Siting Standards for Transmission Lines Exhibit

Cascade Renewable Transmission

Wasco, Hood River, and Multnomah Counties, Oregon

November 2025

Prepared for
Cascade Renewable Transmission, LLC

Submitted to
Oregon Energy Facility Siting Council

Contents

1 Introduction 1
2 Analysis Area 1
3 Transmission Line or Related or Supporting Facility (OAR 345-024-0090(3)(a)) 1
3.1 Assumptions and Methods Used in the Analysis (OAR 345-024-0090(3)(a)(F)) 2
3.2 Distance from Proposed Center Line (OAR 345-024-0090(3)(a)(A) through (C)) 4
3.3 Representative Field Strength Along the Proposed Transmission Line (OAR 345-024-0090(3)(a)(D)) 5
3.4 Mitigation Measures to Reduce Electric or Magnetic Fields (OAR 345-024-0090(3)(a)(E)) 7
3.5 Proposed Monitoring Program (OAR 345-024-0090(3)(a)(G)) 8
3.6 Radio and Television Interference (OAR 345-024-0090(3)(b)) 8
4 Conclusions 8

Figures

Figure 1. Example 500-kV Overhead Transmission Tower and Line 3
Figure 2. 230 kV AC Underground Cable Trench Profile, 3ft-8in Burial Below Grade 4
Figure 3. Electric Field Plot, 500 kV Overhead Line, 3.28 feet (1 meter) Above Grade 6
Figure 4. Magnetic Field Plot, 500 kV Overhead Line, 3.28 feet (1 meter) Above Grade 6
Figure 5. Magnetic Field Plot, 230 kV AC Cable Circuits Buried 3 feet 8 inches Below Grade 7

Tables

Table 1. Buildings with 200 feet of Proposed 230-kV AC Transmission Center Line 5
Table 2. Modeling Analysis for 60Hz, 500kV, AC Overhead Line and 230kV AC Underground Cables 5

Attachments

Attachment 1. January 2024 Memo: Cascade HVDC High Voltage Tie Line EMF Levels

Acronyms

μT	microtesla
AC	alternating current
Applicant	Cascade Renewable Transmission (CRT)
Arms	amps root mean squared
BPA	Bonneville Power Administration
CDEGS	Current Distribution, Electromagnetic Fields, Grounding, and Soil Structure Analysis software
HDD	horizontal directional drilling
HDPE	high-density polyethylene
HVAC	high-voltage alternating current
HVDC	high-voltage direct current
Hz	hertz
kV	kilovolt
kV/m	kilovolts per meter
MW	megawatt
OAR	Oregon Administrative Rules
ROW	right-of-way
SES	SES & Technologies, Ltd.
XLPE	cross-linked polyethylene

1 Introduction

This exhibit meets the submittal requirements related to electric and magnetic fields for the Cascade Renewable Transmission Project (Project), per Oregon Administrative Rules (OAR) 345-024-0090. Analysis in this exhibit demonstrates that the proposed high-voltage (400-kilovolt [kV]) direct current (HVDC) 1,100-megawatt (MW) electric transmission facility (Facility) complies with the applicable site certificate standard.

OAR 345-024-0090 Specific Standards for Siting Facilities

To issue a site certificate for a facility that includes any transmission line under Council jurisdiction, the Council must find that the applicant:

(1) Can design, construct and operate the proposed transmission line so that alternating current electric fields do not exceed 9 kV per meter at one meter above the ground surface in areas accessible to the public;

(2) Can design, construct and operate the proposed transmission line so that induced currents resulting from the transmission line and related or supporting facilities will be as low as reasonably achievable.

2 Analysis Area

The Project Order identifies the analysis area for this exhibit as within transmission lines rights-of-way (ROW). The Project Order also indicates that because the proposed Facility would include alternating current (AC) transmission lines and supporting facilities, this exhibit must include the information about the expected electric and magnetic field from each transmission line required under OAR 345-024-0090(3)(a), and information about any radio interference likely to be caused by the transmission line. As requested in the Project Order, only sections of the Project that include AC lines are discussed in this exhibit.

3 Transmission Line or Related or Supporting Facility (OAR 345-024-0090(3)(a))

(3) If the proposed energy facility is a transmission line or has, as a related or supporting facility, a transmission line of any size:

(a) Information about the expected electric and magnetic fields, including:

RESPONSE

The Applicant proposes to construct and operate the Facility interconnecting the existing Bonneville Power Administration (BPA) Big Eddy 500kV AC substation located near The Dalles, Wasco County, Oregon (Eastern Interconnection), and the existing Portland General Electric (PGE) Harborton 230-kV AC substation located in Portland, Multnomah County, Oregon (Western Interconnection) (see Figure 10 in the Background Information Exhibit).

The Project requires AC transmission interconnection (tie lines) from the Big Eddy 500-kV substation to the eastern converter station and from the western converter station to the Harborton substation.

The eastern converter station would be connected to the existing Big Eddy substation with approximately 500 feet of 500-kV overhead high-voltage alternating current (HVAC) wire, which would be supported by two new lattice structures approximately 80 feet wide and 60 feet tall. One lattice structure would be located in the Big Eddy substation and one lattice structure would be within the eastern converter station; however, the lattice structure associated with the Big Eddy substation would not be part of the Facility.

The western converter station would connect to the Harborton substation with approximately 3.05 miles of two-per-phase, 230-kV HVAC transmission cable installed underground. To cross railroads, or sensitive areas, the transmission cable would be placed with horizontal directional drilling (HDD) or similar trenchless technology such as horizontal auger boring (HAB). Of the 3.05 miles of cable, 0.25 mile would be installed under and across the bed of the Columbia Slough via HDD; 2.3 miles would be trenched in road ROW to the edge of the Willamette River; and 0.5 miles of transmission cable would be installed under and across the bed of the Willamette River via HDD. The trench for the underground HVAC transmission cables would be approximately 9 feet wide by 4.5 feet deep. Within the trench, two 3.5-foot-wide concrete casings would be placed 2 feet apart, each housing three 8-inch high-density polyethylene (HDPE) conduits for transmission cables and two 2-inch HDPE conduit for fiber optic cables. Once complete, backfill would be used from the ductbank to restore grade level. Under the Willamette River and Columbia Slough, each location would have two 34-inch bores with a 12-foot separation. Each bore would hold three 8-inch and two 2-inch HDPE conduits. No overhead transmission line structures would connect the western converter station to the Harborton substation.

3.1 Assumptions and Methods Used in the Analysis (OAR 345-024-0090(3)(a)(F))

(F) The assumptions and methods used in the electric and magnetic field analysis, including the current in amperes on each proposed transmission line;

RESPONSE

For the modeling of the electric and magnetic fields of the 500 kV AC overhead transmission line, a 5L9 tower profile is assumed for a typical 500 kV line rated to transfer 1,100 MW (Figure 1). This 500-kV line uses a 2 x 2,156 kilo circular mils (kcmil), aluminum conductor steel reinforced (ACSR) conductor bundle (18-inch spacers) per phase with 7x#8 Alumoweld shield wires. The 500-kV line is assumed at 3.28 feet above grade and centered on a 200-foot-wide ROW. The 500-kV overhead line is modeled in the SES & Technologies, Ltd. (SES) Current Distribution, Electromagnetic Fields, Grounding, and Soil Structure Analysis (CDEGS) software. A 60 hertz (Hz), AC current of 1,311 amps root mean squared (Arms) per phase, with a 120 degree phase displacement is applied to the circuit (see memo in Attachment 1).

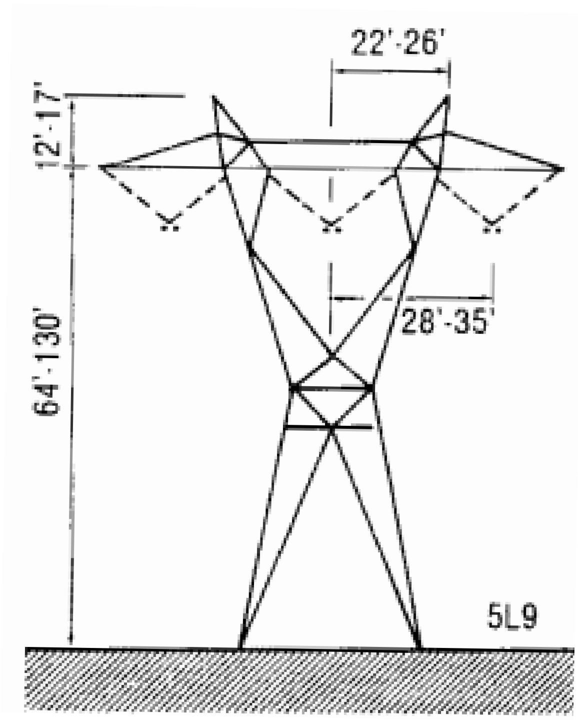

Figure 1. Example 500-kV Overhead Transmission Tower and Line

For the 230-kV AC underground cables, the underground cable system will be cross-linked polyethylene (XLPE) insulated so electric field outside of the cables will be 0 volts per meter (V/m) since the electric field is completely contained within the cable between the high-voltage main conductor and the grounded screen conductor.

Six single core, XLPE-insulated, 230-kV class cables with 2,500 square millimeters (mm^2) copper main conductors installed in two duct banks were modeled for the magnetic fields of the underground cable. Backfill would be used from the ductbank to grade level with the cables buried 3 feet 8 inches below the grade (Figure 2). Magnetic fields were calculated using the SES CDEGS software package HIFREQ module, assuming the underground cables are operating with a 60Hz, AC voltage of 230 kV (132.8 kV phase to ground) with 1,456 Arms flowing in each of the six cables. The phase currents in each circuit were displaced by 120 degrees.

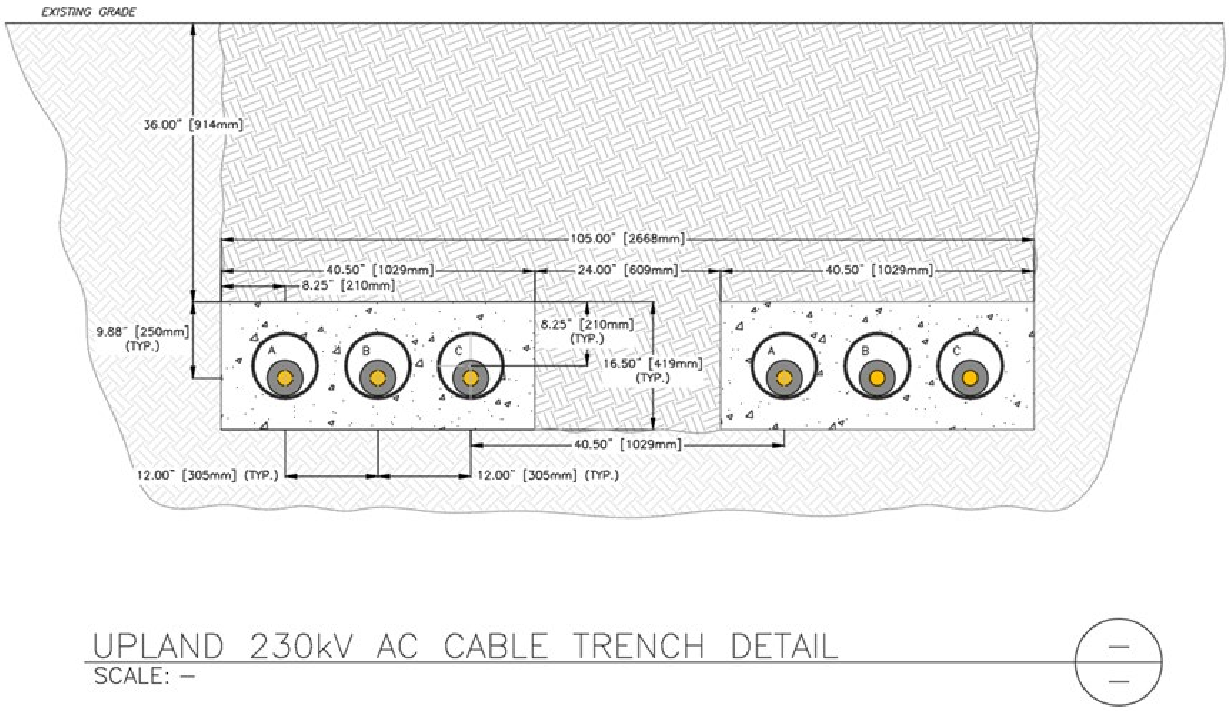

Figure 2. 230 kV AC Underground Cable Trench Profile, 3ft-8in Burial Below Grade

3.2 Distance from Proposed Center Line (OAR 345-024-0090(3)(a)(A) through (C))

(A) The distance in feet from the proposed center line of each proposed transmission line to the edge of the right-of-way;

(B) The type of each occupied structure, including but not limited to residences, commercial establishments, industrial facilities, schools, daycare centers and hospitals, within 200 feet on each side of the proposed center line of each proposed transmission line;

(C) The approximate distance in feet from the proposed center line to each structure identified in (A);

RESPONSE

For this analysis, the 500-kV overhead transmission line was centered on a 200-foot ROW, so the distance in feet from the proposed center line to the edge of the ROW is 100 feet. However, BPA has not yet determined the exact width of this ROW. For the underground AC cable, the ROW corridor would be 9 feet wide, so the distance in feet from the proposed center line to the edge of ROW is 4.5 feet.

The analysis in this exhibit examines field strength out to 200 feet from the centerline.

There are no known or occupied buildings, residences, or other sensitive receptors within 200 feet of the proposed 500-kV AC overhead transmission line.

There are no known residences within 200 feet of the proposed 230-kV AC underground transmission cables; however, there are multiple industrial facilities that are within this radius. Table 1 shows buildings within 200 feet of the proposed 230-kV AC underground transmission cable center line.

Table 1. Buildings with 200 feet of Proposed 230-kV AC Transmission Center Line

Type of Structure	Approximate Distance to Centerline of Project Facility (Feet)
Chemical Manufacturer	75
Distribution Center	90
Distribution Center	95
Distribution Center	95
Machine Shop	100
Distribution Center	100
Machine Shop	130
Distribution Center	150
Distribution Center	170
Industrial Bakery	200

3.3 Representative Field Strength Along the Proposed Transmission Line (OAR 345-024-0090(3)(a)(D))

(D) At representative locations along each proposed transmission line, a graph of the predicted electric and magnetic fields levels from the proposed center line to 200 feet on each side of the proposed center line;

RESPONSE

Table 2 shows the results of the modeling analysis for the 60 Hz, 500-kV AC overhead transmission line and the 230-kV AC underground transmission cables.

Table 2. Modeling Analysis for 60Hz, 500kV, AC Overhead Line and 230kV AC Underground Cables

Circuit	Conductors	Current per conductor	Peak Magnetic Field at 3.28 feet above grade (μT)	Peak Electric Field at 3.28 feet above grade (kV/m)
500 kV, 60 Hz	2/C per phase	656 Arms	9.5	3.23
230 kV, 60 Hz	2/C per phase	1,456 Arms	43.2	0

μT=microtesla; kV/m=kilovolts per meter

The proposed overhead transmission line has a maximum electric field of 3.23 kilovolts per meter (kV/m) approximately 41 feet from the center of the centerline of the tower, decreasing to 0.98 kV/m at the edges of the 200-foot ROW. Figure 3 provides a graph of the electric field calculations for the 500-kV overhead line from the proposed centerline to 100 feet on each side of the proposed center line.

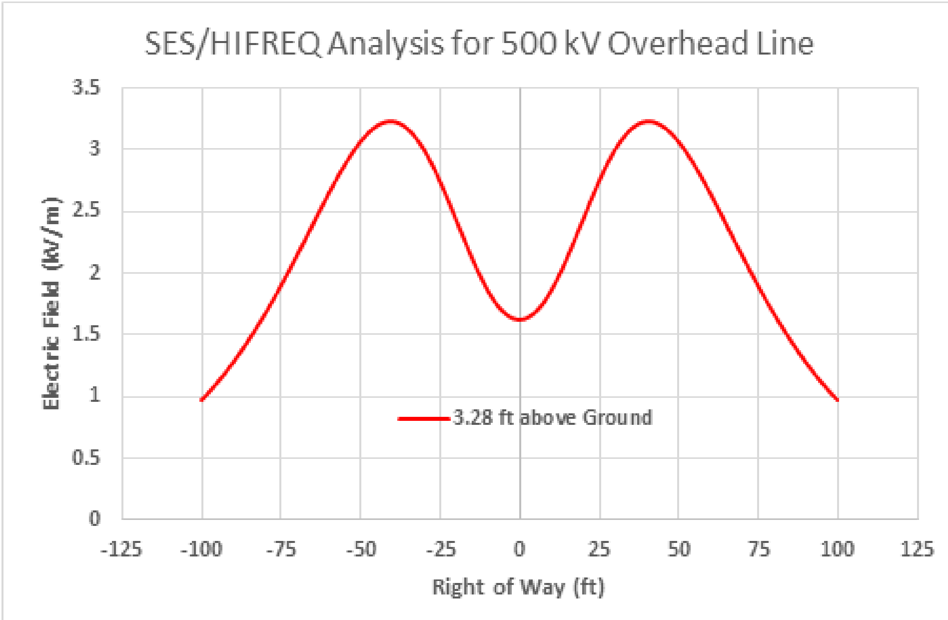

Figure 3. Electric Field Plot, 500 kV Overhead Line, 3.28 feet (1 meter) Above Grade

The proposed 500-kV AC overhead transmission line is estimated to have a maximum magnetic field of 9.5 microtesla (μT) at 3.28 feet (1 meter) above grade when 25 feet from the centerline of the tower, decreasing to 3.6 μT at the edges of the 200-foot ROW. Figure 4 shows the magnetic field plot of the 500-kV AC overhead transmission line for a maximum of 100 feet on each side of the proposed center line.

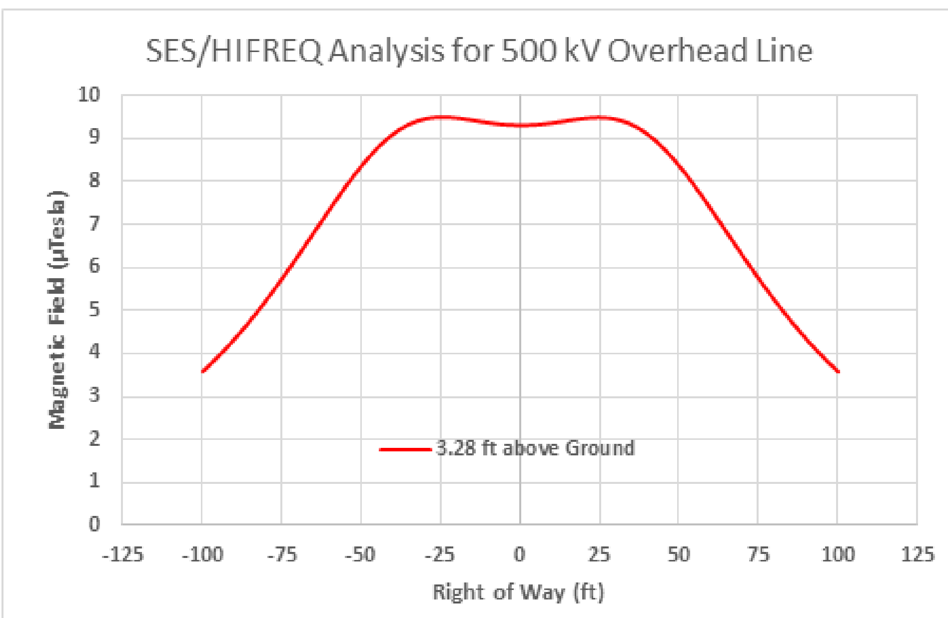

Figure 4. Magnetic Field Plot, 500 kV Overhead Line, 3.28 feet (1 meter) Above Grade

The electric field of the proposed 230-kV AC underground transmission cables would be completely contained within the cable between the high voltage main conductor and the grounded screen conductor. Therefore, it has an electric field of 0 kV/m.

The proposed 230-kV AC underground transmission cables are estimated to have a maximum magnetic field of 43.2 µT at 3.28 feet (1 meter) above grade when less than 10 feet from the centerline of the ROW, decreasing rapidly to almost 0 µT at approximately 60 feet from the proposed centerline. Figure 5 shows the magnetic field plot of the 230-kV AC underground transmission cables for a maximum of 60 feet on each side of the proposed centerline.

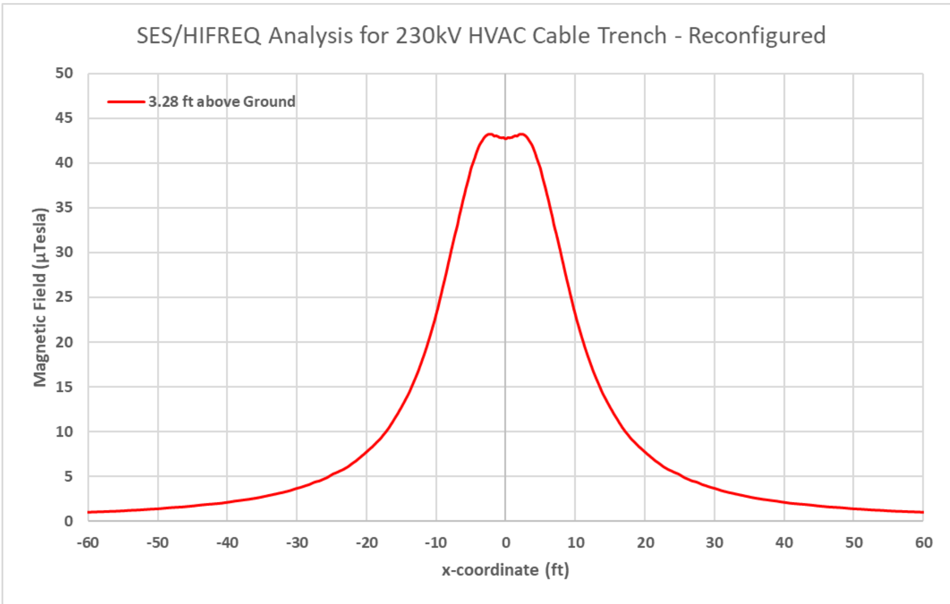

Figure 5. Magnetic Field Plot, 230 kV AC Cable Circuits Buried 3 feet 8 inches Below Grade

3.4 Mitigation Measures to Reduce Electric or Magnetic Fields (OAR 345-024-0090(3)(a)(E))

(E) Any measures the applicant proposes to reduce electric or magnetic field levels;

RESPONSE

The electric fields of both the underground AC transmission cables and overhead AC transmission lines are well below the threshold set by OAR 345-024-0090(1), which is a limit of 9 kV/m at 1 meter above the ground surface in areas accessible to the public. Therefore, no mitigation measures are proposed.

The magnetic fields of both the underground and overhead transmission lines are well below the International Commission on Non-Ionizing Radiation Protection's limit of 200 µT to the general public and the Institute of Electrical and Electronic Engineers' (IEEE) standard C95.1-2019/Cor2-2020 limit of 904 µT for exposure to the general public (Attachment 1). Therefore, no mitigation measures are proposed.

3.5 Proposed Monitoring Program (OAR 345-024-0090(3)(a)(G))

(G) The applicant's proposed monitoring program, if any, for actual electric and magnetic field levels; and

RESPONSE

Due to the estimates for electric and magnetic fields being well below industry and state standards, the Applicant proposes no monitoring program.

3.6 Radio and Television Interference (OAR 345-024-0090(3)(b))

(b) An evaluation of alternate methods and costs of reducing radio interference likely to be caused by the transmission line in the primary reception area near interstate, U.S. and state highways.

RESPONSE

Radio and television interference is caused by corona discharge from the line. This discharge is greatest during rainy weather conditions but can also occur if there is excessive dust or debris on the transmission line. Interference may be noticed as a humming or buzzing sound on weak AM radio signals or as bands of snow across the picture in television signals received by an over-the-air broadcast signal. FM radio signals and digital satellite or cable television signals are not affected.

The 500-kV AC overhead transmission line is proposed to be approximately 500 feet long spanning between the eastern converter station and the Big Eddy substation. There are no occupied residences near this transmission line; therefore, technology like radios and televisions are unlikely to be nearby. Based on this information, radio or television interference is not expected to occur due to the corona effect from this transmission line during inclement weather or other nonoptimal conditions. The underground transmission cables would not be affected by the atmospheric conditions that cause corona discharge, so radio and television interference is not expected.

4 Conclusions

Section 3.3 and Section 3.4 explain that both transmission lines would not exceed the electric field threshold at 3.28 feet (1 meter) above the ground surface. The underground transmission line has an electric field of 0 kV/m, while the overhead transmission line has an electric field of up to 3.23 kV/m, which is well below the threshold of 9 kV/m.

Both transmission lines have low magnetic fields according to industry standards, as discussed in Section 3.4. Both proposed transmission lines are expected to have low electric and magnetic fields compared to industry and state thresholds. The overhead line has a possibility of creating a corona discharge, but it is not near any residences so interference with radios and televisions is unlikely. Due to being well within the safety thresholds for both electric and magnetic fields, mitigation and monitoring measures are not required.

Attachment 1. January 2024 Memo: Cascade HVDC High Voltage Tie Line EMF Levels

Specialist Consultants
to the Electricity Industry

.Ref: MEMO JU9953 Cascade EMF AC Tie Lines rev01

Date: 09-January-2024

To: Ernie Griggs

From: Bradley D. Railing, P.E.
PSC HVDC North America

PowerBridge – Cascade HVDC High Voltage Tie Line EMF Levels

1. Introduction

PowerBridge is developing the Cascade Renewable Transmission Project ("Cascade") to transmit approximately 1,100 MW of renewable resources to help Oregon and Washington meet their renewable energy requirements. Cascade will utilize HVDC transmission technology consisting of two, up to ±400 kV HVDC converter stations and up to ±400 kV DC cable system connected between interconnection points near the Big Eddy Substation and the Harborton Substation as shown by Figure 1.

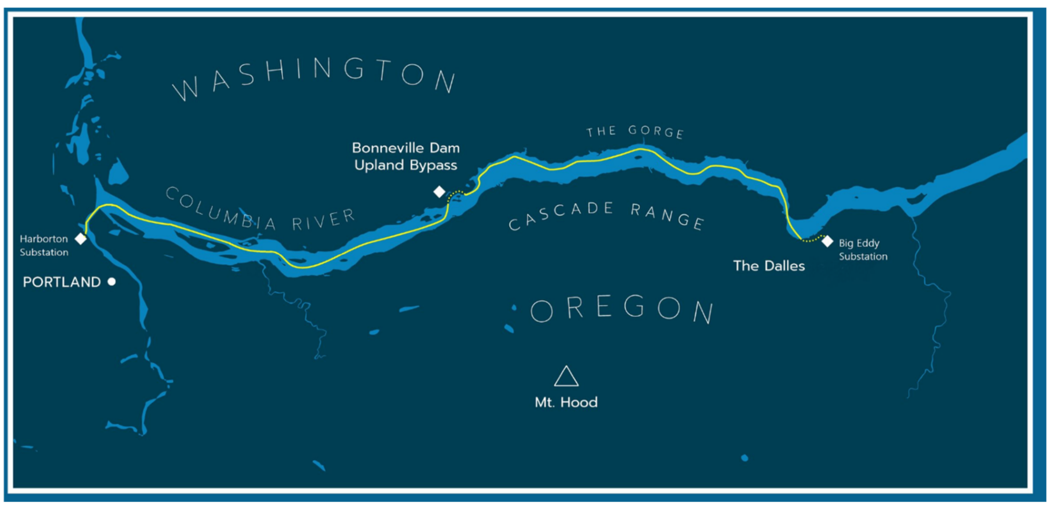

Figure 1 – Cascade Renewable Transmission Project

Cascade's HVDC cable system will consist of approximately 16 miles of underground cable, and 80 miles of submarine cable in the Columbia River. High voltage AC tie-lines will be required at 500 kV near the Big Eddy Substation and at 230 kV near the Harborton Substation. The 500 kV tie line will be a short overhead line while the 230 kV tie line will be XLPE insulated, underground cable system.

Part of the environmental permit preparation is to investigate the electric and magnetic fields (EMF) in the vicinity of the 500 kV and 230 kV tie lines.

This memo report provides a discussion for the electric and magnetic field plots and provides a draft of the narrative that can be included in the Cascade environmental filings for the 500 kV and 230 kV, AC tie lines.

2. Draft Narrative Cascade HVDC AC 500 kV and 230 kV Tie Lines - EMF Levels

The Cascade HVDC 1,100 MW cable system will be comprised of two solid dielectric, XLPE (cross-linked polyethylene) insulated with a steady state operating voltage up to ±400 kV DC. Cable system routing will include approximately 80 miles of submarine cable buried in the Columbia River and 16 miles of underground cable.

The AC tie line from the Big Eddy 500 kV substation to the eastern HVDC converter station will be an overhead line approximately 500 feet long.

The AC tie line from the Harborton Substation to the western HVDC converter station will be an underground cable system approximately 2.75 miles long.

2.1 Electric Field 230 kV AC Underground Cables

The electric field outside of the cables, due to the voltage applied to the high voltage cables, will be 0 V/meter since the electric field is completely contained within the cable between the high voltage main conductor and the grounded screen conductor.

2.2 Magnetic Field 230 kV AC Underground Cables

Magnetic fields were calculated and plotted by the SES CDEGS software package using the HIFREQ module [1]. It will require two, 3-phase, 230 kV cable circuits to transfer 1,100 MW from the western HVDC converter station to the Harborton 230 kV Substation. This will require (6) single core, XLPE insulated, 230 kV class cables with 2,500mm^2 copper main conductors installed in two duct banks.

The plots assume the underground cables are operating with a 60Hz, AC voltage of 230 kV (132.8 kV phase to ground) with 1,456 Arms flowing in each of the six cables. The phase currents in each circuit are displaced by 120°.

Figure 2 shows the trench profile that was used for the 230 kV underground circuit magnetic field plots. Each of the six high voltage cables are installed in conduits, with three conduits in each concrete ductbank. Backfill is used from the ductbank to grade level. The cables are buried 3ft-8in below the grade.

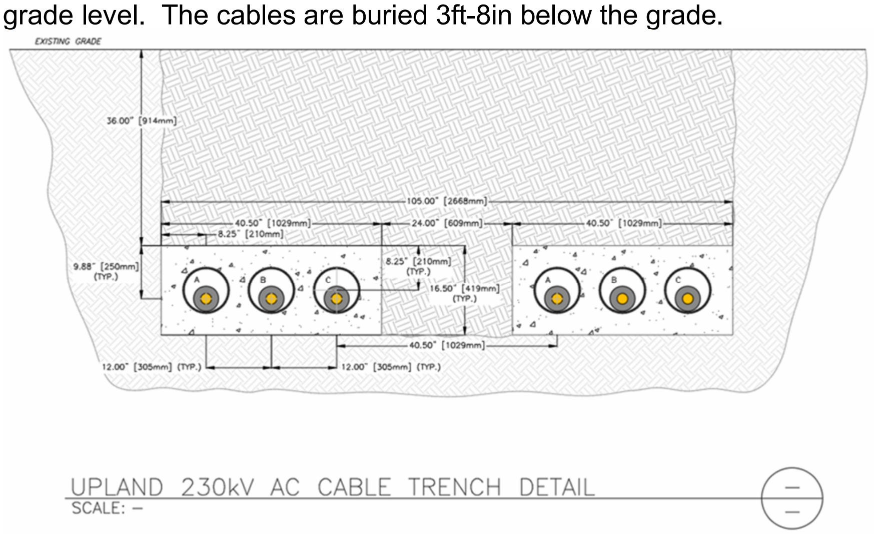

Figure 2 – 230 kV AC Underground Cable Trench Profile, 3ft-8in Burial Below Grade

Figure 3 shows magnetic field plot produce by the 230 kV circuits. The magnetic field is plotted at 3.28 feet above grade.

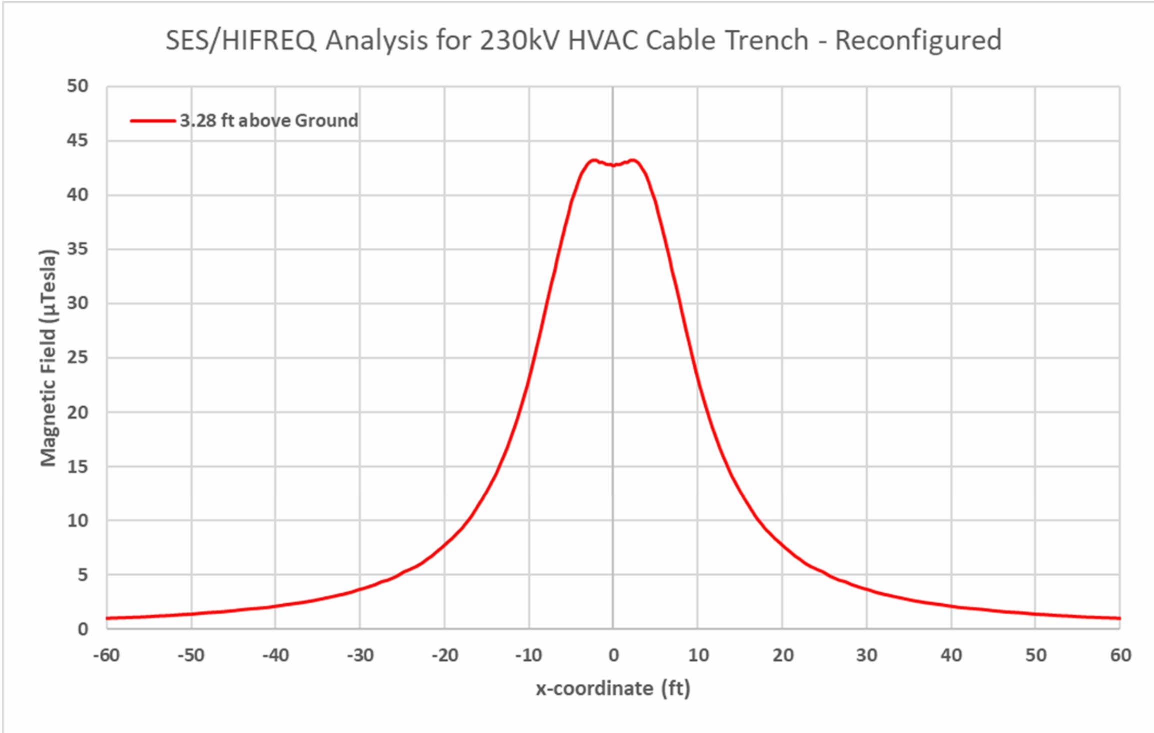

Figure 3 – Magnetic Field Plot, 230 kV AC Cable Circuits Buried 3ft-8in feet below grade

The magnetic field due to the 1,456 Arms, 60Hz current per cable has a maximum field, 3.28 feet directly above grade of approximately 43.2 µT. It can be observed in Figure 3 that the magnetic fields rapidly diminish from the centerline of the cable circuit. These small magnetic fields from the cable circuit would add or subtract to the earth's geomagnetic field of approximately 54 to 55 µT [2].

The magnetic fields in Figure 3 are well below (1) the ICNIRP (International Commission on Non-Ionizing Radiation Protection) limit of 200µT to the general public [3] and (2) the IEEE (Institute of Electrical and Electronic Engineers) standard C95.1-2019/Cor2-2020 limit of 904µT [4] for exposure to the general public.

2.3 Electric and Magnetic Field 500 kV AC Overhead Line

This section provides the electric and magnetic field plots of a 500 kV, 60 Hz AC overhead line circuit that would be required to transfer 1,100 MW.

Figure 5 shows the overhead line tower profile that was used for the 500 kV overhead line circuit electric and magnetic field plots. A 5L9 tower profile [5] was assumed for a typical 500 kV line rated to transfer 1,100 MW. This 500 kV line uses a (2) x 2,156 kcmil, ACSR conductor bundle (18-inch spacers) per phase with 7x#8 Alumoweld shield wires. The 500 kV line is assumed to be centered on a 200-foot wide right of way.

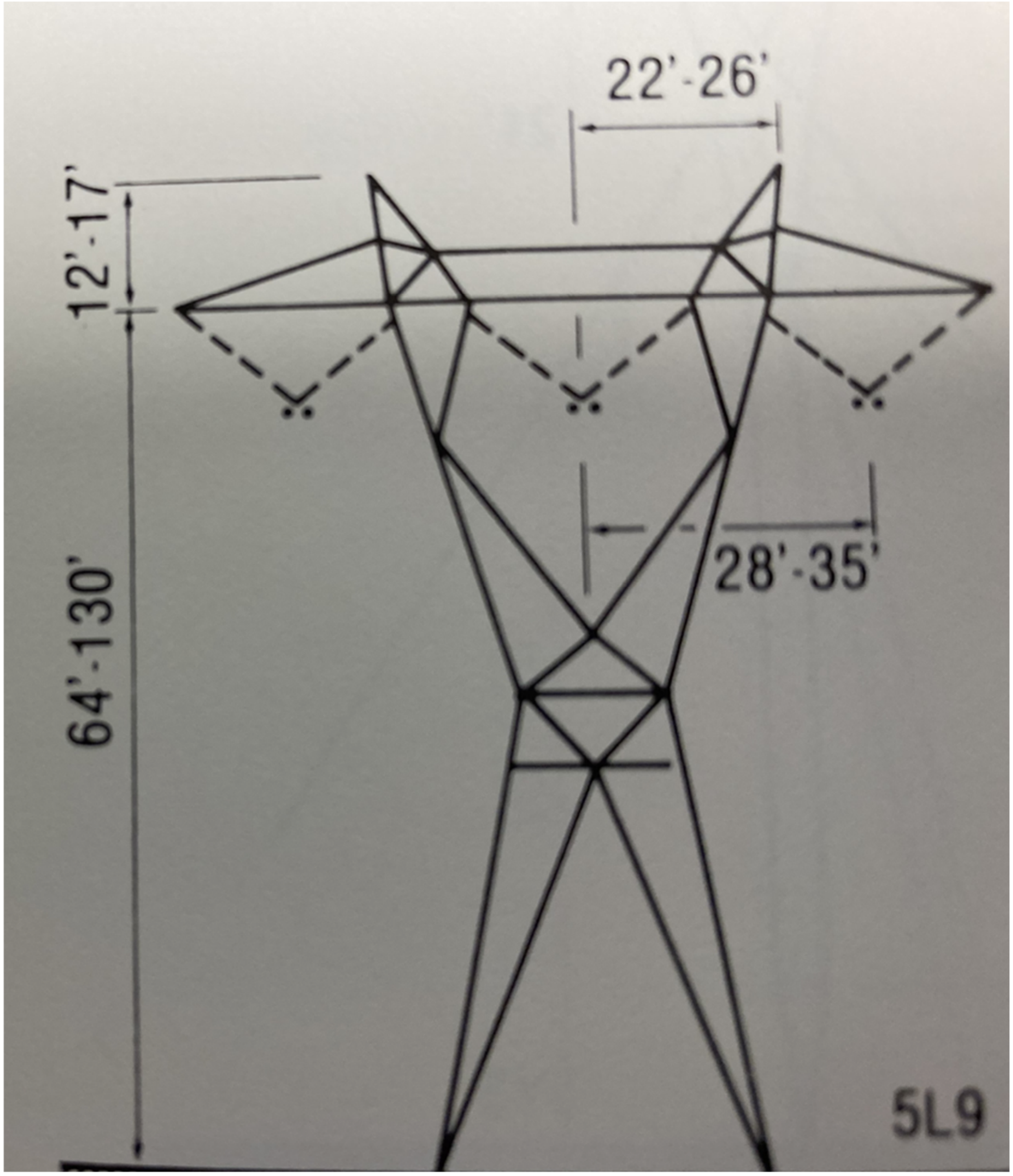

Figure 5 – 500 kV Overhead Line Example 5L9 Tower, 200-foot wide ROW

The 500 kV overhead line was modeled in the SES CDEGS software, and a 60Hz, AC current of 1,311 Arms per phase, with a 120° phase displacement, was applied to the circuit.

Figure 6 shows magnetic field plot of the 500 kV overhead line for the 200-foot width of the right of way. The magnetic field is plotted 3.28 feet above the grade. The magnetic field due to the 1,311 Arms, AC current flowing in the 500 kV overhead line has a maximum field of 9.5 μT at 25 feet from the center of the tower, decreasing to 3.6 μT at the edges of the 200-foot wide right of way.

Figure 7 shows the electric field plot of the 500 kV overhead line for the width of the right of way. The electric field is plotted 3.28 feet above grade. The electric field due to the 60Hz, 500 kV voltage (288.7 kV phase to ground) has a maximum field of 3.23 kV/meter approximately 41 feet from the center of the tower, with the electric field decreasing to 0.98 kV/meter at the edges of the 200-foot wide right of way.

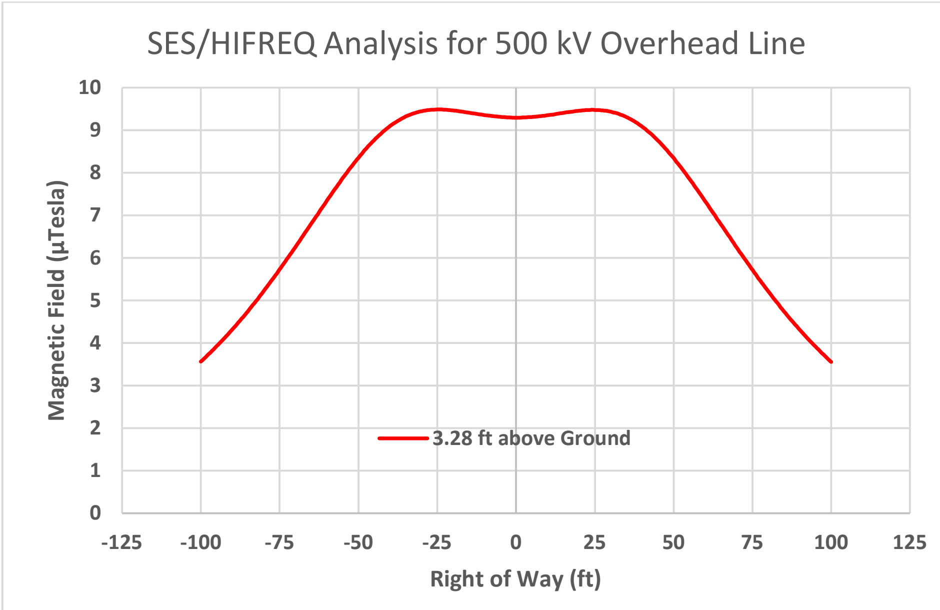

Figure 6 – Magnetic Field Plot, 500 kV Overhead Line, 3.28 feet above grade

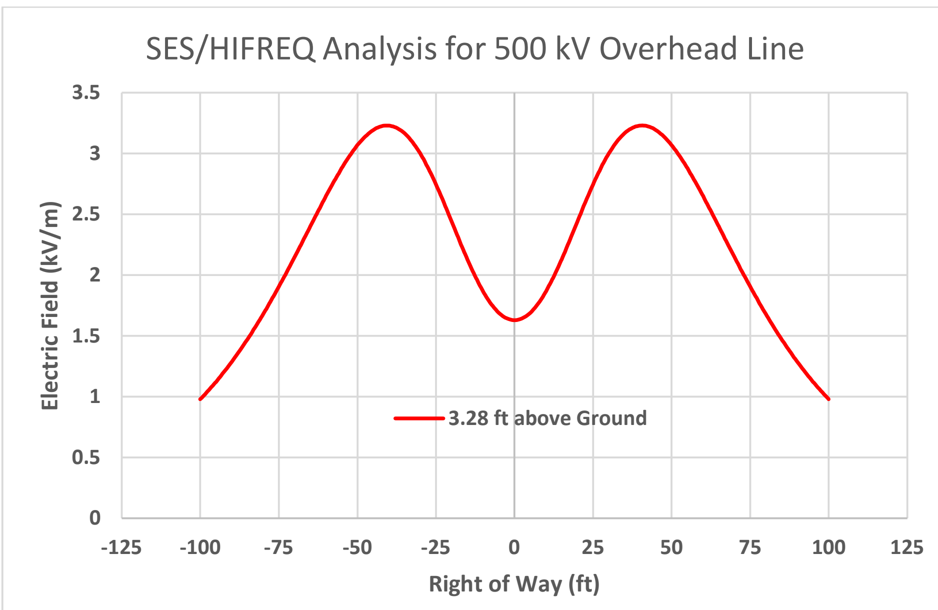

Figure 7 - Electric Field Plot, 500 kV Overhead Line, 3.28 feet above grade

The magnetic fields in Figures 3 and 6 are well below the ICNIRP, 200µT limit and the IEEE C95.1, 904µT limit. Oregon Siting Standards 345-024-0090 for Transmission Lines have a limit of 9kV/m [6] at the edge of the right of way. The 500 kV overhead line in Figure 7 has an electric field that is well below Oregon limit.

2.4 Summary and Conclusions

Cascade will utilize either a ±320 kV or ±400 kV DC operating voltage for the 1,100 MW, HVDC transmission project. The HVDC transmission system will include both underground (16 miles) and submarine cable (80 miles) systems. High voltage AC tie-lines will be required at 500 kV near the Big Eddy Substation and at 230 kV near the Harborton Substation. The 500 kV tie line will be a 500-foot-long overhead line while the 230 kV tie line will be a 2.75 mile long, XLPE insulated, underground cable circuit.

Electric and magnetic fields were calculated and plotted using the SES CDEGS software with the HIFREQ module. The results of the analysis for the 60 Hz, 500 kV overhead tie line and the 230 kV underground circuit are provided in Table 1. These levels are all well below the 200μT limit for exposure to the general public per the ICNIRP (International Commission on Non-Ionizing Radiation Protection 2010), the IEEE C95.1-2019/Cor2-2020 limit of 904μT and the 9kV/m electric field limit in Oregon.

Circuit	Conductors	Current per conductor	Peak Magnetic Field at 3.28 feet above grade (μT)	Peak Electric Field at 3.28 feet above grade (kV/m)
500 kV, 60 Hz	2/C per phase	656 Arms	9.5	3.23
230 kV, 60Hz	2/C per phase	1,456 Arms	43.2	0

Table 1 – 500 kV and 230 kV AC Tie Line Circuit Magnetic and Electric Fields

Please review and let me know if you have any questions or comments.

Yours sincerely,

Bradley D. Railing, P.E.
Principal HVDC Consultant
PSC North America

References:

1. SES CDEGS HIFREQ module (HIFREQ | Electromagnetic Fields Analysis - SES & technologies ltd. (sestech.com)

2. NOAA website, (F_merc (noaa.gov)), Main Field Total Intensity, 54,000 to 55,000 nT for Cascade project area.

3. ICNIRP (International Commission on Non-Ionizing Radiation Protection) for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1Hz to 100 kHz), 2010

4. IEEE Std C95.1-2019/Cor2-2020, IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz Corrigenda 2, Sept 24, 2020.

5. Electric Power Research Institute (EPRI) Transmission Line Reference Book, 2nd edition, 1982.

6. Oregon Siting Standards for Transmission Lines, 345-024-0090.