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PUGET SOUND ENERGY

230 kV Energize Eastside Project

Addendum to EMF Calculations and Report

Revision 0

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132155

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ADDENDUM TO EMF CALCULATIONS AND REPORT

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REVISION HISTORY						
REV.	ISSUE DATE	ISSUED FOR	PREP BY	CHKD BY	APPD BY	NOTES
A	03/23/17	Appvl	JCB	AMC	BCF	Issued for client review.
0	03/31/17	Impl	JCB	GKB	BCF	Issued for implementation based on client comments

"Issued For" Definitions:

- "Prelim" means this document is issued for preliminary review, not for implementation
- "Appvl" means this document is issued for review and approval, not for implementation
- "Impl" means this document is issued for implementation
- "Record" means this document is issued after project completion for project file

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1.0 EXECUTIVE SUMMARY

Puget Sound Energy (PSE) requested that POWER Engineers, Inc. (POWER) perform an Electric and Magnetic Field (EMF) investigation for the Energize Eastside (EE) project. The same methodologies used in "EMF Calculations and Report, Revision 2" dated March 7, 2017 also apply to this addendum.

In this analysis, POWER performed EMF calculations along the Willow1 route alternative with the following parameter changes:

- Both transmission lines analyzed at 230 kV
- Optimal phase configuration of ABC-CBA
- EMF Locations J-2 and J-3 are comprised of Structure C-16
- EMF Locations M-2 and M-3 are comprised of Structure C-16 with pole spacing adjusted to 51 feet to accommodate the Olympic Pipeline running parallel within the corridor at these locations
- Line loading for both lines at 230 kV are shown in Table 3 and Table 4

A summary of the electric and magnetic field results are shown in Tables 1 and 2 respectively.

TABLE 1: SUMMARY OF ELECTRIC FIELD RESULTS

Segment	Maximum		Edge of ROW	
	EMF Location with Largest Value	Upgraded Calculated Value* (kV/m)	EMF Location with Largest Value	Upgraded Calculated Value* (kV/m)
Redmond	All are equal	0.808 (19%)	All are equal	0.443 (11%)
Bellevue North	All are equal	0.808 (19%)	All are equal	0.443 (11%)
Bellevue Central	All are equal	0.808 (19%)	All are equal	0.443 (11%)
Bellevue South: Willow1	J-2, J-3	0.892 (21%)	J-2, J-3	0.743 (18%)
Newcastle	M-2, M-3	1.149 (28%)	M-2, M-3	0.816 (20%)
Renton	All are equal	0.808 (19%)	All are equal	0.443 (11%)

* Percent difference in parenthesis is based on ICNIRP recommended limit of 4.16 kV/m

TABLE 2: SUMMARY OF MAGNETIC FIELD RESULTS

Segment	Maximum			Edge of ROW		
	EMF Location with Largest Value	Upgraded 2017-18 Calculated Value* (mG)	Upgraded 2027-28 Calculated Value* (mG)	EMF Location with Largest Value	Upgraded 2017-18 Calculated Value* (mG)	Upgraded 2027-28 Calculated Value* (mG)
Redmond	All are equal	26.27 (1.3%)	27.45 (1.4%)	All are equal	13.42 (0.67%)	14.05 (0.70%)
Bellevue North	All are equal	26.27 (1.3%)	27.45 (1.4%)	All are equal	13.42 (0.67%)	14.05 (0.70%)
Bellevue Central	All are equal	26.27 (1.3%)	27.45 (1.4%)	All are equal	13.42 (0.67%)	14.05 (0.70%)
Bellevue South: Willow1	J-2, J-3	55.56 (2.8%)	59.26 (3.0%)	J-2, J-3	26.62 (1.3%)	30.44 (1.5%)
Newcastle	M-2, M-3	60.72 (3.0%)	64.71 (3.2%)	M-2, M-3	33.90 (1.7%)	38.65 (1.9%)
Renton	All are equal	43.07 (2.2%)	46.14 (2.3%)	All are equal	20.42 (1.0%)	23.91 (1.2%)

* Percent difference in parenthesis is based on ICNIRP recommended limit of 2,000 mG

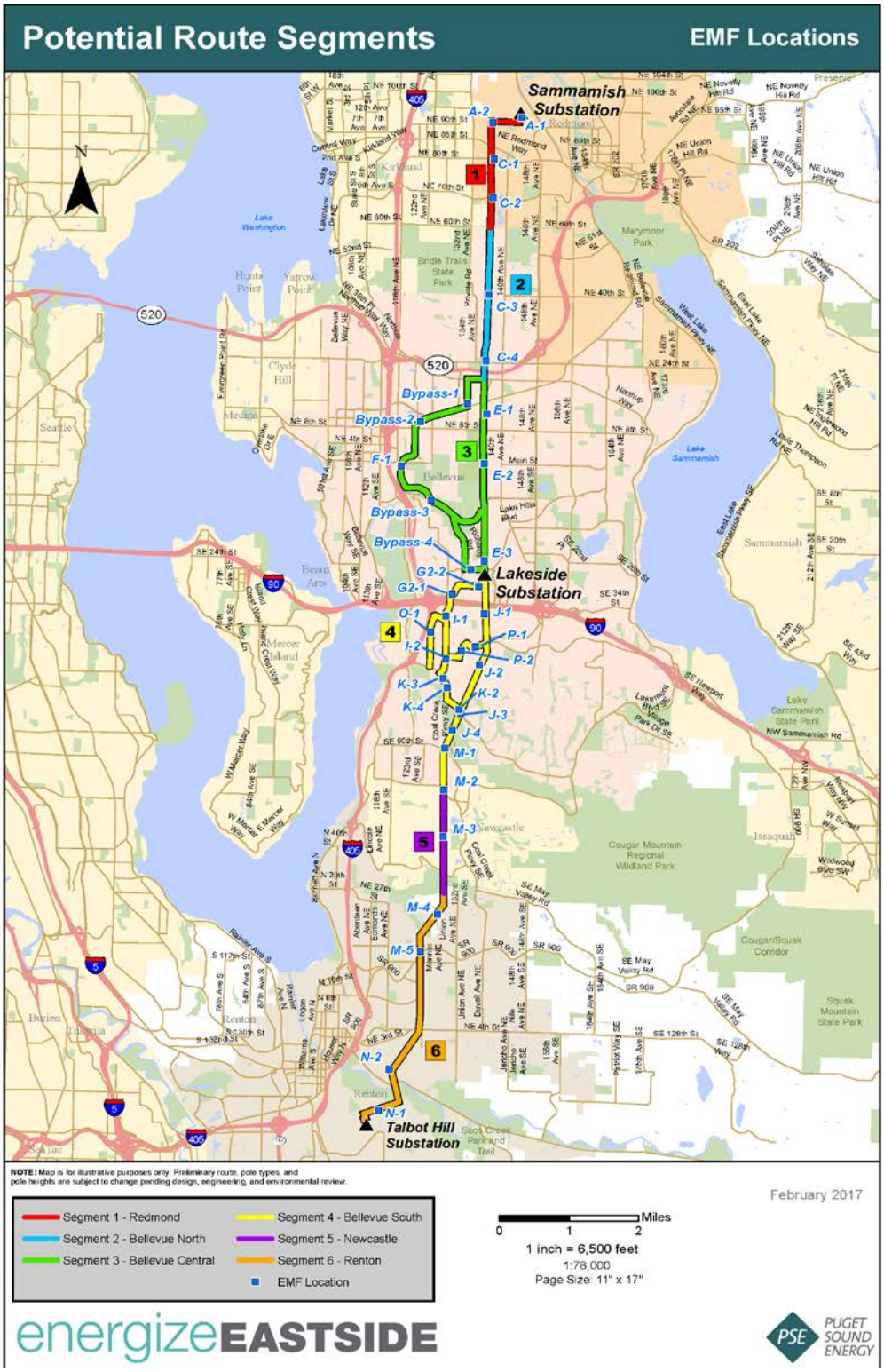

Figure 1: Potential Route Segments

2.0 DATA

TABLE 3: UPGRADED FUTURE LINE LOADING 2017-18				
Both lines at 230 kV (winter 2017-18):				
Line Name:	Talbot Hill-Richards Creek #1	Talbot Hill-Richards Creek #2	Sammamish-Richards Creek #1	Sammamish-Richards Creek #2
Nominal Voltage:	230 kV	230 kV	230 kV	230 kV
Line Rating (amps):	2616	2616	2616	2616
Average loading (amps):	583	577	368	334
Peak loading (amps):	971	961	613	557
Both lines at 230 kV (summer 2018):				
Line Name:	Talbot Hill-Richards Creek #1	Talbot Hill-Richards Creek #2	Sammamish-Richards Creek #1	Sammamish-Richards Creek #2
Nominal Voltage:	230 kV	230 kV	230 kV	230 kV
Line Rating (amps):	2460	2460	2460	2460
Average loading (amps):	92	21	179	187
Peak loading (amps):	123	28	238	249

TABLE 4: UPGRADED FUTURE LINE LOADING 2027-28				
Both lines at 230 kV (winter 2027-28):				
Line Name:	Talbot Hill-Richards Creek #1	Talbot Hill-Richards Creek #2	Sammamish-Richards Creek #1	Sammamish-Richards Creek #2
Nominal Voltage:	230 kV	230 kV	230 kV	230 kV
Line Rating (amps):	2616	2616	2616	2616
Average loading (amps):	580	650	385	349
Peak loading (amps):	966	1083	641	581
Both lines at 230 kV (summer 2028):				
Line Name:	Talbot Hill-Richards Creek #1	Talbot Hill-Richards Creek #2	Sammamish-Richards Creek #1	Sammamish-Richards Creek #2
Nominal Voltage:	230 kV	230 kV	230 kV	230 kV
Line Rating (amps):	2460	2460	2460	2460
Average loading (amps):	134	242	140	137
Peak loading (amps):	179	322	186	182

3.0 GENERAL DESCRIPTION

3.1 Electric Field Analysis and Guidelines

The electric field strength is a measure of the force per unit charge at a given point in space relative to a charged object. It is typically measured in kilovolts per meter (kV/m). Electric field strength is primarily calculated from the line voltage, line geometry, and phasing. It is independent of the current through the line. Values are calculated at the minimum conductor height (mid-span) at a measurement height of one meter above the ground per IEEE Std 644-1994 (R2008), "IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields From AC Power Lines".

The state of Washington does not have adopted guidelines on electric fields from transmission lines; however, there are applicable industry limits. IEEE Std C95.6-2002, "IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz" specifies a reference limit of 5.0 kV/m, and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) publishes a recommended limit of 4.16 kV/m for the general public at the edge of ROW. These recommended values serve as a point of reference for the calculated values. Calculated electric fields for Energize Eastside are well below these guidelines for all proposed routes.

3.2 Magnetic Field Analysis and Guidelines

The reported magnetic field values are the magnetic flux densities at a given point in space reported in units of milligauss. Calculations are performed at the minimum conductor height (mid-span) and are calculated one meter above the ground per IEEE Std 644-1994 (R2008). All values are calculated assuming balanced loading on all three phases. The magnetic fields will vary if there is unbalance on the system; however, transmission unbalance is typically fairly low. Calculated results are directly proportional only if conductor height and other line configuration parameters are assumed to be unchanged.

The state of Washington does not have adopted guidelines on magnetic fields from transmission lines; there are applicable industry limits. IEEE Std C95.6-2002 specifies a reference limit of 9,040 mG, and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) publishes a recommended limit of 2,000 mG for the general public at the edge of ROW. These recommended values serve as a point of reference for the calculated values. Calculated magnetic fields for Energize Eastside are well below these guidelines for all proposed routes.

4.0 REDMOND SEGMENT

EMF locations A-1, A-2, C-1, and C-2 are comprised of Structure C-1 for the upgraded line configuration with a ROW width of 100 feet.

4.1 Electric Field Results

A summary of the results of the electric field analysis for the Redmond Segment are shown in Table 5.

TABLE 5: REDMOND SEGMENT – ELECTRIC FIELD		
EMF LOCATION	UPGRADED MAXIMUM (KV/M)	UPGRADED EDGE OF ROW (KV/M)
A-1	0.808	0.443
A-2	0.808	0.443
C-1	0.808	0.443
C-2	0.808	0.443

4.2 Magnetic Field Results

A summary of the results of the magnetic field using loading values from Table 3 and Table 4 are shown in Table 6 and Table 7.

TABLE 6: REDMOND SEGMENT – MAXIMUM MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
A-1	8.17	10.87	15.76	26.27	6.18	8.21	16.49	27.45
A-2	8.17	10.87	15.76	26.27	6.18	8.21	16.49	27.45
C-1	8.17	10.87	15.76	26.27	6.18	8.21	16.49	27.45
C-2	8.17	10.87	15.76	26.27	6.18	8.21	16.49	27.45

TABLE 7: REDMOND SEGMENT – EDGE OF ROW MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
A-1	3.99	5.32	8.06	13.42	2.96	3.93	8.44	14.05
A-2	3.99	5.32	8.06	13.42	2.96	3.93	8.44	14.05
C-1	3.99	5.32	8.06	13.42	2.96	3.93	8.44	14.05
C-2	3.99	5.32	8.06	13.42	2.96	3.93	8.44	14.05

5.0 BELLEVUE NORTH SEGMENT

EMF locations C-3 and C-4 are comprised of Structure C-1 for the upgraded line configuration with a ROW width of 100 feet.

5.1 Electric Field Results

A summary of the results of the electric field analysis for the Bellevue North Segment are shown in Table 8.

TABLE 8: BELLEVUE NORTH SEGMENT – ELECTRIC FIELD		
EMF LOCATION	UPGRADED MAXIMUM (KV/M)	UPGRADED EDGE OF ROW (KV/M)
C-3	0.808	0.443
C-4	0.808	0.443

5.2 Magnetic Field Results

A summary of the results of the magnetic field using loading values from Table 3 and Table 4 are shown in Table 9 and Table 10.

TABLE 9: BELLEVUE NORTH SEGMENT – MAXIMUM MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
C-3	8.17	10.87	15.76	26.27	6.18	8.21	16.49	27.45
C-4	8.17	10.87	15.76	26.27	6.18	8.21	16.49	27.45

TABLE 10: BELLEVUE NORTH SEGMENT – EDGE OF ROW MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
C-3	3.99	5.32	8.06	13.42	2.96	3.93	8.44	14.05
C-4	3.99	5.32	8.06	13.42	2.96	3.93	8.44	14.05

6.0 BELLEVUE CENTRAL SEGMENT

EMF locations E-1, E-2, and E-3 are comprised of Structure C-1 for the upgraded line configuration with a ROW width of 100 feet.

6.1 Electric Field Results

A summary of the results of the electric field analysis for the Bellevue Central Segment are shown in Table 11

TABLE 11: BELLEVUE CENTRAL SEGMENT – ELECTRIC FIELD		
EMF LOCATION	UPGRADED MAXIMUM (KV/M)	UPGRADED EDGE OF ROW (KV/M)
E-1	0.808	0.443
E-2	0.808	0.443
E-3	0.808	0.443

6.2 Magnetic Field Results

A summary of the results of the magnetic field using loading values from Table 3 and Table 4 are shown in Table 12 and Table 13.

TABLE 12: BELLEVUE CENTRAL SEGMENT – MAXIMUM MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
E-1	8.17	10.87	15.76	26.27	6.18	8.21	16.49	27.45
E-2	8.17	10.87	15.76	26.27	6.18	8.21	16.49	27.45
E-3	8.17	10.87	15.76	26.27	6.18	8.21	16.49	27.45

TABLE 13: BELLEVUE CENTRAL SEGMENT – EDGE OF ROW MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
E-1	3.99	5.32	8.06	13.42	2.96	3.93	8.44	14.05
E-2	3.99	5.32	8.06	13.42	2.96	3.93	8.44	14.05
E-3	3.99	5.32	8.06	13.42	2.96	3.93	8.44	14.05

7.0 BELLEVUE SOUTH SEGMENT: WILLOW1

EMF location J-1 is comprised of Structure C-1, and EMF locations J-2 and J-3 are comprised of Structure C-16 for the upgraded line configuration with a ROW width of 100 feet.

7.1 Electric Field Results

A summary of the results of the electric field analysis for the Bellevue South Segment Willow1 are shown in Table 14.

TABLE 14: BELLEVUE SOUTH SEGMENT WILLOW1 – ELECTRIC FIELD		
EMF LOCATION	UPGRADED MAXIMUM (KV/M)	UPGRADED EDGE OF ROW (KV/M)
J-1	0.808	0.443
J-2	0.892	0.743
J-3	0.892	0.743

7.2 Magnetic Field Results

A summary of the results of the magnetic field using loading values from Table 3 and Table 4 are shown in Table 15 and Table 16.

TABLE 15: BELLEVUE SOUTH SEGMENT WILLOW1 – MAXIMUM MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
J-1	4.24	5.67	25.86	43.07	10.11	13.44	27.70	46.14
J-2	4.56	6.10	33.36	55.56	12.09	16.09	35.57	59.26
J-3	4.56	6.10	33.36	55.56	12.09	16.09	35.57	59.26

TABLE 16: BELLEVUE SOUTH SEGMENT WILLOW1 – EDGE OF ROW MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
J-1	2.96	3.96	12.26	20.42	6.47	8.60	14.35	23.91
J-2	3.14	4.20	15.98	26.62	7.48	9.95	18.27	30.44
J-3	3.14	4.20	15.98	26.62	7.48	9.95	18.27	30.44

8.0 NEWCASTLE SEGMENT

EMF locations J-4 and M-1 are comprised of Structure C-1, and EMF locations M-2 and M-3 are comprised of Structure C-16 for the upgraded line configuration with a ROW width of 100 feet.

8.1 Electric Field Results

A summary of the results of the electric field analysis for the Newcastle Segment are shown in Table 17.

TABLE 17: NEWCASTLE SEGMENT – ELECTRIC FIELD		
EMF LOCATION	UPGRADED MAXIMUM (KV/M)	UPGRADED EDGE OF ROW (KV/M)
J-4	0.808	0.443
M-1	0.808	0.443
M-2	1.149	0.816
M-3	1.149	0.816

8.2 Magnetic Field Results

A summary of the results of the magnetic field using loading values from Table 3 and Table 4 are shown in Table 18 and Table 19.

TABLE 18: NEWCASTLE SEGMENT – MAXIMUM MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
J-4	4.24	5.67	25.86	43.07	10.11	13.44	27.70	46.14
M-1	4.24	5.67	25.86	43.07	10.11	13.44	27.70	46.14
M-2	4.70	6.29	36.46	60.72	12.95	17.24	38.84	64.71
M-3	4.70	6.29	36.46	60.72	12.95	17.24	38.84	64.71

TABLE 19: NEWCASTLE SEGMENT – EDGE OF ROW MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
J-4	2.96	3.96	12.26	20.42	6.47	8.60	14.35	23.91
M-1	2.96	3.96	12.26	20.42	6.47	8.60	14.35	23.91
M-2	3.54	4.74	20.35	33.90	9.02	11.99	23.20	38.65
M-3	3.54	4.74	20.35	33.90	9.02	11.99	23.20	38.65

9.0 RENTON SEGMENT

EMF locations M-4, M-5, N-1, and N-2 are comprised of Structure C-1 for the upgraded line configuration with a ROW width of 100 feet.

9.1 Electric Field Results

A summary of the results of the electric field analysis for the Renton Segment are shown in Table 20.

TABLE 20: RENTON SEGMENT – ELECTRIC FIELD		
EMF LOCATION	UPGRADED MAXIMUM (KV/M)	UPGRADED EDGE OF ROW (KV/M)
M-4	0.808	0.443
M-5	0.808	0.443
N-1	0.808	0.443
N-2	0.808	0.443

9.2 Magnetic Field Results

A summary of the results of the magnetic field using loading values from Table 3 and Table 4 are shown in Table 21 and Table 22.

TABLE 21: RENTON SEGMENT – MAXIMUM MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
M-4	4.24	5.67	25.86	43.07	10.11	13.44	27.70	46.14
M-5	4.24	5.67	25.86	43.07	10.11	13.44	27.70	46.14
N-1	4.24	5.67	25.86	43.07	10.11	13.44	27.70	46.14
N-2	4.24	5.67	25.86	43.07	10.11	13.44	27.70	46.14

TABLE 22: RENTON SEGMENT – EDGE OF ROW MAGNETIC FIELD								
EMF LOCATION	2017-18 UPGRADED LINE CONFIGURATION				2027-28 UPGRADED LINE CONFIGURATION			
	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)	Summer Average (mG)	Summer Peak (mG)	Winter Average (mG)	Winter Peak (mG)
M-4	2.96	3.96	12.26	20.42	6.47	8.60	14.35	23.91
M-5	2.96	3.96	12.26	20.42	6.47	8.60	14.35	23.91
N-1	2.96	3.96	12.26	20.42	6.47	8.60	14.35	23.91
N-2	2.96	3.96	12.26	20.42	6.47	8.60	14.35	23.91