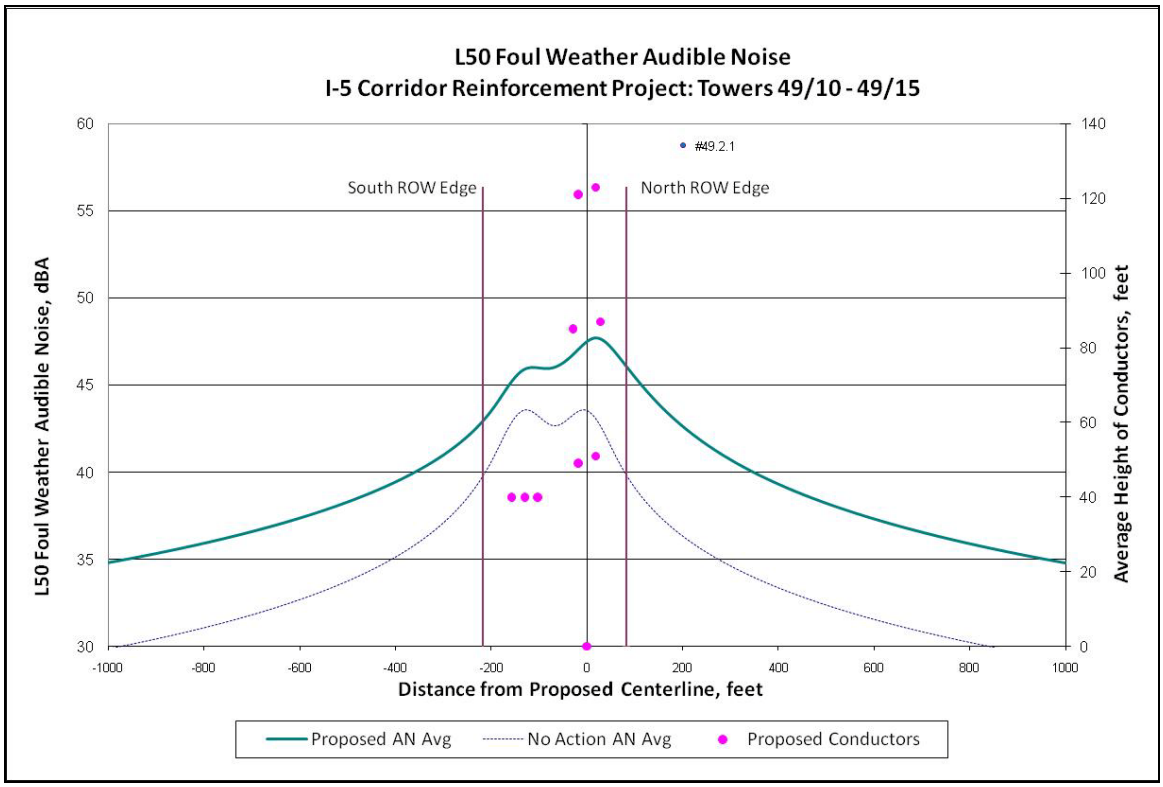


Table 33: Calculation 50.1.0

Calculation 50.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
50	50/5 - 50/13	1.46				
50	50/21 - 50/26	0.80				

Calculation 50.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		North Edge	South Edge	Peak On ROW	North Edge	South Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.0	0.8	0.1	0.1	1.6
	Proposed	0.3	2.3	5.3	0.2	2.4	8.9
Magnetic Field, mG	No Action	1	0	3	8	1	35
	Proposed	3	12	35	12	48	185
Audible Noise, dBA Foul weather L50	No Action	19.8	14.6	Not Applicable			
	Proposed	44.2	47.2				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	10	10	Not Applicable			
	Proposed	30	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	-7	-7	Not Applicable			
	Proposed	12	21				

Figure 79: Calculation 50.1.0 – Electric Fields

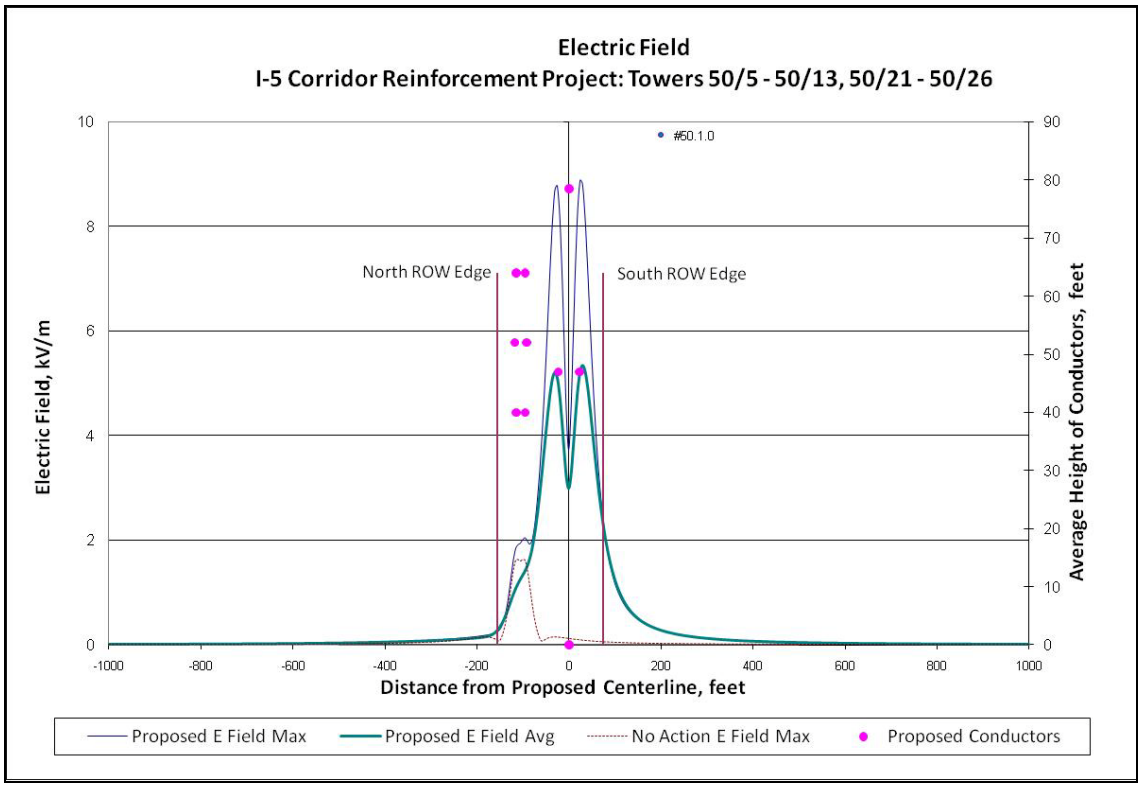


Figure 80: Calculation 50.1.0 – Magnetic Fields

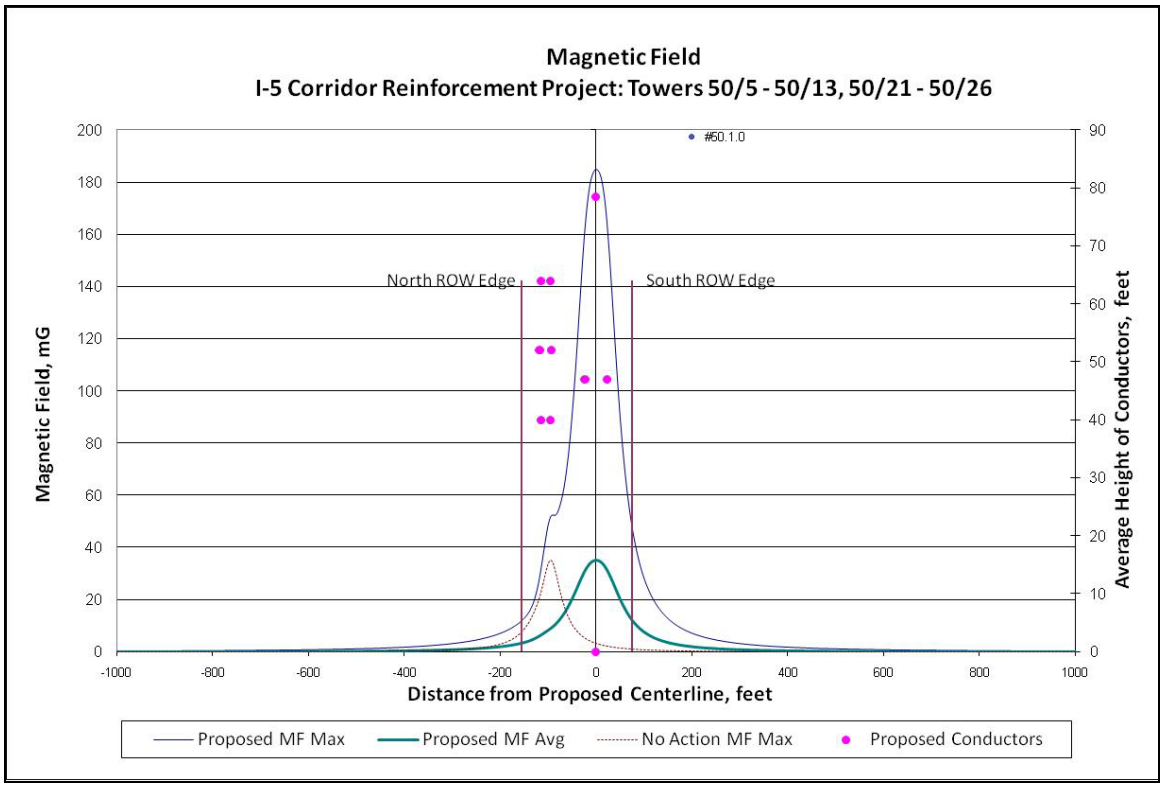


Figure 81: Calculation 50.1.0 – Audible Noise Levels

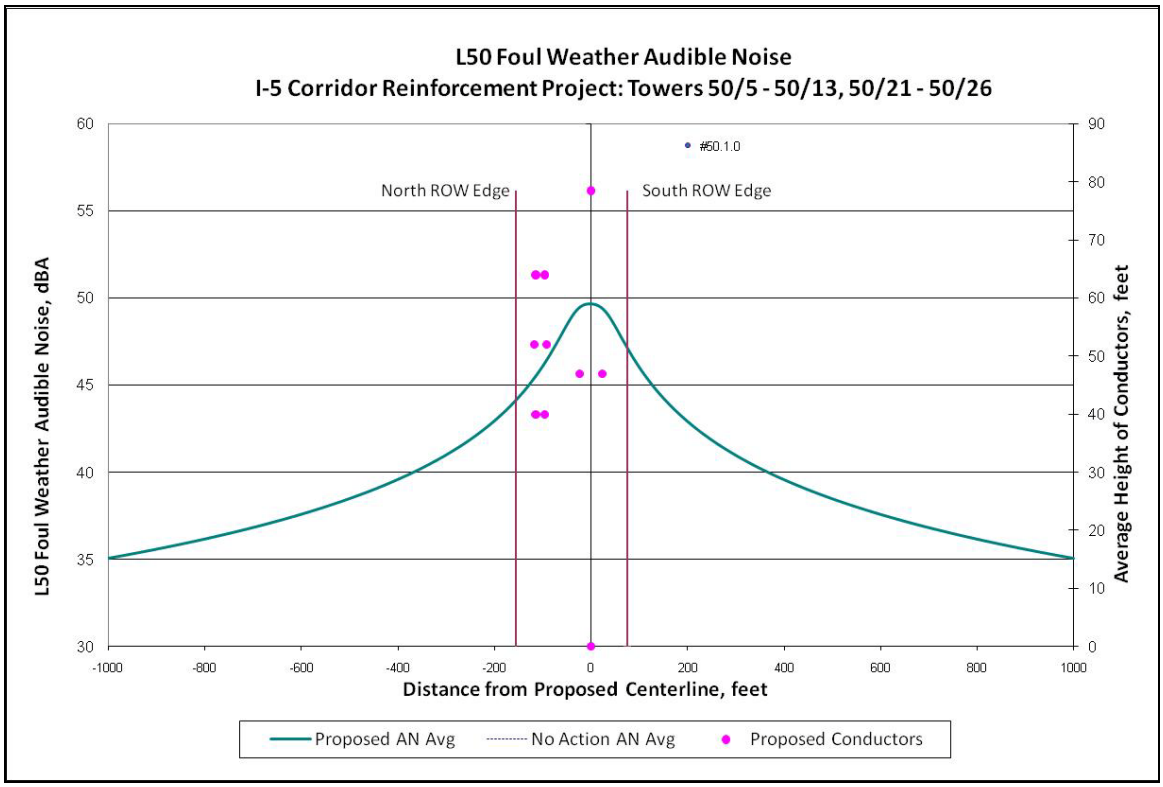


Table 34: Calculation 50.1.1

Calculation 50.1.1: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
50	50/5 - 50/13	1.46				
50	50/21 - 50/26	0.80				

Calculation 50.1.1: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		North Edge	South Edge	Peak On ROW	North Edge	South Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	0.0	0.8	0.1	0.1	1.6
	Proposed	0.2	2.3	5.3	0.3	2.3	8.8
Magnetic Field, mG	No Action	1	0	3	8	1	35
	Proposed	3	12	34	11	48	183
Audible Noise, dBA Foul weather L50	No Action	19.8	14.6	Not Applicable			
	Proposed	44.1	47.2				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	10	10	Not Applicable			
	Proposed	30	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	-7	-7	Not Applicable			
	Proposed	12	21				

Figure 82: Calculation 50.1.1 – Electric Fields

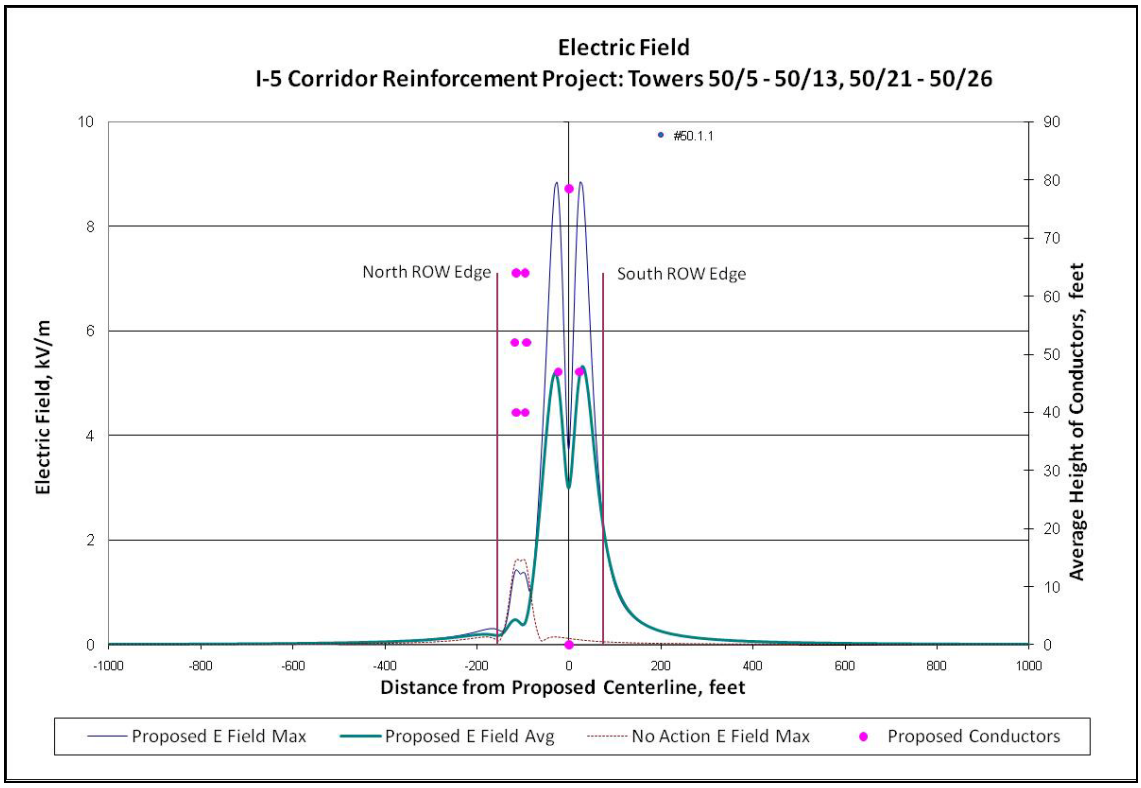


Figure 83: Calculation 50.1.1 – Magnetic Fields

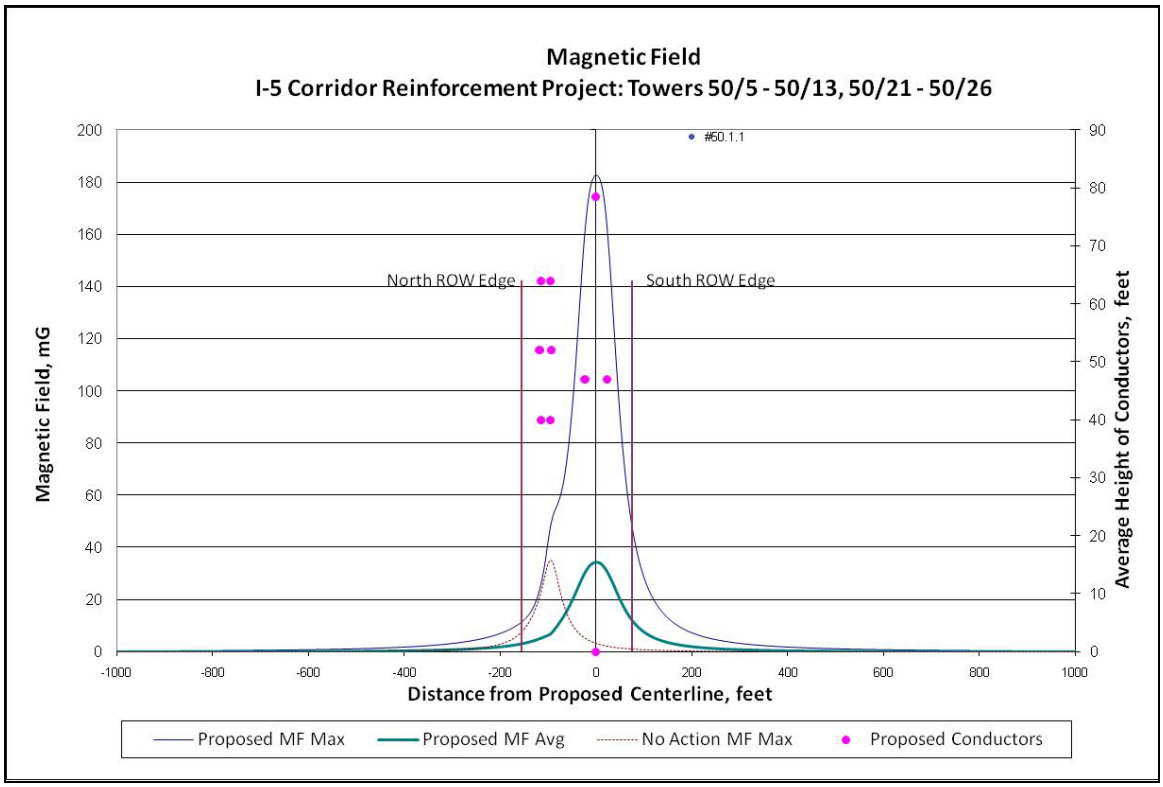


Figure 84: Calculation 50.1.1 – Audible Noise Levels

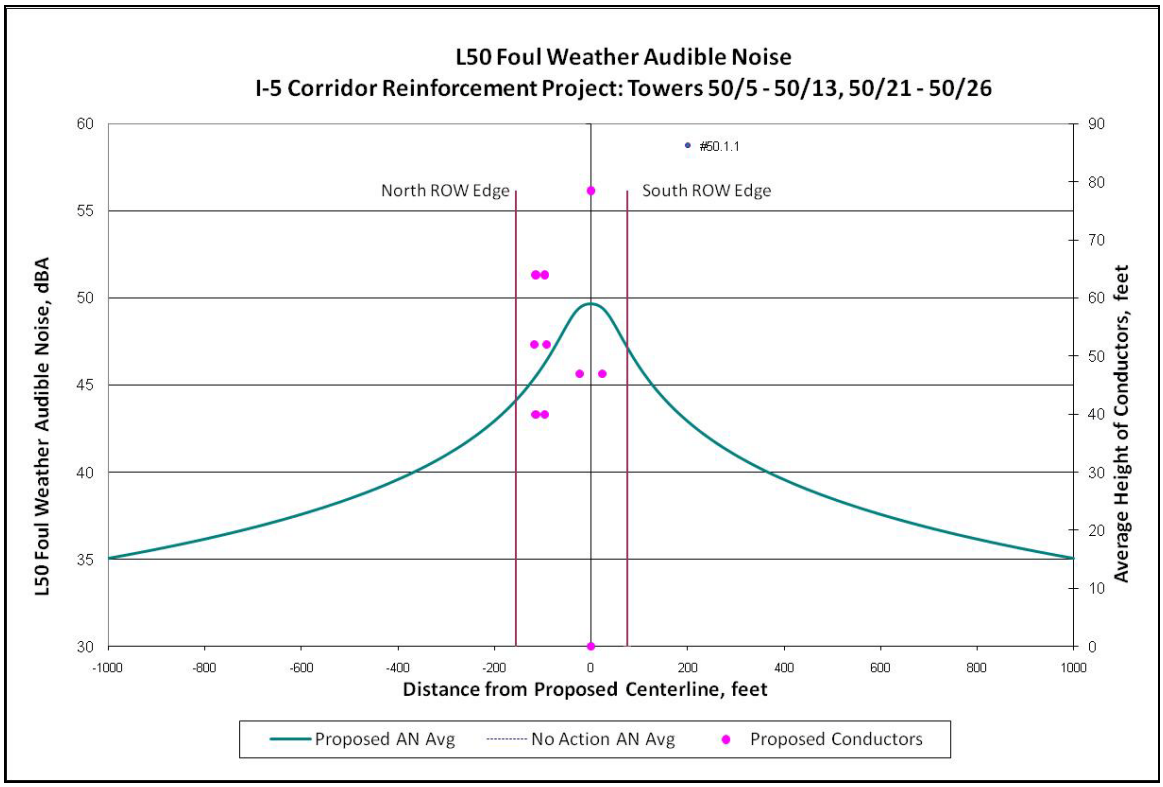


Table 35: Calculation 51.1.0

Calculation 51.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
51	51/1 - 51/11	2.07		52	52/9 - 52/12	0.44
52	52/1 - 52/2	0.13				

Calculation 51.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		East Edge	West Edge	Peak On ROW	East Edge	West Edge	Peak On ROW
Electric Field, kV/m	No Action	1.2	1.2	2.0	1.4	1.4	3.8
	Proposed	0.2	2.0	5.3	0.2	2.0	8.9
Magnetic Field, mG	No Action	15	15	29	48	48	129
	Proposed	8	11	33	24	43	179
Audible Noise, dBA Foul weather L50	No Action	42.1	42.1	Not Applicable			
	Proposed	46.2	47.5				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	27	Not Applicable			
	Proposed	31	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	14	14	Not Applicable			
	Proposed	13	21				

Figure 85: Calculation 51.1.0 – Electric Fields

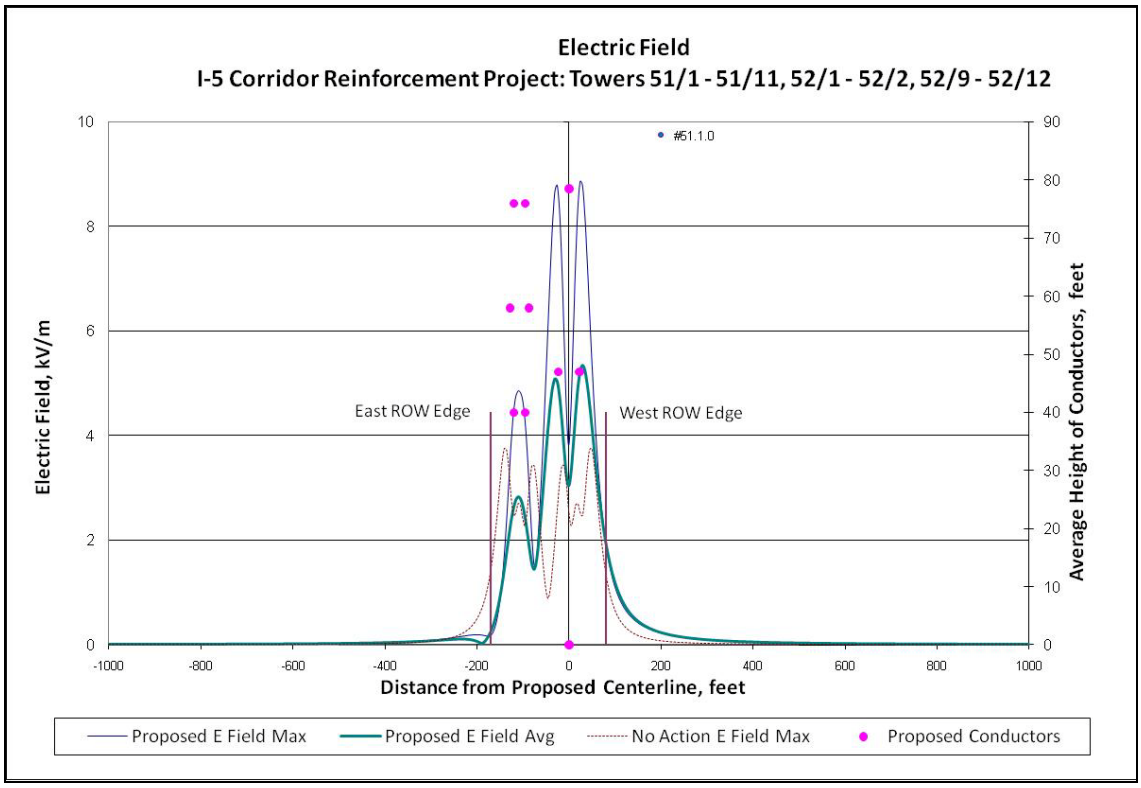


Figure 86: Calculation 51.1.0 – Magnetic Fields

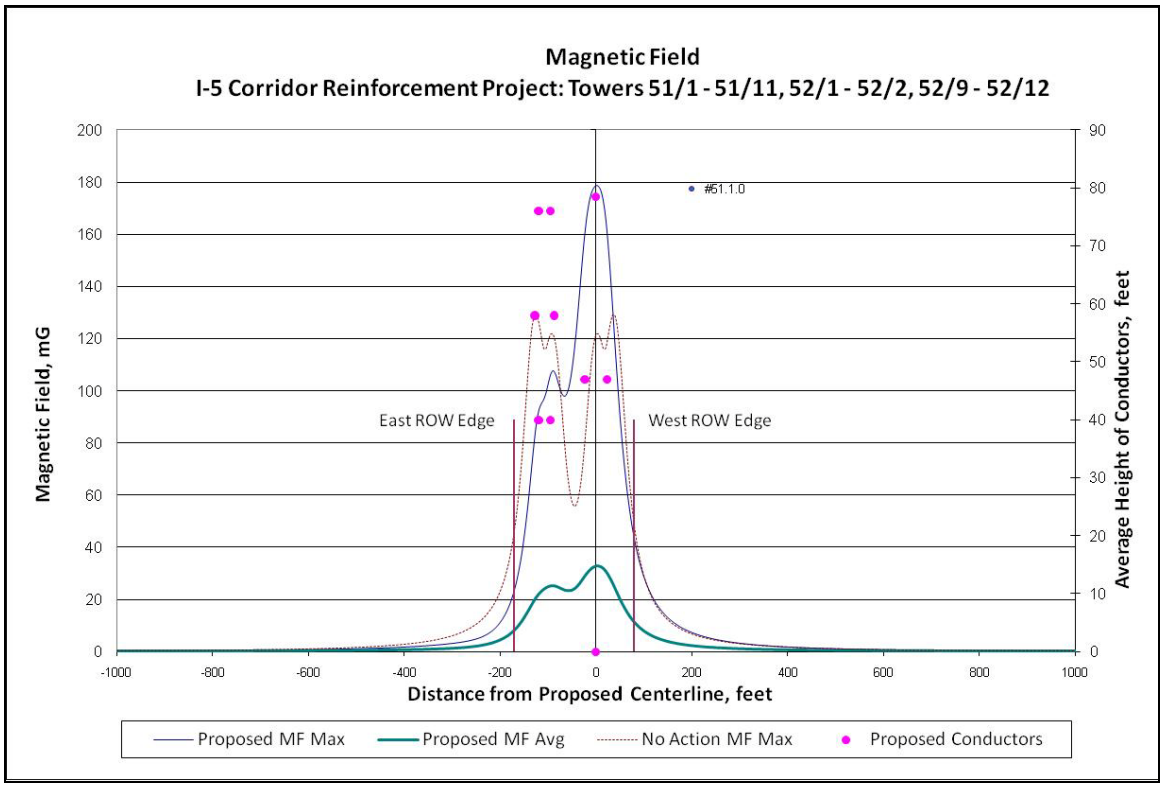


Figure 87: Calculation 51.1.0 – Audible Noise Levels

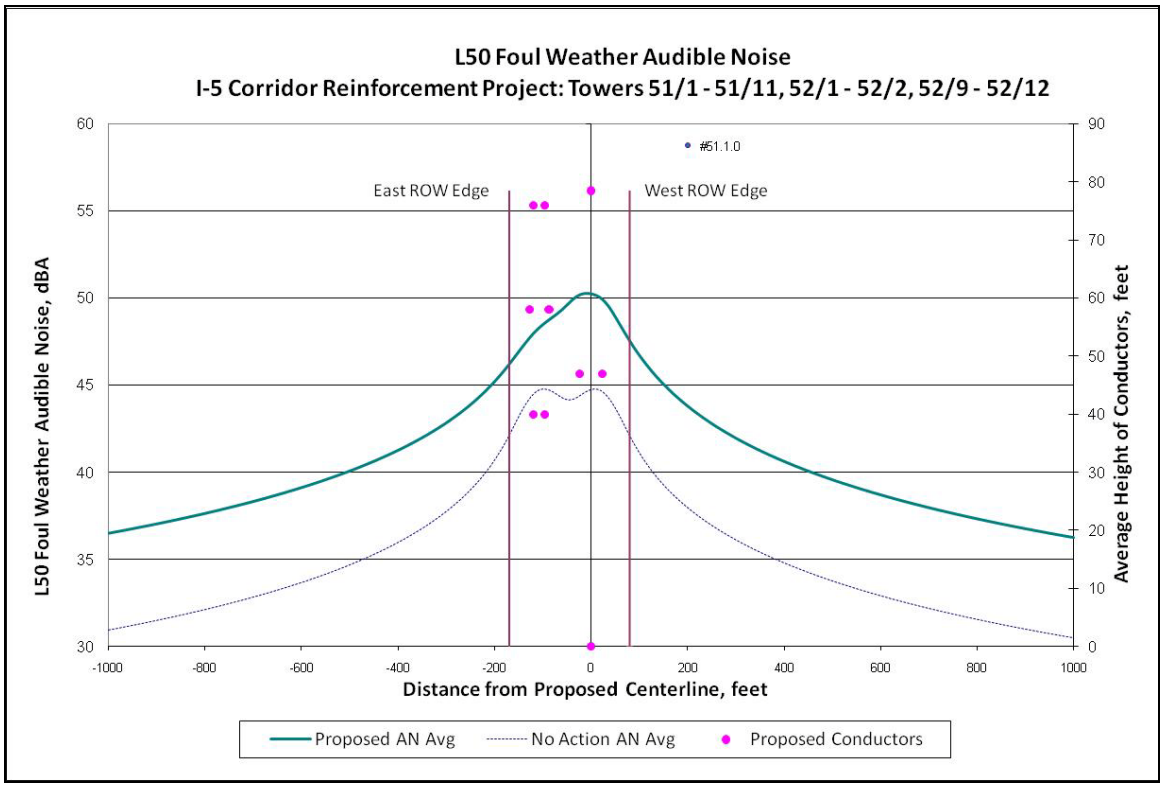


Table 36: Calculation 51.1.1

Calculation 51.1.1: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
52	52/12 - 52/17	1.23				

Calculation 51.1.1: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		East Edge	West Edge	Peak On ROW	East Edge	West Edge	Peak On ROW
Electric Field, kV/m	No Action	1.2	1.2	2.3	1.3	1.3	4.0
	Proposed	0.5	2.0	5.4	0.5	2.0	8.9
Magnetic Field, mG	No Action	13	13	35	42	42	147
	Proposed	8	12	35	26	44	183
Audible Noise, dBA Foul weather L50	No Action	41.9	41.9	Not Applicable			
	Proposed	46.7	47.7				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	27	Not Applicable			
	Proposed	30	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	15	15	Not Applicable			
	Proposed	14	21				

Figure 88: Calculation 51.1.1 – Electric Fields

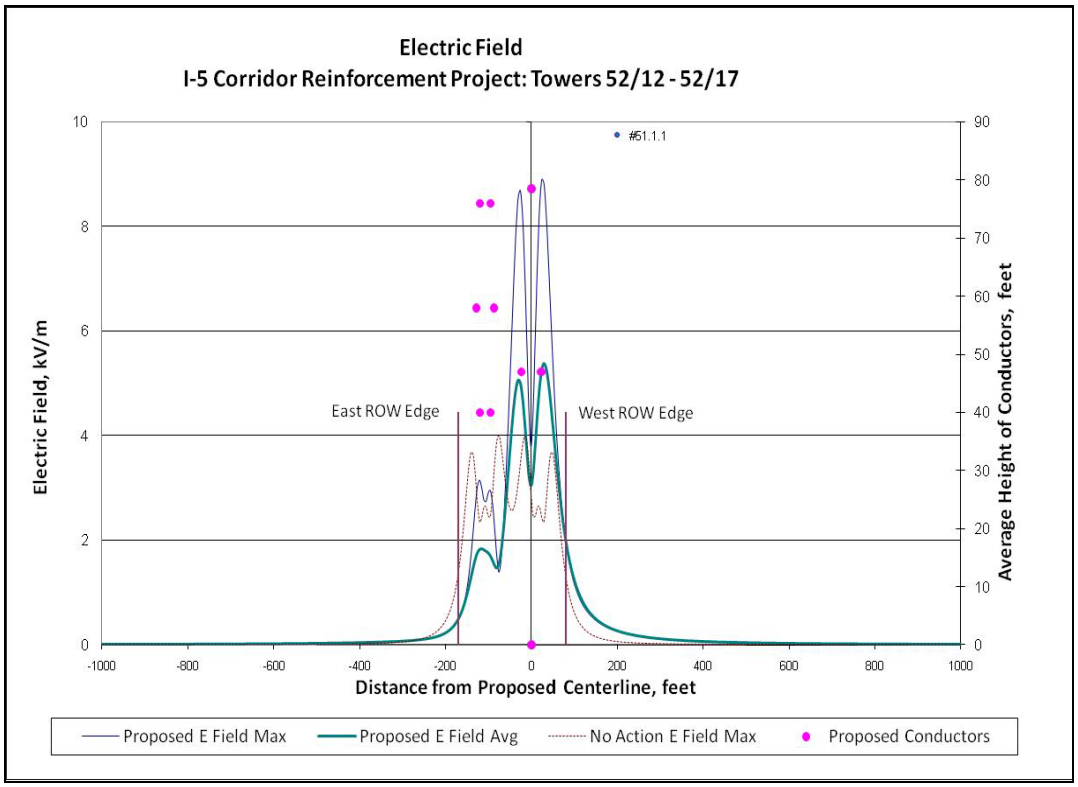


Figure 89: Calculation 51.1.1 – Magnetic Fields

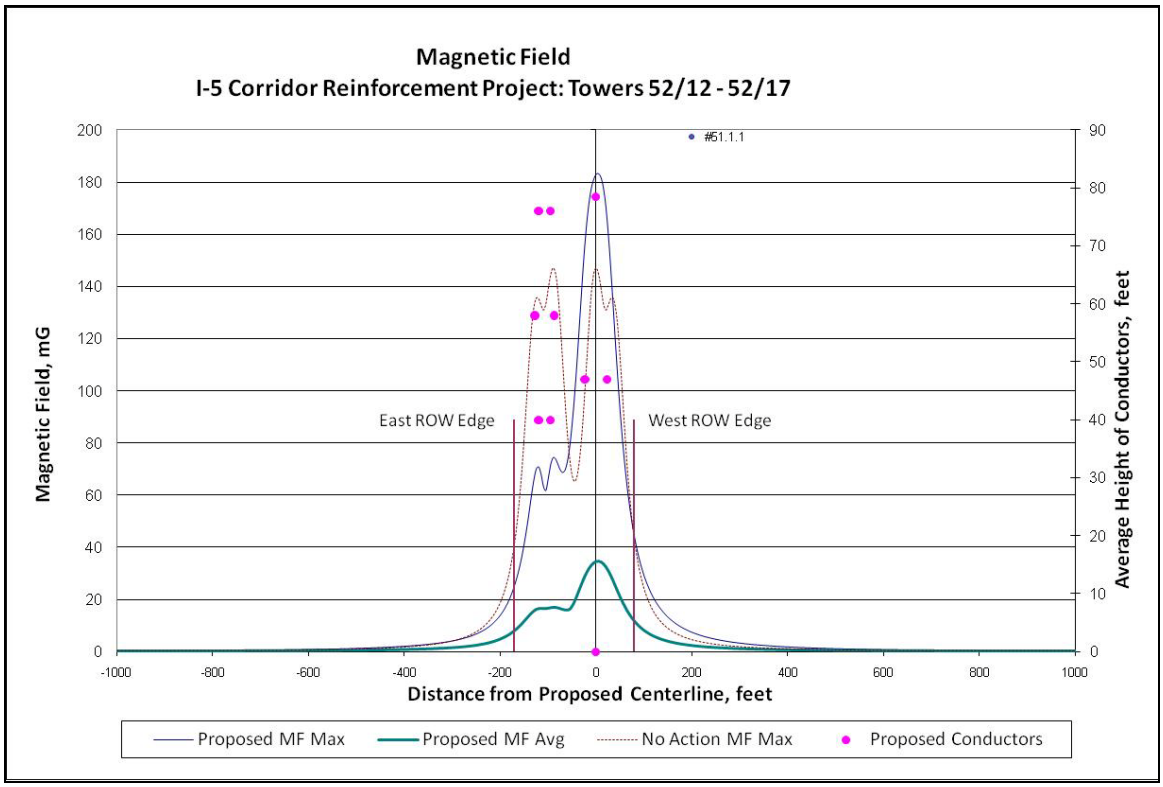


Figure 90: Calculation 51.1.1 – Audible Noise Levels

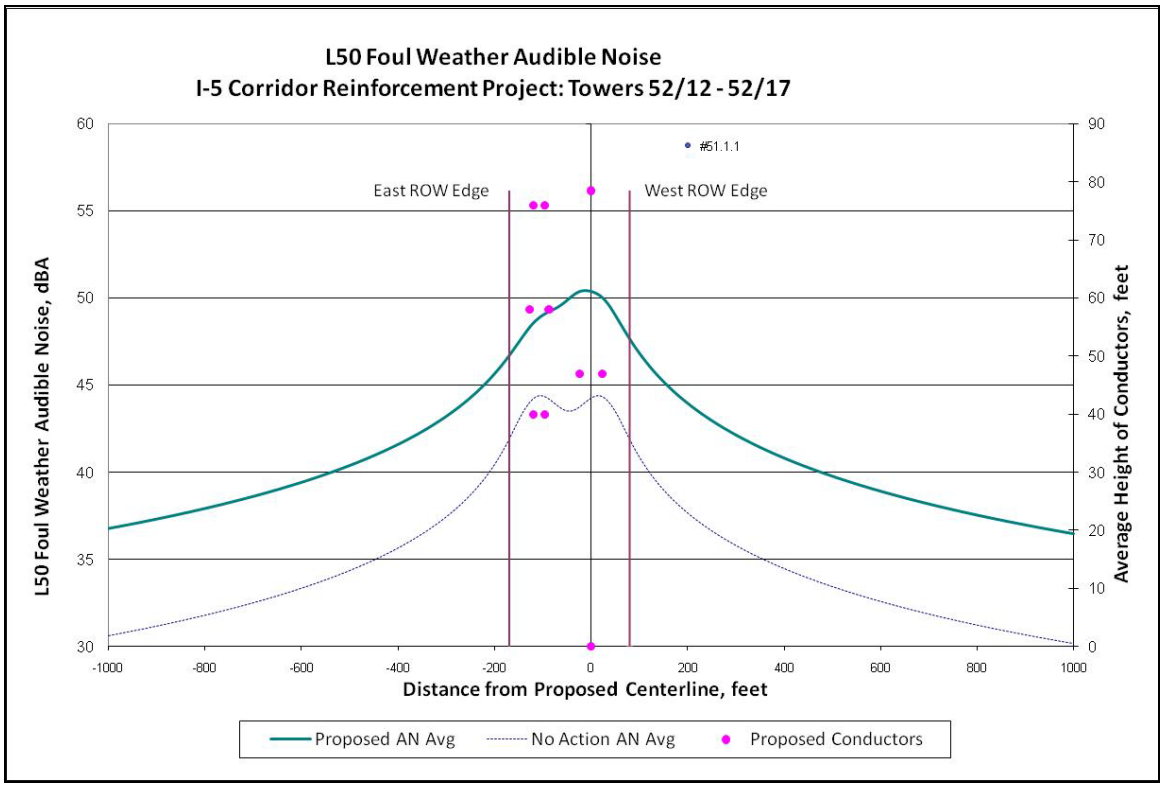


Table 37: Calculation 52.2.0

Calculation 52.2.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
52	52/2 - 52/9	1.48				

Calculation 52.2.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		East Edge	West Edge	Peak On ROW	East Edge	West Edge	Peak On ROW
Electric Field, kV/m	No Action	0.2	1.2	2.0	1.4	0.2	3.8
	Proposed	0.1	2.0	5.3	0.1	2.0	8.9
Magnetic Field, mG	No Action	4	15	29	11	48	129
	Proposed	2	11	33	5	43	179
Audible Noise, dBA Foul weather L50	No Action	39.2	42.1	Not Applicable			
	Proposed	44.0	47.5				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	27	27	Not Applicable			
	Proposed	31	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	14	14	Not Applicable			
	Proposed	13	21				

Figure 91: Calculation 52.2.0 – Electric Fields

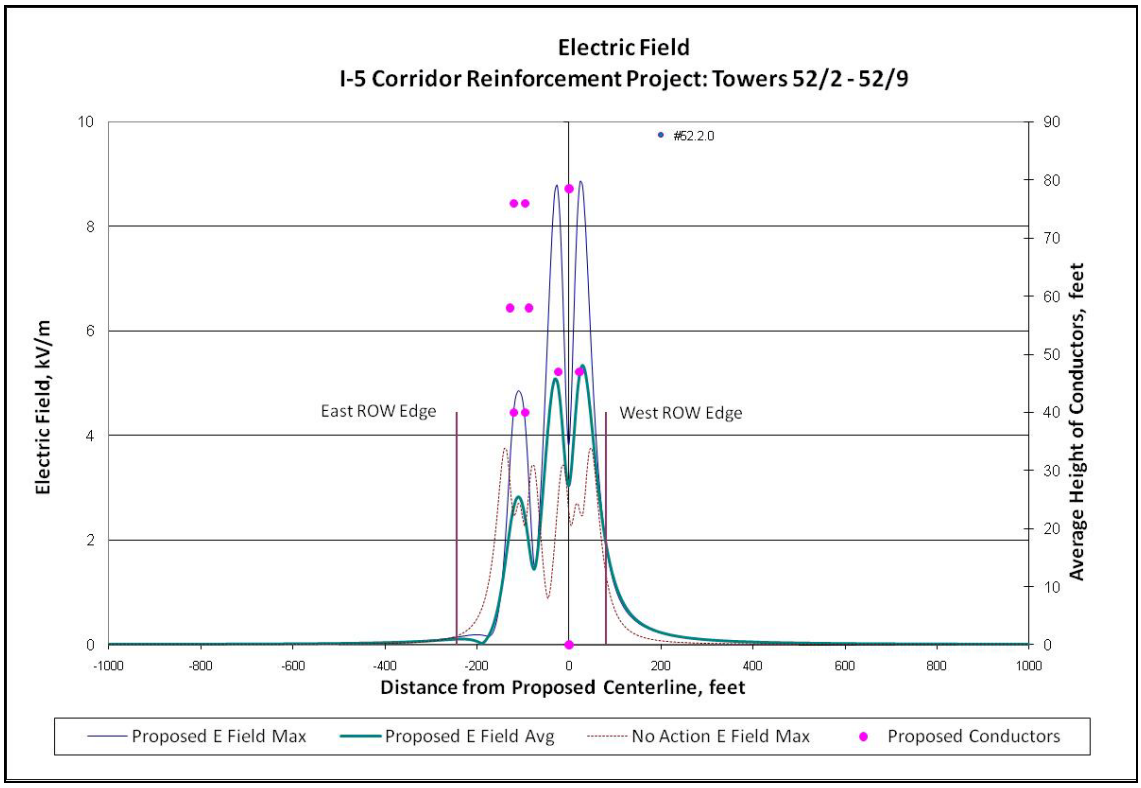


Figure 92: Calculation 52.2.0 – Magnetic Fields

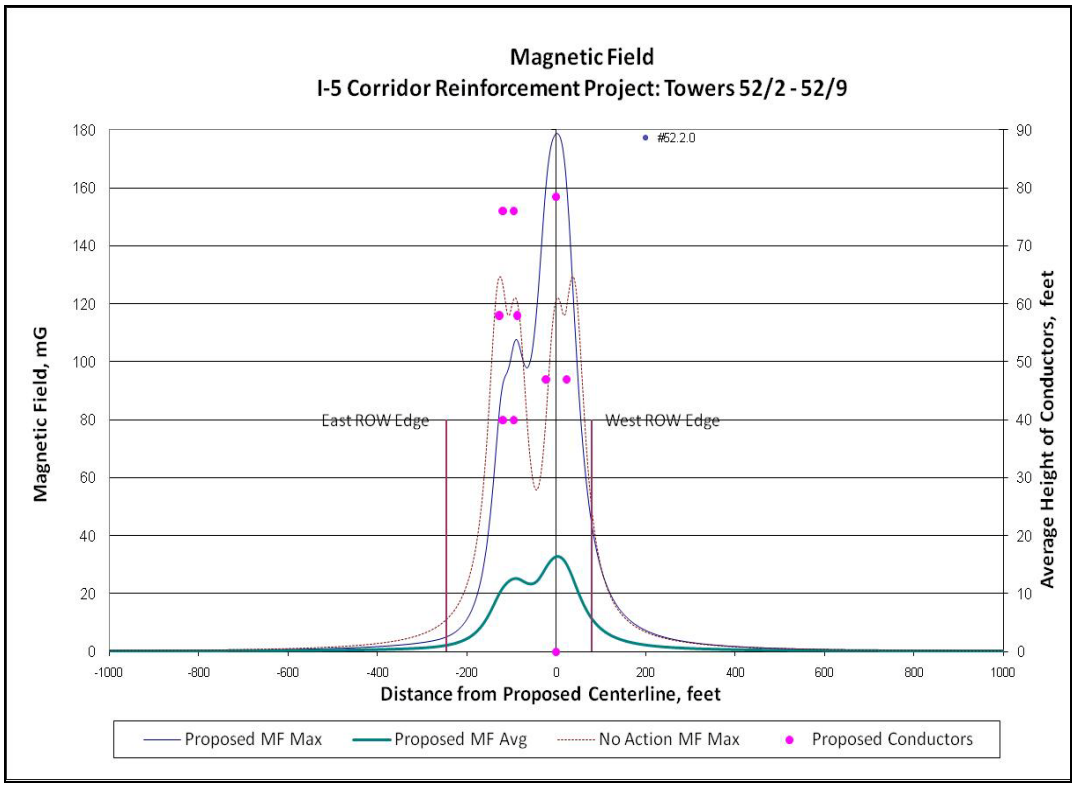


Figure 93: Calculation 52.2.0 – Audible Noise Levels

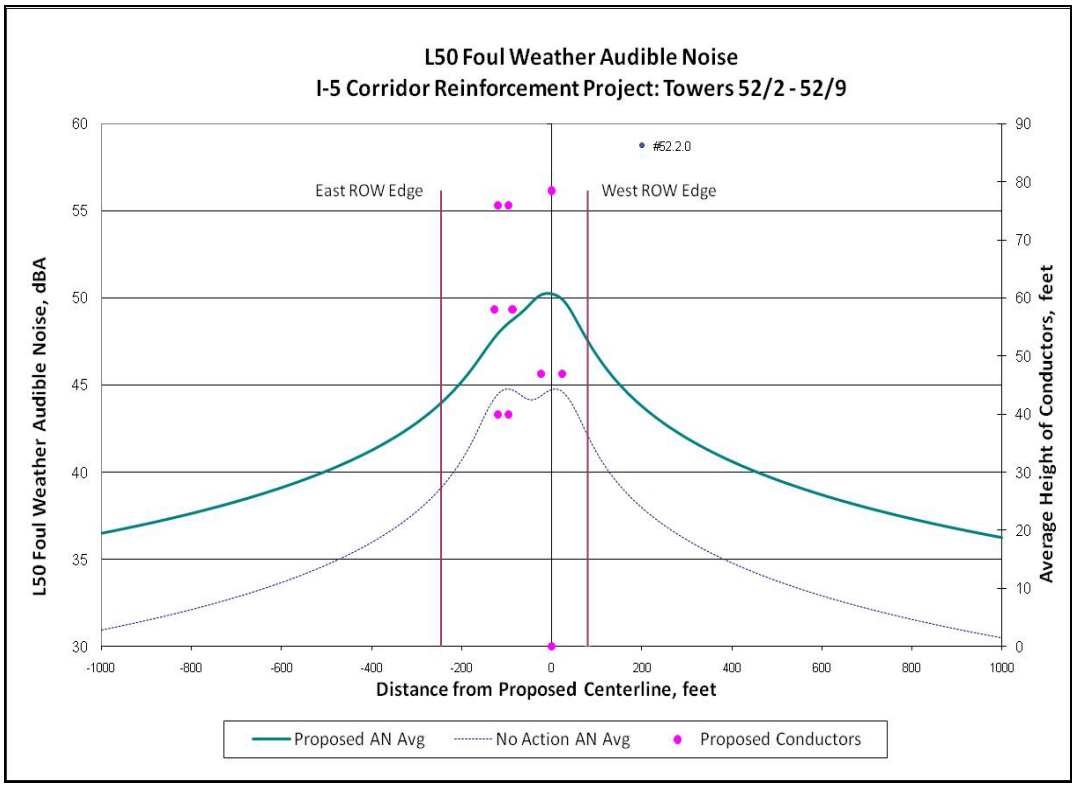


Table 38: Calculation A.1.0

Calculation A.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
A	A/1 - A/9	1.81				
A	A/9 - A/12	0.71				

Calculation A.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		East Edge	West Edge	Peak On ROW	East Edge	West Edge	Peak On ROW
Electric Field, kV/m	No Action	0.1	2.6	5.5	0.1	2.9	9.0
	Proposed	1.9	2.6	5.5	1.9	2.9	9.0
Magnetic Field, mG	No Action	2	18	49	6	73	235
	Proposed	12	19	62	44	75	257
Audible Noise, dBA Foul weather L50	No Action	50.7	52.4	Not Applicable			
	Proposed	52.2	52.6				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	36	36	Not Applicable			
	Proposed	36	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	18	21	Not Applicable			
	Proposed	21	21				

Figure 94: Calculation A.1.0. – Electric Fields

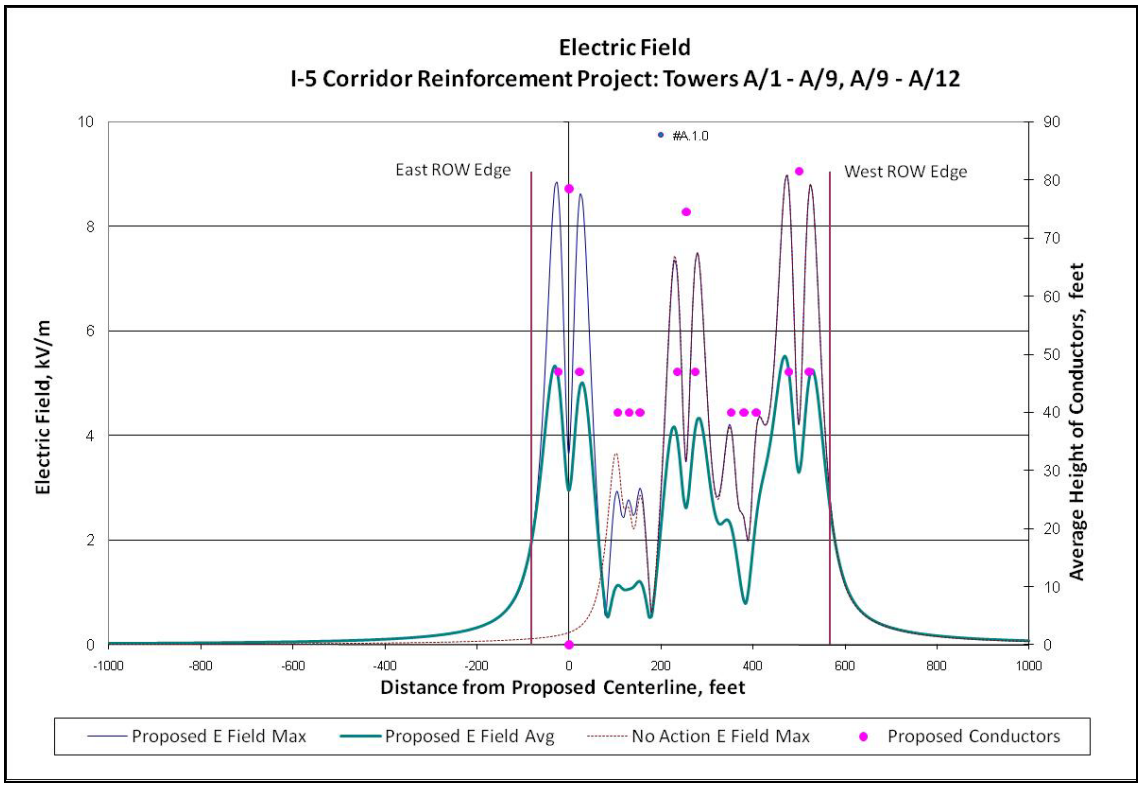


Figure 95: Calculation A.1.0. – Magnetic Fields

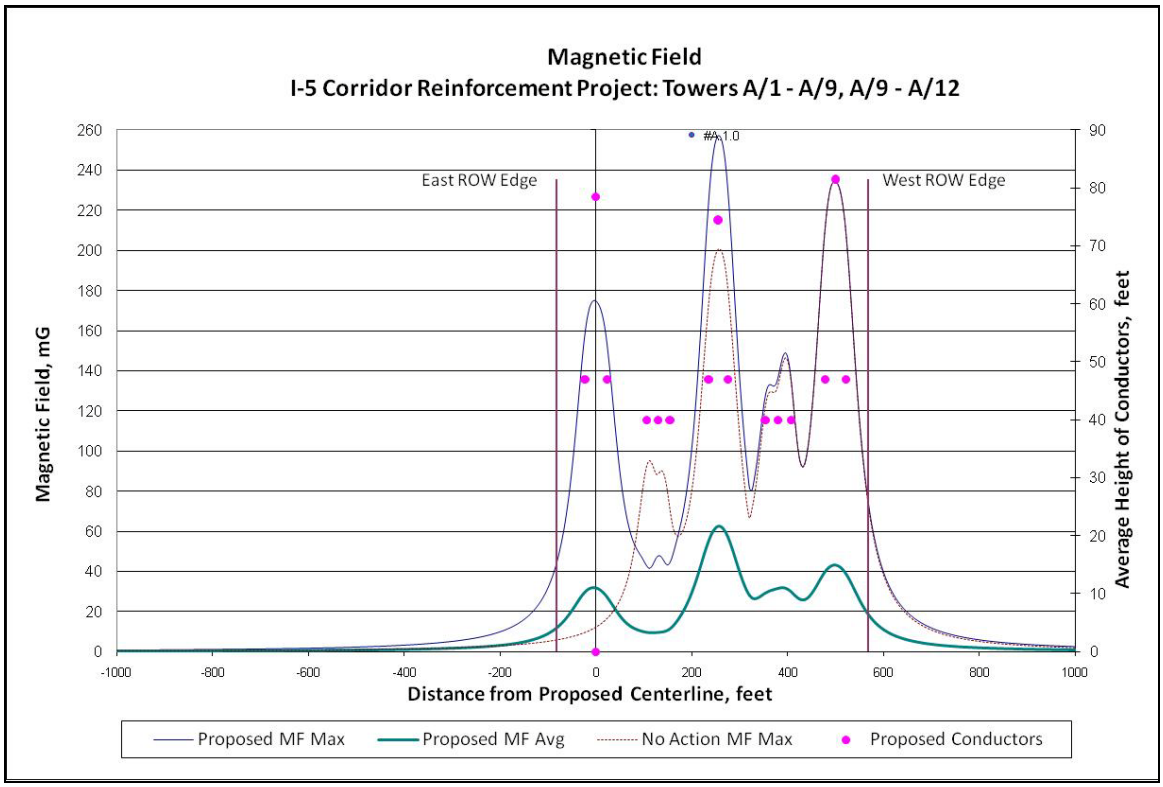


Figure 96: Calculation A.1.0. – Audible Noise Levels

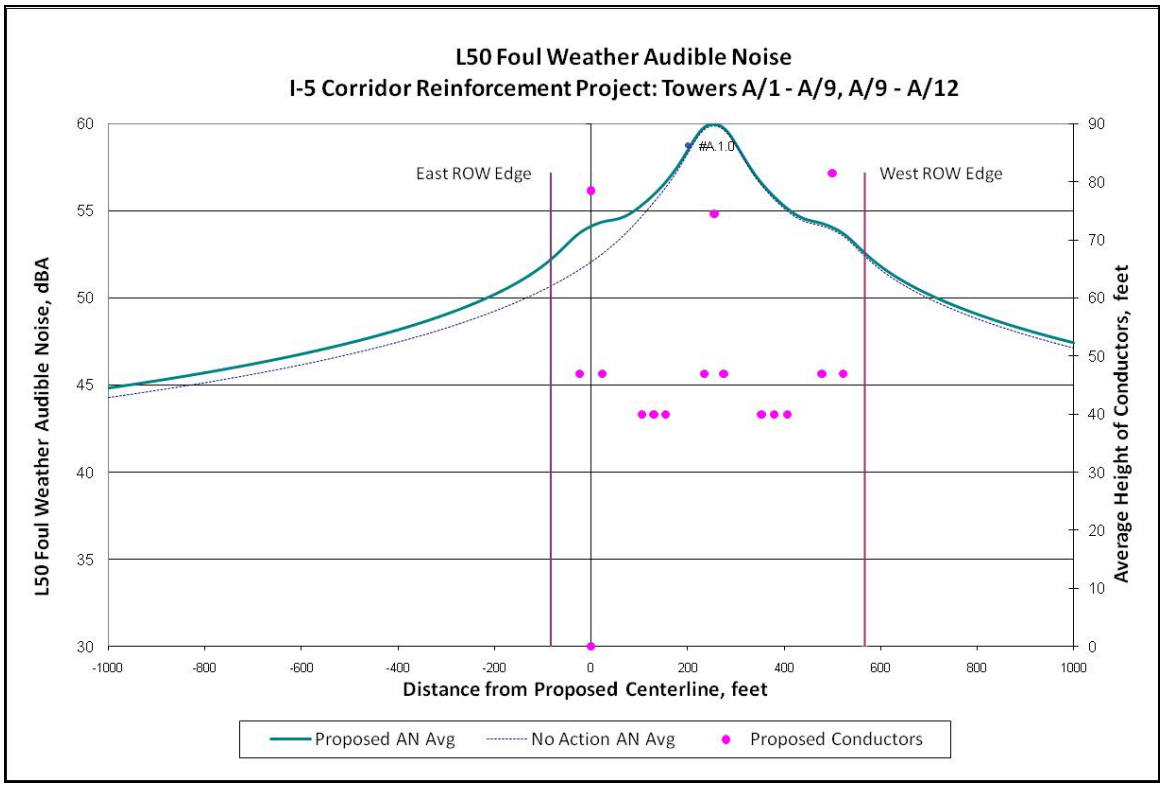


Table 39: Calculation C.1.0

Calculation C.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
C	C/1 - C/17	3.00				
E	E/1 - E/6	1.07				

Calculation C.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		East Edge	West Edge	Peak On ROW	East Edge	West Edge	Peak On ROW
Electric Field, kV/m	No Action	1.3	2.6	5.5	1.3	2.9	9.0
	Proposed	1.2	2.6	5.8	1.3	2.9	8.8
Magnetic Field, mG	No Action	14	18	49	41	73	235
	Proposed	8	19	68	28	74	270
Audible Noise, dBA Foul weather L50	No Action	56.5	51.4	Not Applicable			
	Proposed	56.4	51.6				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	44	36	Not Applicable			
	Proposed	45	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	29	21	Not Applicable			
	Proposed	30	21				

Figure 97: Calculation C.1.0. – Electric Fields

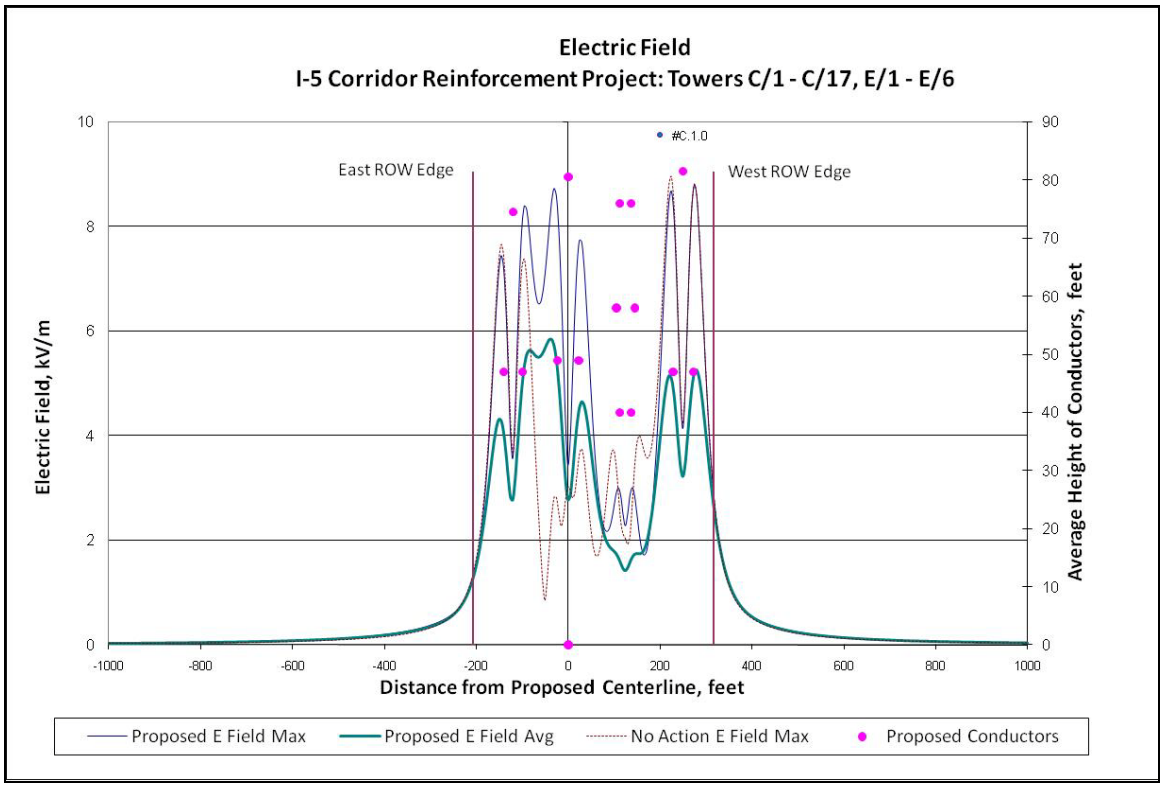


Figure 98: Calculation C.1.0. – Magnetic Fields

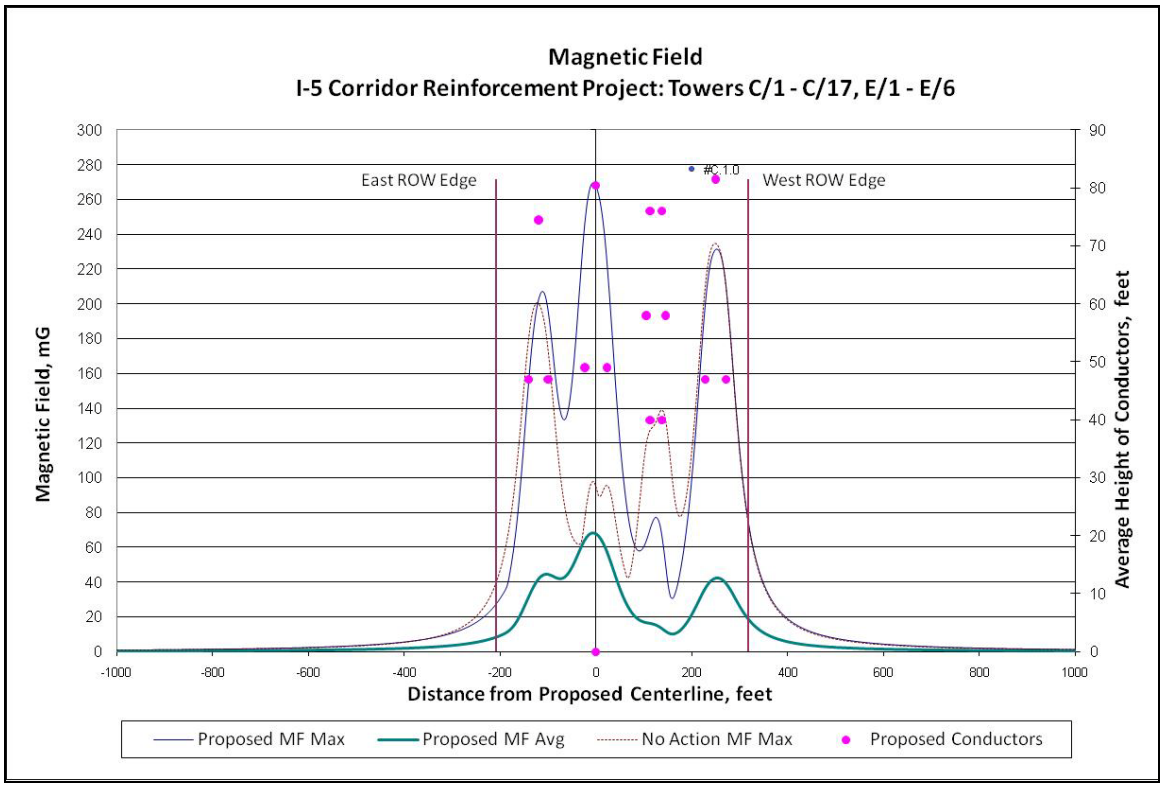


Figure 99: Calculation C.1.0. – Audible Noise Levels

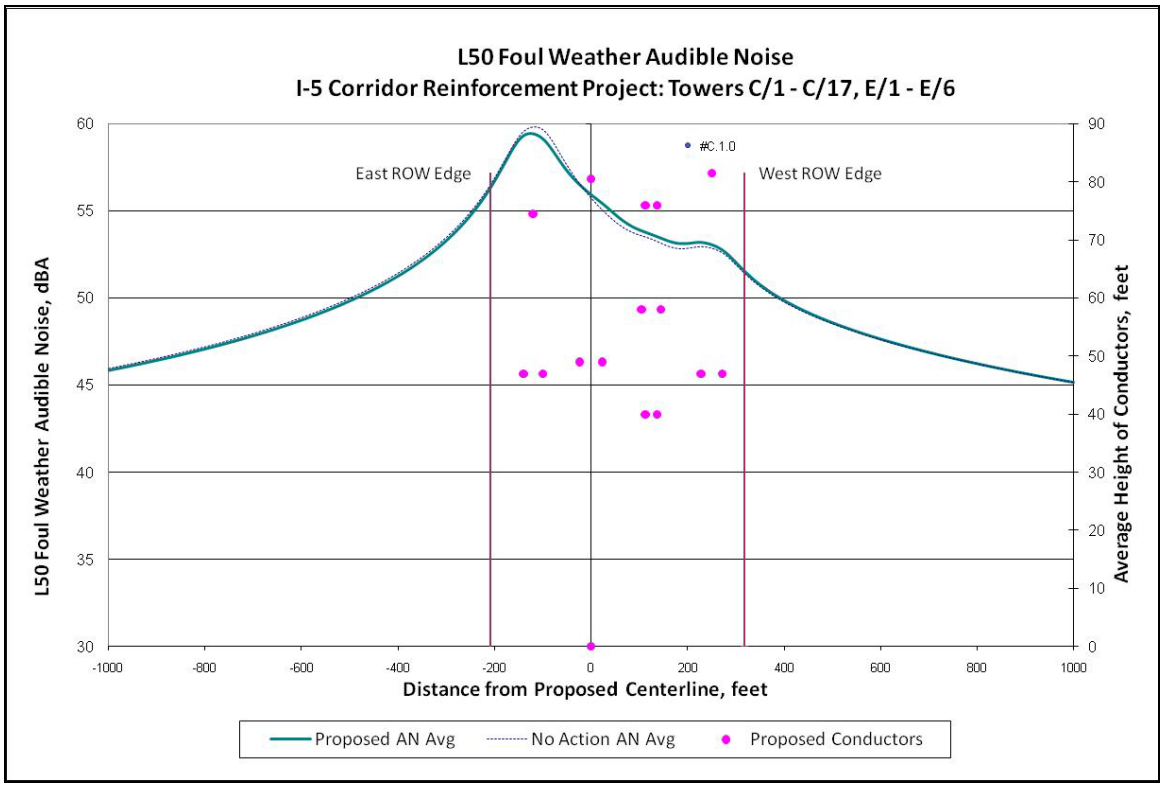


Table 40: Calculation D.1.0

Calculation D.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
D	D/1 - D/17	2.86				

Calculation D.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		East Edge	West Edge	Peak On ROW	East Edge	West Edge	Peak On ROW
Electric Field, kV/m	No Action	0.2	2.6	5.5	0.2	2.9	9.0
	Proposed	1.8	2.6	5.8	1.8	2.9	9.0
Magnetic Field, mG	No Action	3	18	49	8	73	235
	Proposed	8	18	68	31	72	278
Audible Noise, dBA Foul weather L50	No Action	52.7	51.4	Not Applicable			
	Proposed	53.4	51.5				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	44	36	Not Applicable			
	Proposed	37	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	29	21	Not Applicable			
	Proposed	21	21				

Figure 100: Calculation D.1.0. – Electric Fields

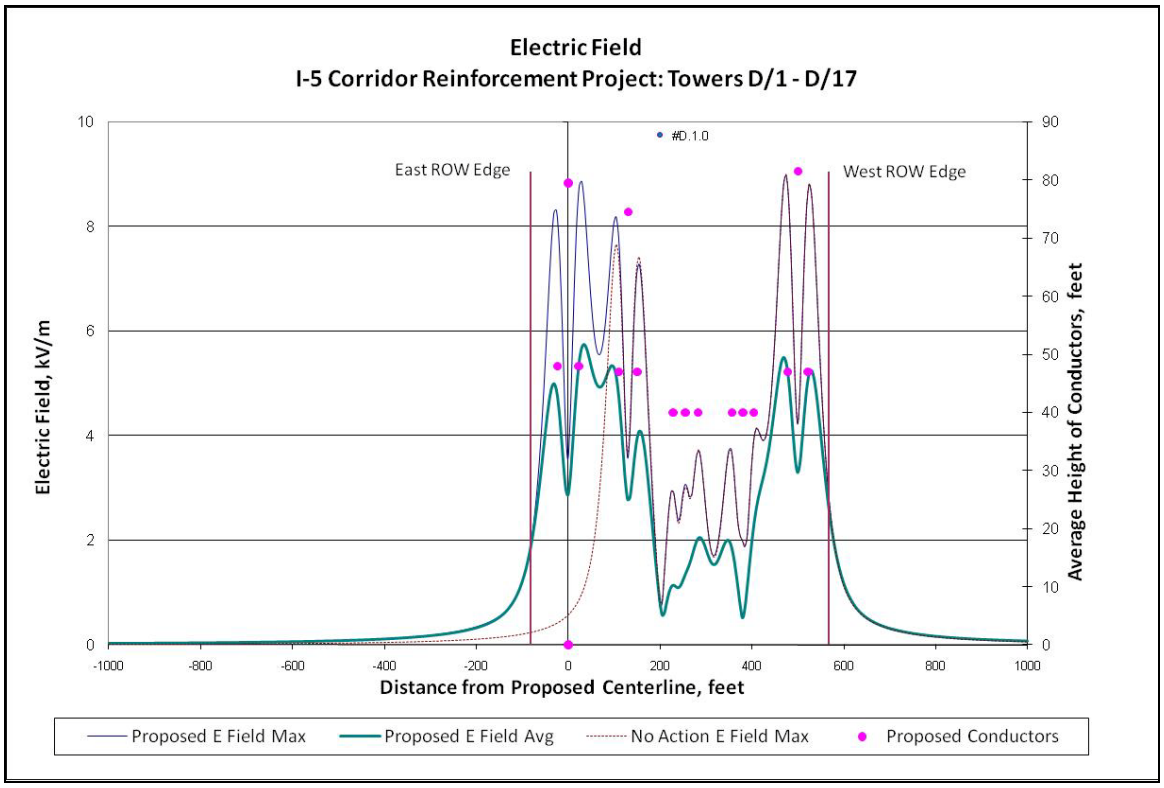


Figure 101: Calculation D.1.0. – Magnetic Fields

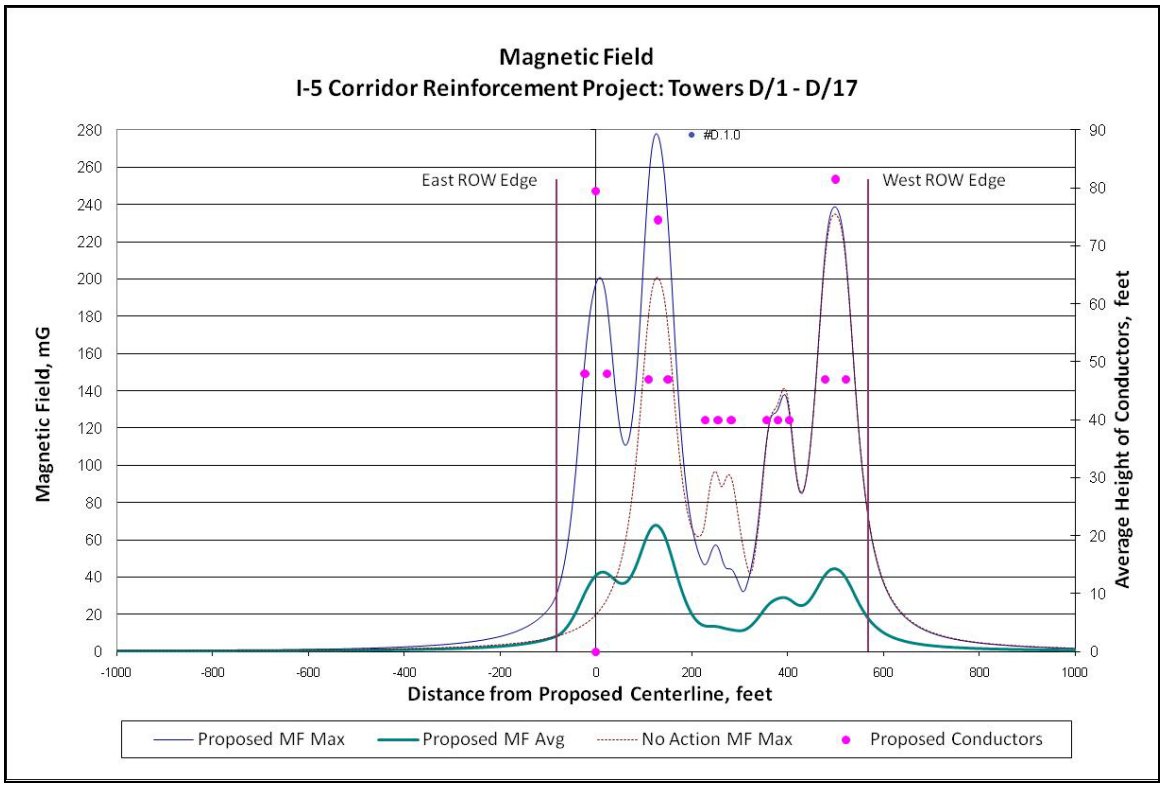


Figure 102: Calculation D.1.0. – Audible Noise Levels

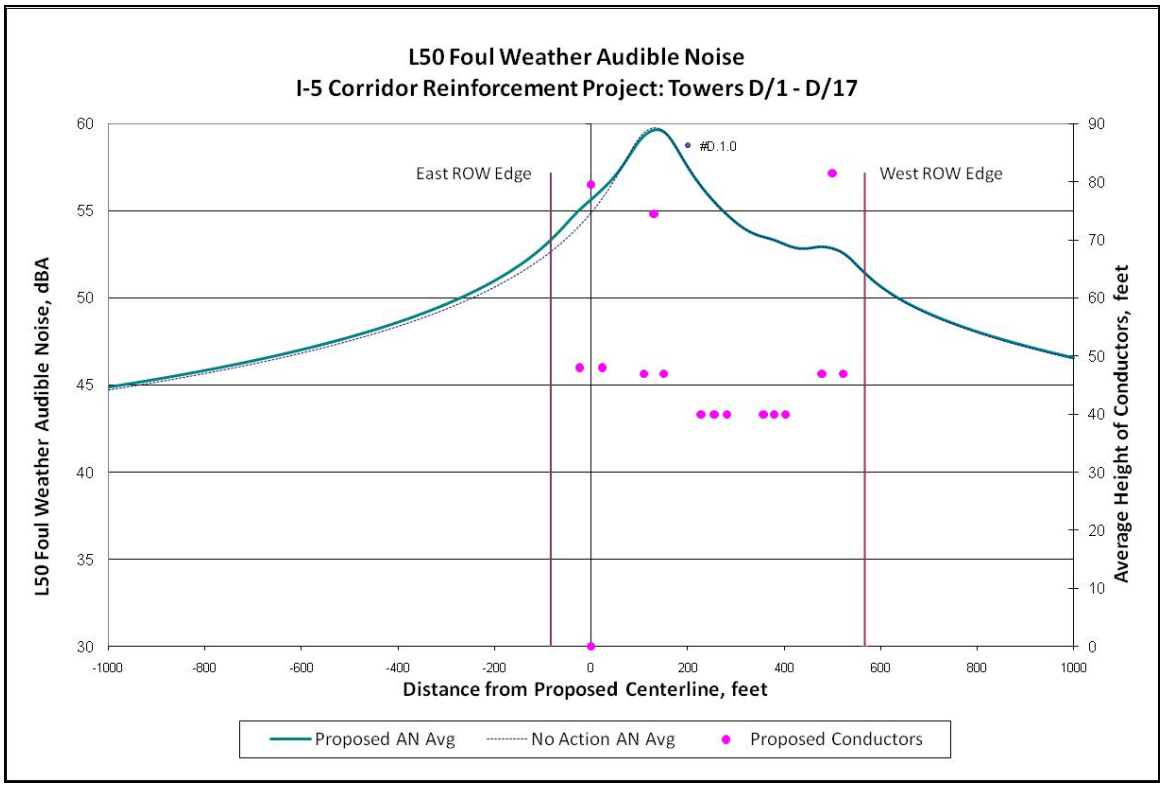


Table 41: Calculation R.1.0

Calculation R.1.0: Electrical Sections						
Segment	Towers	Length		Segment	Towers	Length
R	R/10 - R/19	1.75				

Calculation R.1.0: Summary of Fields and Corona Effects							
	ROW Status	Average			Maximum		
Location		South Edge	North Edge	Peak On ROW	South Edge	North Edge	Peak On ROW
Electric Field, kV/m	No Action	0.3	0.1	2.9	0.1	0.4	5.3
	Proposed	0.3	2.2	5.7	0.4	2.3	8.8
Magnetic Field, mG	No Action	3	4	48	10	6	133
	Proposed	3	9	53	13	42	186
Audible Noise, dBA Foul weather L50	No Action	48.0	47.9	Not Applicable			
	Proposed	48.3	50.0				
Fair Weather RI, dB(uV/m) @ 100 ft from conductors	No Action	29	37	Not Applicable			
	Proposed	29	36				
Foul Weather TVI, dB(uV/m) @ 100 ft from conductors	No Action	12	23	Not Applicable			
	Proposed	13	21				

Figure 103: Calculation R.1.0. – Electric Fields

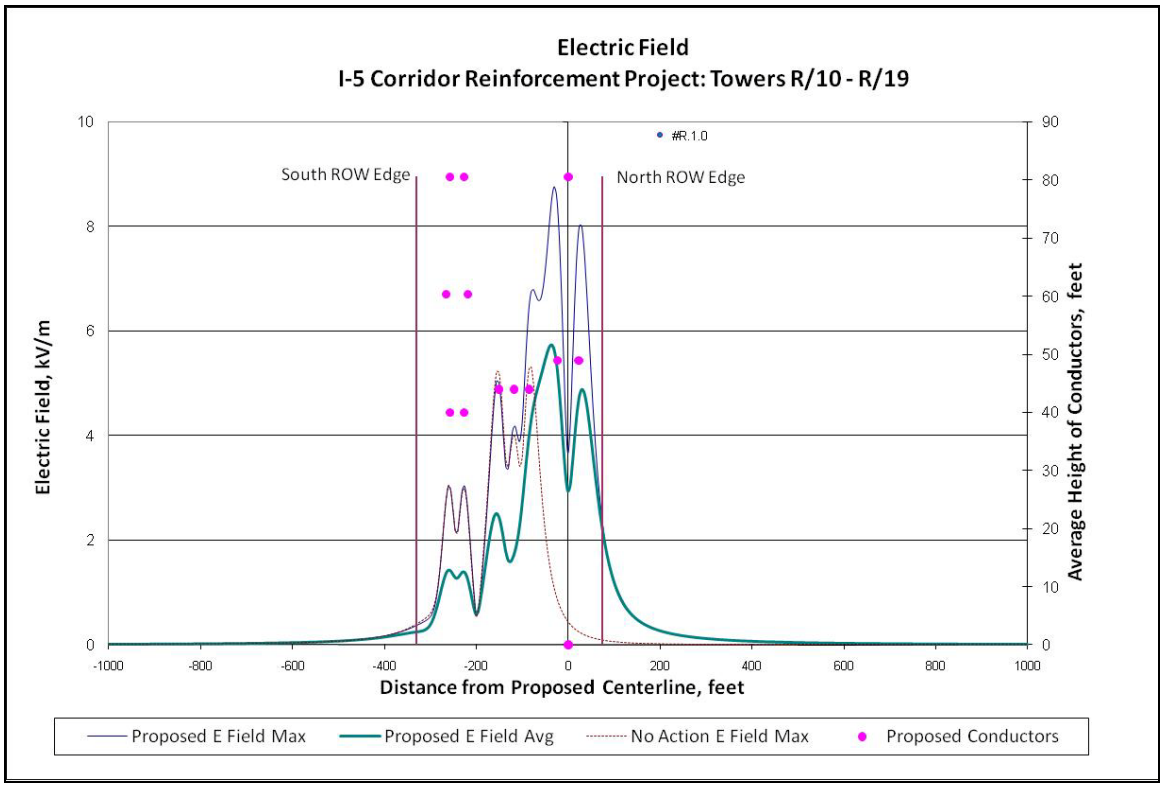


Figure 104: Calculation R.1.0. – Magnetic Fields

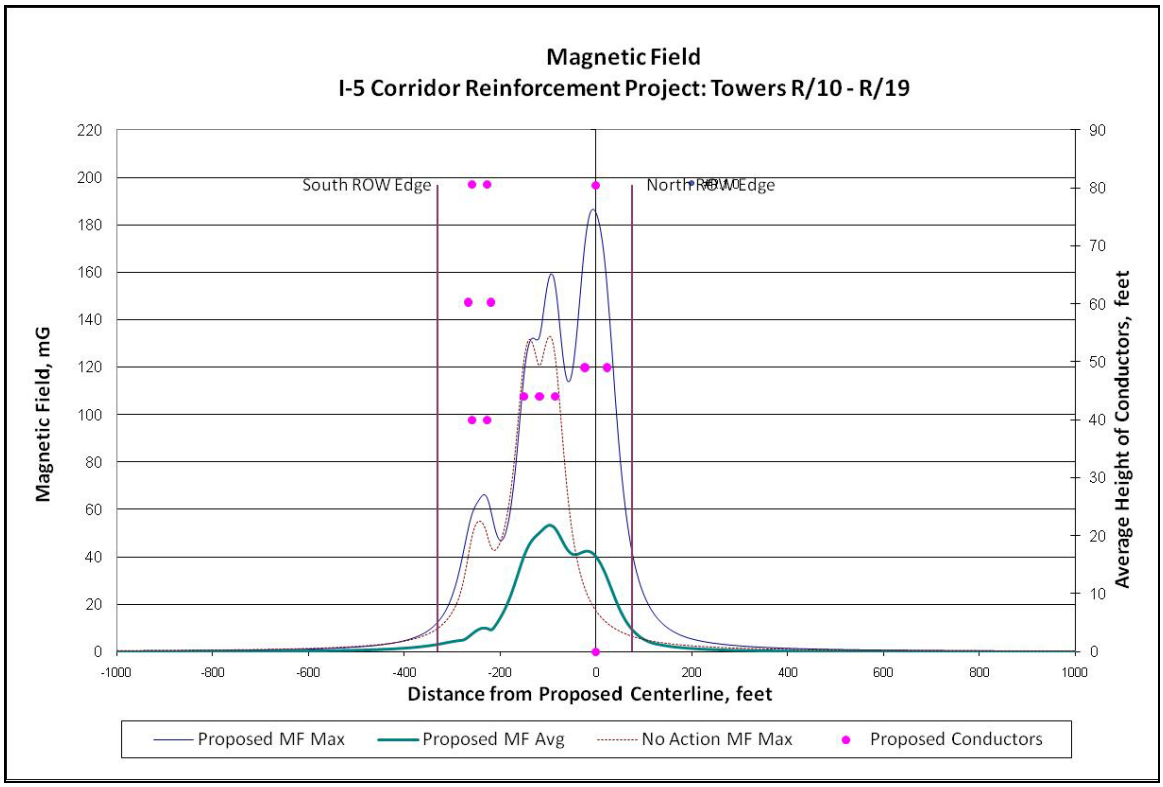
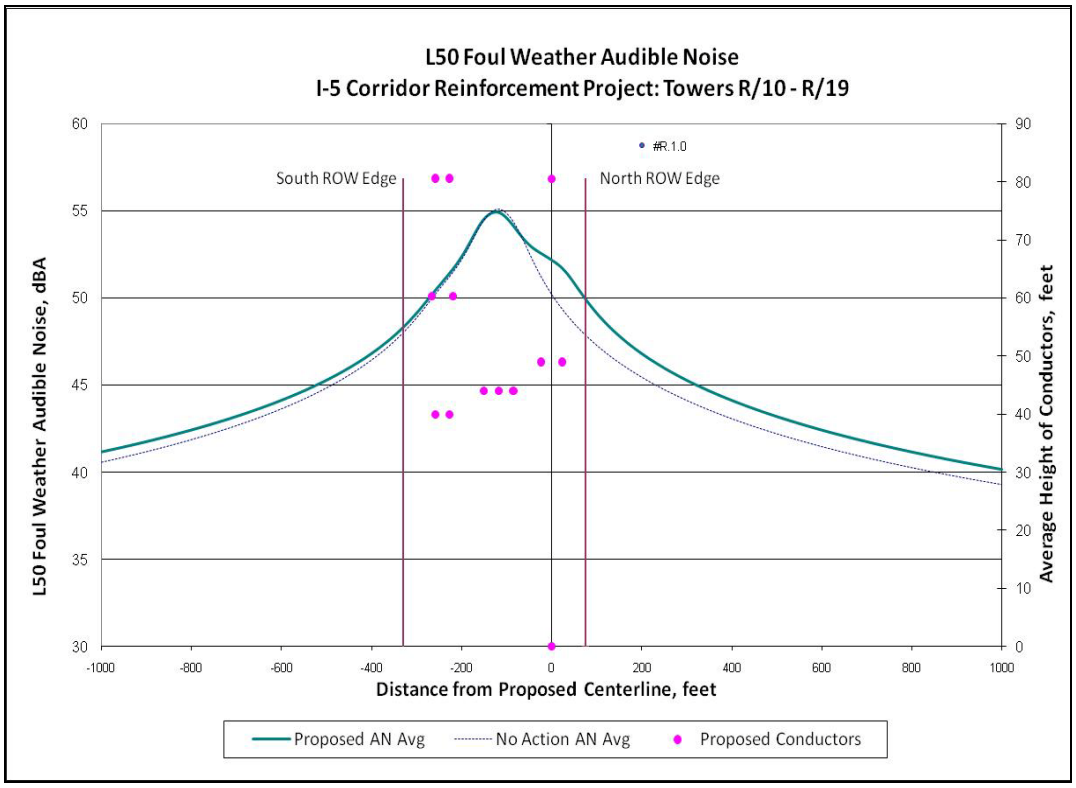


Figure 105: Calculation R.1.0. – Audible Noise Levels



BONNEVILLE POWER ADMINISTRATION
DOE/BP-4390 • November 2012