APPENDIX A

Methodology of Estimating Tailpipe Emissions

APPENDIX A

Tailpipe Emissions Estimation from Haultrucks and Support Equipment using NONROAD

To support the Notice of Intent (NOI) application and per Utah Division of Air Quality (UDAQ) guidance, tailpipe emissions from haultrucks and support equipment were estimated using the U.S. Environmental Protection Agency's (EPA's) NONROAD emission factors and methodology. This appendix outlines this analysis.

Annual tailpipe emissions were estimated for each year from 2010 through 2029 to determine the emissions associated with the proposed increase of annual material moved of ore and waste rock to 260,000,000 tons per year.

Description of Mobile Emission Sources

Based on current mine plans, Kennecott Utah Copper LLC (KUC) estimated fleet distribution for the haultrucks and other support equipment.

KUC may purchase new haultrucks almost every year, and older trucks are either phased out or are rebuilt. KUC also uses front-end loaders, track dozers, rubber-tire dozers, graders, trackhoes, water trucks, construction trucks, diesel shovels, and diesel drills to support operations at the Bingham Canyon Mine (BCM). The types of haultruck engines and support equipment engines representing the present and future fleet at the BCM are listed in Table A-1.

TABLE A-1
Projected List of BCM Nonroad Engines

Equipment Type	Model	Tier	Horsepower
Haultrucks	CAT 793C	0	2,337
	CAT 793D	1	2,415
	CAT 795F	2	3,440
	KOM 930	1,2,4F	3,500
Track Dozers	CAT D10	0	580
	CAT D10	1	613
	CAT D10	2	661
	CAT D10	3, 4F	646
	CAT D11	0	850
	CAT D11	1, 4T, 4F	936

TABLE A-1
Projected List of BCM Nonroad Engines

Equipment Type	Model	Tier	Horsepower
Graders	CAT 16	1	289
	CAT 16	2	299
	CAT 16	3, 4T, 4F	297
	CAT 24H	0	500
	CAT 24	0	540
	CAT 24	2, 4F	533
Rubber-tired Dozers	CAT 834	0	487
	CAT 834	3, 4T, 4F	525
	CAT 854	1	880
Front-end Loaders	KOM WA500	1	235
	KOM WA600	3, 4F	396
	KOM WA700	1	502
	CAT 992	2	800
	CAT 992	4T, 4F	801
	KOM WA1200	0	1,560
	KOM WA1200	1, 4F	1,782
Trackhoes	CAT 330	2	264
	CAT 330	4F	268
	CAT 385	3, 4T, 4F	523
	KOM PC800	1, 4F	323
	KOM PC400	1	246
Water Trucks	CAT 789	0	1,900
	CAT 793C	1	2,300
	CAT 793D	2	2,415
Hydraulic Shovels	O&K RH 200	0	2,100
	O&K RH 200	1	2,520
Construction Trucks	KOM 785-7	1	1,200
Diesel Drills	P&H	1, 2	1,100
	ATLAS COPCO	2, 4F	750

KUC has estimated the hours of operation of each engine type based on estimated production activity for each year of analysis. The estimated haultruck hours are listed in Table A-2. A complete listing of the projected hours of operation per year for each support equipment type is included in the detailed calculations (Appendix B-1).

TABLE A-2
Projected KUC Haultruck Fleet Operational Hours by EPA Engine Tier Level (in thousands of hours)

Truck Type	Engine	2011	2012	2013	2014	2015	2016	2017	2018	2019
CAT 793C Fleet (2,337 hp)	Tier 0	46	-	-	-	-	-	-	-	-
CAT 793D Fleet (2,415 hp)	Tier 1	203	203	203	203	203	161	203	161	84
CAT 795F Fleet (3,440 hp)	Tier 2	12	-	-	-	-	-	-	-	-
KOM Fleet (3,500 hp)	Tier 1	179	215	215	186	207	193	157	193	143
	Tier 2	81	301	336	336	336	336	336	336	336
	Tier 4f	-	-	-	-	213	213	207	207	207
Total Hours		**475**	**719**	**754**	**725**	**960**	**903**	**904**	**897**	**770**

TABLE A-2, CONTINUED
Projected KUC Haultruck Fleet Operational Hours by EPA Engine Tier Level (in thousands of hours)

Truck Type	Engine	2020	2021	2022	2023	2024	2025	2026	2027	2028
CAT 793C Fleet (2,337 hp)	Tier 0	-	-	-	-	-	-	-	-	-
CAT 793D Fleet (2,415 hp)	Tier 1	-	-	-	-	-	-	-	-	-
CAT 795F Fleet (3,440 hp)	Tier 2	-	-	-	-	-	-	-	-	-
KOM Fleet (3,500 hp)	Tier 1	-	-	-	-	-	-	-	-	-
	Tier 2	315	86	64	136	215	200	29	50	36
	Tier 4f	207	207	114	100	107	107	207	193	207
Total Hours		**522**	**293**	**179**	**236**	**322**	**307**	**236**	**243**	**243**

NOTES:
hp = horsepower

Emission Standards

The emissions calculations are driven by the EPA-assigned tier designation of the engine. The tier values refer to federal nonroad diesel emissions standards. The first federal standards (Tier 1) for new nonroad diesel engines were adopted in 1994 for engines over 37 kilowatts (kW) (50 horsepower [hp]), to be phased in from 1996 to 2000. In 1996, a Statement of Principles (SOP) pertaining to nonroad diesel engines was signed between the EPA, California Air Resources Board, and engine manufacturers. On August 27, 1998, the EPA signed the final rule reflecting the provisions of the SOP.

The 1998 nonroad engine regulations are structured as a three-tiered progression. Each tier involves a phase-in (by horsepower rating) over several years. Tier 1 standards were phased in from 1996 to 2000. The more stringent Tier 2 standards take effect from 2001 to 2006,

and the yet more stringent Tier 3 standards phase in from 2006 to 2008 (Tier 3 standards apply only for engines from 37–560 kW). On May 11, 2004, the EPA signed the final rule introducing Tier 4 emission standards, which are to be phased in over the period of 2008–2015. Any diesel engine manufactured prior to the adoption of the tier standards is labeled as a Tier 0 engine.

The regulations for the horsepower classes included in this analysis are summarized in Table A-3. The full table of nonroad engine emission standards can be found in the U.S. *Code of Federal Regulations*, Title 40, Part 89.

TABLE A-3
Nonroad Engine Emissions Standards (g/hp-hr)

Engine Power (hp)	Model Years	Regulation	HC	CO	NO_X	PM
≥175 to ≤300	1996–2005	Tier 1	1.0	8.5	6.9	0.4
	2003–2005	Tier 2		2.6		0.15
	2006–2010	Tier 3		2.6		
	2011–2013	Tier 4 transitional [a]	0.14 (50%)		0.30 (50%)	0.01
	2014	Tier 4 final	0.14		0.30	0.01
≥300 to ≤600	1996–2000	Tier 1	1.0	8.5	6.9	0.4
	2001–2005	Tier 2		2.6		0.15
	2006–2010	Tier 3		2.6		
	2011–2013	Tier 4 transitional [a]	0.14 (50%)		0.30 (50%)	0.01
	2014	Tier 4 final	0.14		0.30	0.01
≥600 to ≤750	1996–2001	Tier 1	1.0	8.5	6.9	0.4
	2002–2005	Tier 2		2.6		0.15
	2006–2010	Tier 3		2.6		
	2011–2013	Tier 4 transitional [a]	0.14 (50%)		0.30 (50%)	0.01
	2014	Tier 4 final	0.14		0.30	0.01
≥750 except generator sets	2000–2005	Tier 1	1.0	8.5	6.9	0.4
	2006–2010	Tier 2		2.6		0.15
	2011–2014	Tier 4 transitional [a]	0.30		2.6	0.075
	2015+	Tier 4 final	0.14		2.6	0.03

NOTES:
CO = carbon monoxide
g/hp-hr = gram per horsepower-hour
HC = hydrocarbon
NO_x = nitrogen oxide
PM = particulate matter

EPA emission standards for nonroad diesel engines are published in the U.S. Code of Federal Regulations, Title 40, Part 89 [40 CFR Part 89].

[a] Percentages are model year sales fractions required to comply with the indicated NO_X standard, for model years where less than 100 percent is required.

Potential to emit (PTE) estimates were calculated based on tier availability communicated to KUC from the equipment and engine manufacturers.

NONROAD Methodology

Emission factors were calculated using the methodology described in the NONROAD modeling guidance. Emission factors were applied to the annual activity for each type of engine and vehicle to estimate annual emissions. NONROAD 2005 is an EPA model designed to predict emissions from various nonroad equipment categories. The model predicts emissions of hydrocarbon (HC), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur oxides (SO_x), and particulate matter (PM) based on regional listings of specific equipment and further stratifies the engine by horsepower rating and federal engine tier standards.

In order to calculate the emissions of a known fleet of vehicles, NONROAD population and activity files can be customized with the specific fleet data. Alternatively, emission factor equations used by the model are available within the technical documentation.

Because of the large number of project years and variations in the vehicle fleet population in each project year, vehicle emission factors were calculated using the methodology described in the EPA NONROAD technical document *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition* (EPA, 2004a). The following equation was used to estimate emissions:

Annual emissions = emission factor (g/hp-hr) * engine horsepower (hp) * hours of operation (hr) * load factor

Load factors represent the average load on an engine that operates at a variety of speeds or load conditions. KUC and the haultruck engine manufacturers developed a site-specific load factor of 0.34 for the haultrucks at the mine. Load factors for support equipment, shovels, and drills were selected based on Tables 9 and 10 of the document *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling* (EPA, 2004b). An average load factor of 0.43 was applied to the diesel drills, and a loader-specific load factor of 0.48 was used for the front-end loaders. The remaining equipment types used a load factor of 0.58 designated for the "crawler cycle class." This is a representative load factor as it represents slow moving, high powered construction vehicles.

Emission Factor Calculations

Steady-state emission factors for each engine type were calculated and then adjusted based on transient adjustment factors and deterioration factors according to the following equation from *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition* (EPA, 2004a):

$$EF_{adj} = EF_{SS} \times TAF \times DF - S_{PMadj}$$

Steady-state emission factors (EF_{SS}) are determined based on model year and horsepower category. Transient adjustment factors (TAF) vary by engine type to account for how engine speed and load variations in the field effect emissions. Deterioration factors (DFs) adjust for age-related deterioration and are a function of technology type and the age of the engine. DF is not used for sulfur dioxide (SO_2) emissions. S_{PMadj} is an additional adjustment to the

PM less than 10 micrometers in aerodynamic diameter (PM_{10}) emission factor to account for variations in fuel sulfur content.

Further details about the emission factor equation are laid out in *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition* (EPA, 2004a). All input values are based on model year and horsepower, using the values suggested in the document. The specific inputs used for this analysis are documented in the calculation worksheets.

Calculated emission factors are presented in Table A-4, grouped by horsepower class and federal engine tier standards. These emission factors were applicable to all haultrucks and support equipment considered in this analysis.

TABLE A-4

Emission Factors by Horsepower Class (g/hp-hr)

	Pollutant	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4t	Tier 4f
175- to 300-hp class	HC	1.05	0.34	0.33	0.20	0.13	0.13
	CO	4.90	1.26	1.26	1.32	0.09	0.09
	NO_x	8.15	5.43	3.83	2.39	2.52	0.28
	SO_2	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
	PM_{10}	0.64	0.37	0.15	0.15	0.01	0.01
300- to 600-hp class	HC	1.05	0.22	0.18	0.18	0.13	0.13
	CO	4.90	2.20	1.42	1.48	0.10	0.10
	NO_x	8.15	5.85	4.16	2.39	2.52	0.28
	SO_2	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
	PM_{10}	0.64	0.28	0.15	0.15	0.01	0.01
600- to 750-hp class	HC	1.05	0.16	0.18	0.18	0.13	0.13
	CO	4.90	2.24	2.24	2.34	0.15	0.15
	NO_x	8.15	5.66	3.93	2.39	2.52	0.28
	SO_2	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
	PM_{10}	0.64	0.31	0.15	0.15	0.01	0.01
>750-hp class	HC	1.05	0.31	0.18	NA	0.29	0.13
	CO	4.90	1.29	1.29	NA	0.09	0.09
	NO_x	8.15	5.99	3.93	NA	2.41	2.41
	SO_2	0.0049	0.0049	0.0049	NA	0.0049	0.0049
	PM_{10}	0.64	0.26	0.15	NA	0.02	0.02

NOTES:

g/hp-hr = grams per horsepower-hour

All emission factors represent the lesser of EPA emission limits and factors calculated using EPA NONROAD methodology.

Analysis Results

Annual emissions from each vehicle type were estimated based on the calculated emission factors, engine horsepower, and hours of operation for each year 2010 through 2029. Tables A-5 and A-6 summarize the annual haultruck and support equipment tailpipe emissions, respectively, between 2010 and 2029. The detailed calculation files are included in Appendix B-1.

TABLE A-5

Projected Estimated Haultruck Emissions by Truck Type (tons/year)

		2011	2012	2013	2014	2015	2016	2017	2018	2019
CAT 793C	HC	30	-	-	-	-	-	-	-	-
	CO	197	-	-	-	-	-	-	-	-
	NO_x	328	-	-	-	-	-	-	-	-
	SO_2	0.2	-	-	-	-	-	-	-	-
	PM_{10}	26	-	-	-	-	-	-	-	-
CAT 793D	HC	57	57	57	57	57	45	57	45	24
	CO	237	237	237	237	237	188	237	188	98
	NO_x	1,100	1,100	1,100	1,100	1,100	872	1,100	872	455
	SO_2	0.9	0.9	0.9	0.9	0.9	0.7	0.9	0.7	0.4
	PM_{10}	48	48	48	48	48	38	48	38	20
CAT 795F	HC	3	-	-	-	-	-	-	-	-
	CO	20	-	-	-	-	-	-	-	-
	NO_x	61	-	-	-	-	-	-	-	-
	SO_2	0.1	-	-	-	-	-	-	-	-
	PM_{10}	2	-	-	-	-	-	-	-	-
KOM 930	HC	92.2	159.2	167.4	155.8	202.3	196.4	180.8	195.4	175.0
	CO	438	871	930	881	1,164	1,139	1,072	1,133	1,048
	NO_x	1,820	3,238	3,416	3,192	4,034	3,922	3,623	3,904	3,511
	SO_2	1.68	3.33	3.56	3.37	4.87	4.78	4.51	4.74	4.42
	PM_{10}	77.9	134.1	141.0	131.1	142.8	137.9	125.4	137.8	120.5
Total	HC	194	216	225	213	259	242	238	241	199
	CO	892	1,108	1,166	1,118	1,400	1,327	1,309	1,320	1,146
	NO_x	3,309	4,337	4,516	4,292	5,134	4,794	4,723	4,776	3,966
	SO_2	2.9	4.2	4.5	4.3	5.8	5.5	5.4	5.5	4.8
	PM_{10}	154	182	189	179	191	176	174	176	141

TABLE A-5 (CONTINUED)

Projected Estimated Haultruck Emissions by Truck Type (tons/year)

		2020	2021	2022	2023	2024	2025	2026	2027	2028
CAT 793C	HC	-	-	-	-	-	-	-	-	-
	CO	-	-	-	-	-	-	-	-	-
	NO_x	-	-	-	-	-	-	-	-	-
	SO_2	-	-	-	-	-	-	-	-	-
	PM_{10}	-	-	-	-	-	-	-	-	-
CAT 793D	HC	-	-	-	-	-	-	-	-	-
	CO	-	-	-	-	-	-	-	-	-
	NO_x	-	-	-	-	-	-	-	-	-
	SO_2	-	-	-	-	-	-	-	-	-
	PM_{10}	-	-	-	-	-	-	-	-	-
CAT 795F	HC	-	-	-	-	-	-	-	-	-
	CO	-	-	-	-	-	-	-	-	-
	NO_x	-	-	-	-	-	-	-	-	-
	SO_2	-	-	-	-	-	-	-	-	-
	PM_{10}	-	-	-	-	-	-	-	-	-
KOM 930	HC	111.5	57.1	35.5	50.0	70.0	66.6	43.5	46.1	45.2
	CO	770	384	241	345	486	462	288	307	300
	NO_x	2,278	1,098	694	1,017	1,445	1,371	803	869	840
	SO_2	3.36	1.88	1.15	1.52	2.07	1.98	1.51	1.56	1.56
	PM_{10}	66.8	21.3	15.1	29.1	44.8	42.0	9.9	13.9	11.4
Total	HC	111	57	36	50	70	67	44	46	45
	CO	770	384	241	345	486	462	288	307	300
	NO_x	2,278	1,098	694	1,017	1,445	1,371	803	869	840
	SO_2	3.4	1.9	1.1	1.5	2.1	2.0	1.5	1.6	1.6
	PM_{10}	67	21	15	29	45	42	10	14	11

TABLE A-6

Estimated Support Equipment Emissions (tons/year)

	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
HC	43.0	39.3	38.3	38.0	38.0	34.8	33.8	32.9	31.7
CO	272	242	231	229	228	204	191	176	168
NO_x	695	665	644	641	638	588	561	539	517
SO_2	0.70	0.75	0.77	0.78	0.78	0.78	0.76	0.75	0.72
PM_{10}	36.3	31.3	28.7	28.3	28.1	24.6	23.2	21.9	20.8
	2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
HC	25.5	23.5	22.0	21.6	21.5	20.8	20.8	19.5	19.5
CO	131	107	93.4	82.5	79.0	67.6	67.4	67.0	66.9
NO_x	405	363	327	312	309	297	296	286	285
SO_2	0.60	0.55	0.51	0.51	0.52	0.51	0.51	0.49	0.49
PM_{10}	15.6	13.9	12.6	11.9	11.7	10.9	10.9	10.8	10.8

References

United States Environmental Protection Agency (EPA). 2004a. *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition*. Assessment and Standards Division, Office of Transportation and Air Quality. EPA420-P-04-009, NR-009c. April.

United States Environmental Protection Agency (EPA). 2004b. *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling*. Assessment and Standards Division, Office of Transportation and Air Quality. EPA420-P-04-005, NR-005c. April.

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