Appendix O

Greenhouse Gas and Energy Modeling for the Lower Klamath Project

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for the

Lower Klamath Project

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O.1 Introduction

This technical report identifies and analyzes the potential greenhouse gas (GHG) emissions and energy use associated with the Lower Klamath Project (Proposed Project) and the alternatives analyzed in the Draft Environmental Impact Report (DEIR) in 2018. The overall Proposed Project has remained consistent with what was analyzed in 2018 but there is new and refined information on construction equipment and activities, including changes to equipment estimates.

O.2 Project Description

The Proposed Project and alternatives analyzed in this technical report are those described in Section 2 *Proposed Project* and Section 4 *Alternatives* of the Draft EIR, and include: Proposed Project; Partial Removal Alternative; Continued Operations with Fish Passage Alternative; Two Dam Removal Alternative; Three Dam Removal Alternative; and No Hatchery Alternative.

O.3 Methodology

The Proposed Project, and to the extent relevant, the alternatives, include construction activities for pre-dam removal activities, decommissioning of the four dams and powerhouse structures, restoration of the reservoir footprints and disturbed upland areas, and completion of other related activities. The GHG and energy consumption assessment was based on a detailed list of each piece of construction equipment for each construction phase to be completed under the Proposed Project and each alternative. In addition, proposed work hours; total quantities of material hauled and imported; and information on daily trips for construction workers and material hauling were also included in the assessment.

The proposed construction activity is primarily located in Siskiyou County, within the jurisdiction of the Siskiyou County Air Pollution Control District (SCAPCD), with activity at J.C. Boyle located in Klamath County, Oregon. As such, emissions estimated were conducted in accordance with SCAPCD guidance and approved methods. Emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) were estimated. The other two pollutants commonly evaluated in various mandatory and voluntary reporting protocols, hydrofluorocarbons and perfluorocarbons, are not expected to be emitted in large quantities and were not estimated for the Proposed Project. The Proposed Project and alternative’s energy use was estimated by quantifying total fuel use from construction equipment, hauling of material, and worker commutes. Detailed explanation of methods used for estimate emissions are further explained below and detailed assumptions and calculations are contained in Attachment A.

O.3.1 Greenhouse Gas Methodology

Quantification of GHG emissions were conducted using a combination of methods, including the use of emission factors from the U.S. Environmental Protection Agency's (USEPA) published *AP-42: Compilation of Air Emissions Factors*, exhaust emission factors from the Sacramento Metropolitan Air Quality Management District's (SMAQMD) Road Construction Emissions Model (RCEM), and the California Emissions Estimator Model (CalEEMod) version 2016.3.2. Although the RCEM model was created by SMAQMD, this model is recommended for use throughout California for CEQA analyses.

Exhaust emissions from construction equipment were estimated using SMAQMD RCEM, version 9.0. Although the model was developed by SMAQMD, emission rates and engine usage factors for construction equipment are based on the same California Air Resources Board (CARB)-approved model (i.e., OFFROAD) used in CalEEMod and statewide for conducting emissions modeling and is therefore appropriate for use in this analysis. Exhaust emissions from supplemental construction equipment such as lawnmowers, chippers, and chainsaws were estimated using OFFROAD 2007, since these equipment types are not included in the SMAQMD's RCEM. Additional supplemental construction equipment including worker boats and helicopters were estimated using USEPA and the Federal Office of Civil Aviation emissions factors, respectively. The CARB EMFAC 2017 model was used to estimate emissions from on-road vehicles from worker commute trips and truck hauling trips.

All GHG pollutants have a global warming potential (GWP) which represents the degree of impact from different gases. Furthermore, it is a measure of how much energy one ton of gas absorbed by the atmosphere over a given time, in comparison to one ton of carbon CO_2 (USEPA 2019). Each GHG emission inventoried in this report is has an applied GWP which is expressed at carbon dioxide equivalent (CO_2e). Due to advances in science the GWPs are modified regularly according to the Intergovernmental Panel on Climate Change's (IPCC) Assessment Reports. For this report, GWP are based on the Fourth Assessment Report to be consistent with the latest version of CalEEMod version 2016.3.2. All project emissions for CO_2, CH_4, and N_2O, were converted to metric tons of CO_2e ($MTCO_2e$).

O.3.1.1 Off-Road Equipment Exhaust Emissions

Construction equipment type, quantity, and hours of use were provided for each pre-dam removal phase including seed collection, IEV control, construction access, road, bridge, and culvert improvements, recreation facilities removal, flood improvements, and the Yreka Water Supply Pipeline Relocation, and the Fall Creek and Iron Gate Hatchery modification phase; the four dam and powerhouse removal phase; and the restoration phase. Horsepower ratings were obtained from online searches of manufacture websites. Where equipment horsepower ratings were not available, they were obtained from similar equipment types or were based on CalEEMod defaults. Exhaust emission rates for each piece of equipment were estimated using SMAQMD's RCEM OFFROAD 2021 emission factors according to each equipment's horsepower rating, anticipated daily operation hours, and equipment quantity. Load factors from CalEEMod were then applied based on equipment type (e.g., cranes, excavators, loaders, etc.). Certain equipment types proposed during the pre-dam removal phase such as lawn and garden equipment exhaust emissions were estimated using OFFROAD 2007 based on hours of use and quantity. It was conservatively assumed that all equipment used for each subphase would operate simultaneously for the entire work shift.

O.3.1.2 On-Road Exhaust Emissions

On-road GHG emissions from worker commute trips and truck hauling trips were estimated using EMFAC 2017 emission factors. Vehicle classifications for worker commute trips were assumed to be all Light-Duty gasoline and diesel (i.e., light duty automobile (LDA), light duty truck (LDT1), LDT2) while truck hauling trips were assumed to be all Heavy-Heavy Duty Diesel California International Registration Plan (CAIRP) Construction Trucks (i.e., T7 CAIRP Construction). Worker commute trips exhaust emissions were estimated based on the estimated number of workers per day for each dam and powerhouse removal and the total daily vehicle miles traveled (VMT) from each worker. Table O-1 provides the number of workers, maximum trip length from each worker, and daily VMT.

Table O-1. Summary of Worker Commute VMT.

	Peak # Workers/day[1]	**Maximum Trip Length[2]**	**Daily VMT (miles)**
J.C. Boyle	45	58.6	5,274
Copco No. 1	55	58.6	6,446
Copco No. 2	40	58.47	4,678
Iron Gate	80	46.4	7,424

Notes: Daily roundtrip VMT was estimated by applying the maximum trip length to the peak number of workers per day multiplied by 2.

[1] Appendix B: *Definite Plan – Section 5.*

[2] Maximum trip length is from each dam site to Medford, Oregon.

Under the Proposed Project, hauling would occur from material generated from each of the four dam and powerhouse removals. Waste material including earth, concrete, rebar, mechanical and electrical equipment, building waste, powerlines, and treated wood would be hauled to various on-site or off-site disposal sites including the Pelletier Transfer Station. Total hauling trips and daily VMT were applied to EMFAC 2017 emissions factors to estimate total hauling exhaust emissions according to each dam and powerhouse removal. Table O-2 provides the total hauling amounts and daily VMT for each hauling material type.

Table O-2. Summary of Waste Disposal Hauling VMT.

	J.C. Boyle	Copco No. 1	Copco No. 2	Iron Gate
Earth	130,800 yd^3	-	2,100 yd^3	1,257,000 yd^3
Concrete	51,900 yd^3	104,000 yd^3	16,600 yd^3	20,700 yd^3
Rebar	4,100 tons	1,100 tons	400 tons	1,000 tons
Mech. And Elec. Equip.	2,500 tons	1,100 tons	2,900 tons	1,200 tons
Building Waste	2,700 yd^3	1,700 yd^3	9,500 yd^3	2,300 yd^3
Power Lines	-	4.3 miles	6.7 miles	0.5 miles
Treated wood	-	-	700 tons	-
Wood Utility Poles	-	120 poles	100 poles	-
Daily Off-Road VMT	161	61	470	250

Notes: "yd^3" = cubic yards; VMT = Vehicle Miles Traveled
Trips were estimated based on a truck hauling capacity of 22 CY for earth and concrete, 10 tons for rebar, 8 tons for mechanical and electrical equipment, and 10 CY for building waste. Daily VMT was estimated by applying the number of trips to trip distances (provided in Attachment A) divided by the total number of days during the construction phase.
Source: Appendix B: *Definite Plan – Section 5*

O.3.2 Supporting Activities

After dam and powerhouse removal, restoration of the reservoir footprints would be accomplished using helicopters for reseeding of grasses, helicopters are not included in the RCEM and CalEEMod emissions models. Emissions factors for a Bell 206L engine helicopter with a shaft horsepower (shp) of 450 were provided by the Federal Office of Civil Aviation in Switzerland and were applied to the total hours of use to estimate total helicopter emissions. Restoration activities would also require the use of marine workboats. Emissions factors for workboats were estimated using the USEPA *Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data* (2000) emissions factor algorithms. The emissions factors were then applied to the total hours of use to estimate total workboat emissions.

O.3.3 Project Schedule and Phasing

Because the Proposed Project has overlapping construction phases, mass GHG emissions were estimated for the Proposed Project/No Hatchery Alternative and the other alternative scenarios. The total mass emissions for the Proposed Project include the phases and their corresponding subphases for pre-dam removal, Copco No. 1 deconstruction, Iron Gate deconstruction, J.C. Boyle deconstruction, Copco No. 2 deconstruction, and restoration. To derive total GHG emissions, daily equipment use estimates and associated daily emissions were summed and then multiplied by the anticipated duration of each phase and subphase, as depicted in the Definite Plan. Detailed assumptions are shown in Attachment A.

O.3.4 Energy Use Methodology

Quantification of energy use from construction equipment, hauling of material, and worker commutes was conducted using a combination of sources including EMFAC2017 and South Coast Air Quality Management District (SCAQMD). As indicated in the GHG methodology, construction equipment type, quantity, horsepower rating, and hours of use were provided for each pre-dam removal phase including seed collection, IEV control, construction access, road, bridge, and culvert improvements, recreation facilities removal, flood improvements, and the Yreka Water Supply Pipeline Relocation, and the Fall Creek and Iron Gate Hatchery modification phase; the four dam and powerhouse removal phase; and the restoration phase. Where equipment quantities were not provided, they were estimated based on hours and days of each phase. Where equipment horsepower ratings were not provided, they were obtained from similar equipment types or were based on CalEEMod defaults.

Construction equipment diesel fuel use was estimated by applying each equipment's horsepower rating, quantity, operating hours/day, and number of days for the corresponding construction phase to the SCAQMD average number of gallons of diesel per horsepower per hour factor. Gasoline and diesel fuel use from on- and off-road light duty and heavy-duty vehicles were based on the number of total worker commute, vendor, and hauling trips. Worker commute trips were estimated based on the estimated number of workers per day for each dam and powerhouse removal and the number of days for each dam and powerhouse removal. Vendor trips were based on the number of pick-up trucks that were provided in the construction equipment inventory and the number of days during each dam and powerhouse removal. Hauling trips were estimated based on the total hauling volume, truck carrying capacity, and the number of construction days during each dam and powerhouse demolition phases. Total trips were then applied to an average length of each trip to get the number of total miles. Worker, vendor, and hauling trips were then applied to number of gallons of gasoline and diesel per mile factor estimated using EMFAC2017.

O.4 GHG Emissions

Using the GHG emissions factors described in Section O.3, an emission inventory was developed for the Proposed Project and each alternative. The emissions inventory includes emissions from equipment use, hauling of material, worker commutes, and other associated activity. Emissions were estimated for the entire length of the Proposed Project. Table O-3 provides a summary of the GHG emissions for the Proposed Project and each alternative.

Table O-3. Summary of GHG Emissions by Alternative.

Alternatives	$MTCO_2e$
Proposed Project and No Hatchery Alternative	20,128
Partial Removal Alternative	13,417
Continued Operations with Fish Passage Alternative	7,058
Two Dam Removal Alternative	11,204
Three Dam Removal Alternative	12,432

Notes: Emissions calculations are provided in Attachment A.

Table O-3 shows that the Proposed Project and No Hatchery Alternative would emit the most amount of GHG emissions compared to the other alternatives. The following discussion provides more detail emissions for each construction activity according to the Proposed Project and alternatives.

O.4.1 Proposed Project/Full Facilities Removal and No Hatchery Alternative

The total GHG emissions shown in Table O-4 are associated with the Proposed Project and No Hatchery Alternative. The Proposed Project involves the removal of all dam and powerhouses and their associated facilities. As indicated above, the No Hatchery Alternative is the same as the Proposed Project except that operations at the Iron Gate Hatchery would cease at the time of dam removal and would not continue for eight years following dam removal, and the Fall Creek Hatchery would not reopen with upgraded facilities. Table O-4 shows that the J.C. Boyle dam and powerhouse removal and restoration phase are the largest contributors to the total emissions.

Table O-4. Summary of GHG Emissions from the Proposed Project and No Hatchery Alternative.

Construction Phase	$MTCO_2e$
Pre-Dam Removal	663
Iron Gate Dam Removal	4,267
Copco No. 1 Dam Removal	3,772
Copco No. 2 Removal	1,415
J.C. Boyle Removal	7,605
Restoration	2,406
Total Emissions	**20,128**

Notes: Emissions calculations are provided in Attachment A.

O.4.2 Partial Removal Alternative

Table O-5 shows the total emissions from the Partial Removal Alternative. As indicated, this alternative requires the same construction phases and activities as the Proposed Project, but with less intensity. For this alternative, equipment operating hours and volumes of material to be hauled were reduced, therefore resulting in less emissions than the Proposed Project.

Table O-5. Summary of GHG Emissions from the Partial Removal Alternative.

Construction Phase	$MTCO_2e$
Pre-Dam Removal	663
Iron Gate Dam Removal	128
Copco No. 1 Dam Removal	3,134
Copco No. 2 Removal	1,163
J.C. Boyle Removal	5,924
Restoration	2,406
Total Emissions	**13,417**

Notes: Emissions calculations are provided in Attachment A.

O.4.3 Continued Operations with Fish Passage Alternative

Under the Continued Operations with Fish Passage Alternative all facilities associated with the four dams would remain, while additional facilities would be constructed or upgraded at each dam to allow for volitional fish passage. This alternative excludes pre-dam removal and restoration construction activities. Under this alternative, not all structures and facilities will be removed, and therefore would require less equipment than the Proposed Project and other alternatives. A reduced amount of equipment and less construction activities results in less emissions than the other alternatives.

Table O-6 shows the total emissions from the Continued Operations with Fish Passage Alternative. These emissions estimates are based on the construction of fish ladders at all four dams (i.e., Copco No.1, Copco No. 2 and J.C. Boyle).

Table O-6. Summary of GHG Emissions from the Continued Operations with Fish Passage Alternative.

Construction Phase	$MTCO_2e$
Iron Gate Dam Modification and Fish Ladder Construction	2,781
Copco No. 1 Dam Modification and Fish Ladder Construction	3,070
Copco No. 2 Dam Modification and Fish Ladder Construction	380
J.C. Boyle Dam Modification and Fish Ladder Construction	827
Total Emissions	**7,058**

Notes: Emissions calculations are provided in Attachment A.

O.4.4 Two Dam Removal Alternative

The Two Dam Alternative is similar to the equipment and construction activities as the Proposed Project, however only Copco No. 1 and Iron Gate are the only two dam and powerhouses to be removed. With the exclusion of dam and powerhouse demolition for J.C. Boyle and Copco No. 2, emissions are reduced from the Proposed Project. Table O-7 provides the total emissions from the Two Dam Removal Alternative. These emissions estimates are based on the removal of two dams (i.e., Copco No. 1 and Iron Gate) and the construction of fish ladders at two dams (i.e., Copco No. 2 and J.C. Boyle).

Table O-7. Summary of GHG Emissions from the Two Dam Removal Alternative.

Construction Phase	$MTCO_2e$
Pre-Dam Removal	663
Copco No. 1 Dam Removal	3,772
Iron Gate Dam Removal	4,267
J.C. Boyle Dam Modification and Fish Ladder Construction	827
Copco No. 2 Dam Modification and Fish Ladder Construction	380
Restoration	1,294
Total Emissions	**11,204**

Notes: Emissions calculations are provided in Attachment A.

O.4.5 Three Dam Removal Alternative

The Three Dam Alternative is similar to the equipment and construction activities as the Proposed Project; however, the J.C. Boyle dam and powerhouse would not be removed. With the exclusion of dam and powerhouse demolition for J.C. Boyle, emissions are reduced from the Proposed Project. Table O-8 provides the total emissions from the Three Dam Removal Alternative. These emissions estimates are based on the removal of three dams (i.e., Copco No. 1, Copco No. 2, and Iron Gate) and the construction of fish ladders at one dam (i.e., J.C. Boyle).

Table O-8. Summary of GHG Emissions from the Three Dam Removal Alternative.

Construction Phase	$MTCO_2e$
Pre-Dam Removal	663
Copco No. 1 Dam Removal	3,772
Copco No. 2 Dam Removal	1,415
Iron Gate Dam Removal	4,267
J.C. Boyle Dam Modification and Fish Ladder Construction	827
Restoration	1,488
Total Emissions	**12,432**

Notes: Emissions calculations are provided in Attachment A.

O.5 Energy Use

By applying the methodology in Section O.3, total fuel use for construction was estimated for the Proposed Project and each alternative. Automotive fuels would be consumed to transport people to and from the project site. In addition, fuels would be required for construction elements and the transport of construction materials. Table O-8 provides the total gasoline from on-road vehicles and diesel from on- and off-road equipment and vehicles use.

Table O-8. Summary of Energy Use by Alternative.

Alternatives	Total Diesel (gallons)	Total Gasoline (gallons)
Proposed Project and No Hatchery Alternative	4,790,332	246,859
Partial Removal Alternative	4,070,853	246,859
Continued Operations with Fish Passage Alternative	887,796	246,859
Two Dam Removal Alternative	3,580,666	246,859
Three Dam Removal Alternative	3,754,867	246,859

Notes: Emissions calculations are provided in Attachment A.

O.6 Mitigation

KRRC has proposed and agreed to implement the following Mitigation Measures to reduce Proposed Project GHG emissions.

O.6.1 Onsite Mitigation

Mitigation Measure AQ-1 – Off-Road Construction Equipment Engine Tier
For the construction activities occurring within California, any off-road construction equipment (e.g., loaders, excavators, etc.) that are 50 horsepower or greater must be equipped with engines that meet the EPA Tier 4 Final emissions standards for off-road compression-ignition (diesel) engines, unless such an engine is not available for a particular item of equipment. To the extent allowed by CARB Off-Road Diesel Fueled Fleets regulations, Tier 3 and Tier 4 interim engines will be allowed when the contractor has documented, with appropriate evidence, that no Tier 4 Final equipment or emissions equivalent retrofit equipment is available or feasible (CARB 2016c). Documentation may consist of signed statements from at least two construction equipment rental firms.

Mitigation Measure AQ-2 – On-Road Construction Equipment Engine Model Year
Any heavy-duty on-road construction equipment must be equipped with engines that meet the model year (MY) 2010 or newer on-road emission standards.

Mitigation Measure AQ-3 – Heavy-Duty Trucks Engine Model Year
Any heavy-duty trucks used to transport materials to or from the construction sites must be equipped with engines that meet the MY 2010 or later emission standards for on-road heavy-duty engines and vehicles. Older model engines may also be used if they are retrofitted with control devices to reduce emissions to the applicable emission standards.

O.6.2 Offsite Mitigation

Project construction would result in a total of 20,128 $MTCO_2e$. To reduce GHG emissions from construction activity to zero, it is proposed to purchase carbon credits through any one of the following verifiable entities/registries: CARB, Climate Action Reserve, California Air Pollution Control Officers Association, the APCD, or any other equivalent or verifiable registry. Such offsets would meet the requirements of CEQA Guidelines Section 15126.4(C)(3) and meet the following criteria:

- **Real**—They represent reductions actually achieved (not based on maximum permit levels).
- **Additional/surplus**—They are not already planned or required by regulation or policy (i.e., not double counted).
- **Quantifiable**—They are readily accounted for through process information and other reliable data.
- **Enforceable**—They are acquired through legally binding commitments/agreements.
- **Validated**—They are verified through the accurate means by a reliable third party.

- **Permanent**—They will remain as GHG reductions in perpetuity.

Carbon offset credits must be purchased equal to the total estimated amount of GHG emissions that would be emitted from construction activities (i.e., 20,128 $MTCO_2e$). The price per MT of CO_2e varies depending on the availability of credits on the market, the number of credits purchased at one time, and the type and location of carbon offset being purchased. Current pricing estimates range from $0.85 to $8.5 per $MTCO_2e$.

O.6.3 Mitigation Effectiveness

Implementation of Mitigation Measure ENR-1 would effectively reduce project-generated construction emissions to zero. Implementation of Mitigation Measures AQ-1 through AQ-3 would also result in small reductions in GHG emissions, but would primarily reduce criteria air pollutants and ozone precursors.

O.7 Additional Measures

In addition to Mitigation Measures ENR-1, and AQ-1 through AQ-3, below are additional measures that could reduce the amount of GHG emissions associated with vehicle and construction equipment use, but primarily reduce criteria air pollutants and ozone precursors.

- Maintain all construction equipment in proper working condition according to manufacturer's specifications. The equipment must be checked by a certified mechanic and determine to be running in proper condition before it is operated.
- Minimize idling time either by shutting equipment off when not in use or reducing the time of idling to 5 minutes [required by California Code of Regulations, Title 13, sections 2449(d)(3) and 2485]. Provide clear signage that posts this requirement for workers at the entrances to the site.
- Replace fossil-fueled equipment with electrically driven equivalents, when available and feasible (provided they are not run via a portable generator set)
- To the extent feasible and available, the lead agency shall require their construction contractors, through bid specifications, to use high performance renewable diesel fuel in all diesel equipment.

O.8 References

KRRC. 2019. FERC Nos. P-2082; P-14803, NATDAM-OR00559, CA00323, CA00234, CA00325; Response to Independent Board of Consultants' recommendations. Prepared by PerkinsCoie, Bellevue, Washington (on behalf of KRRC) for Federal Energy Regulatory Commission, Washington, D.C.

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