Appendix 23A
Mass Emissions Estimation Methodology

This appendix discusses the approach and methodology used to estimate construction and operational emissions resulting from the Delta Conveyance Project (project) and alternatives for this Draft Environmental Impact Report (Draft EIR). The analysis evaluates maximum daily and yearly emissions to comply with CEQA guidelines[1] in the air quality study area. Emissions analyzed include ozone (O_3) precursors (reactive organic gases [ROGs[2]] and nitrogen oxides [NO_X]) and criteria pollutants of carbon monoxide (CO), particulate matter (PM10 and PM2.5), and sulfur dioxide (SO_2); and greenhouse gases (GHG) of carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), hydrofluorocarbons (HFC), and sulfur hexafluoride (SF_6). Where applicable, the analysis also quantifies toxic air contaminants (TAC), such as diesel particulate matter (DPM) and certain metals.

As discussed in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, restoration is required to mitigate effects on federal and state wetlands/waters, as well as to offset effects on other water and upland habitats that may be impacted by the project. These actions lead to the restoration of portions of Bouldin Island and areas along Interstate 5. The restoration actions are collectively referred to as compensatory mitigation. In addition to potential air quality and GHG effects resulting from the project, potential air quality and GHG effects resulting from the implementation of compensatory mitigation (see Appendix 3F*)* are assessed alongside impacts of the project alternatives in Chapter 23, *Air Quality and Greenhouse Gases*. The types of construction activities (e.g., grading) and equipment (e.g., cranes) needed for habitat restoration are similar to what would be required for construction of the project, although they would be of substantially lesser magnitude. Where applicable, this appendix describes the mass emissions quantification method for compensatory mitigation.

Results of the emissions analysis are evaluated in Chapter 23, Impacts AQ-1 through AQ-4 and AQ-9. Readers are directed to the following additional appendices for further information on the air quality and GHG analysis.

- Appendix 23B, *Air Quality and GHG Analysis Activity Data*: Provides all analysis inputs for the estimation of criteria pollutants and GHG emissions.
- Appendix 23C, *Health Risk Assessment and Ambient Air Quality Analysis Methodology*: Presents the methodology used to conduct the health risk assessment and localized ambient air quality analysis.
- Appendix 23D, *Criteria Pollutant Health Impact Assessment Methodology*: Presents the methodology used to correlate construction-generated regional criteria pollutant emissions to potential human health consequences.

[1] The analysis was prepared to support the forthcoming NEPA document and therefore also complies with NEPA guidelines.

[2] ROG is synonymous with volatile organic compounds (VOC); both terms are used in this document depending on the emissions source.

23A.1 Construction

23A.1.1 Schedule

Based on current information, it is anticipated that preliminary field investigations would begin at the earliest in 2025, with construction of the project beginning about 2 years later. However, based on information available at the time of the CEQA analysis modeling, emissions were quantified assuming preliminary field investigations would begin in 2024 and project construction in 2026. It is projected that the emissions intensity of equipment and vehicle operation in 2027 would be lower than under 2026 conditions because of improvements in engine technology and regulations to reduce combustion emissions. Accordingly, the construction analysis reflects a conservative representation of emissions.

During peak construction periods, work would occur at several locations within the study area, with overlapping construction of various project components. Working hours and workers present at any time would vary, depending on the activities being performed. Table 23A-1 summarizes the expected timeframe for construction of each of the physical project components (e.g., intakes), movement of reusable tunnel material (RTM), and on-site batching operations. Refer to Appendix 23B, *Air Quality and GHG Analysis Activity Data*, for the detailed construction schedule, including phase descriptions and start and end dates.

Table 23A-1. General Schedule

Physical Component	Expected Timeframe
Bethany Aqueduct	CY 5 to CY 10 (Alternative 5)
Batch plants [a]	CY 1 (Alternatives 1, 2b, 3, 4b); CY 1, CY 5, and CY 6 (Alternatives 2a, 4a); CY 1 and CY 5 (Alternatives 2c, 4c); CY 1 and CY 3 (Alternative 5)
Batch plants (operation)	CY 2 to CY 11 (Alternatives 1, 2b, 2c, 3, 4b, 4c); CY 2 to CY 12 (Alternatives 2a, 4a); Cy 1 and CY 2 to CY 13 (Alternative 5)
Bethany Reservoir Pumping Plant and Surge Basin	CY 3 to CY 13 (Alternative 5)
Bethany Discharge	CY 5 to CY 10 (Alternative 5)
Intakes	CY 1 to CY 12 (Alternatives 1, 2a, 2c, 3, 4a, 4c, 5); CY 1 to CY 11 (Alternatives 2b, 4b)
Levees [b]	CY 3 (all alternatives)
Park-and-ride lots	CY 1 (all alternatives)
Rail depots [c]	CY 1 (Alternatives 1, 2a, 2b, 2c); CY 1 and CY 2 (Alternatives 3, 4a, 4b, 4c, 5)
Roads	CY 1 to CY 12 (Alternatives 1, 2a, 2b, 2c); CY 1 to CY 13 (Alternatives 3, 4a, 4b, 4c, 5)
RTM handling	CT 5 to CY 12 (Alternatives 1, 2c, 2b); CY 10 to CY 13 (Alternatives 2a, 4c); CY 4 to CY 10 (Alternative 2b); CY 5 to CY 14 (Alternatives 3, 4a); CY 3 to CY 12 (Alternative 5)
Shafts and tunnel [d]	CY 1 to CY 12 (Alternatives 1, 2b, 2c, 3, 4b); CY 1 to CY 13 (Alternatives 2a, 4a, 4c, 5) CY 1 to CY 11 (Alternative 4a)
Southern Complex	CY 1 to CY 12 (Alternatives 1, 2b, 2c, 4b); CY 1 to CY 13 (Alternatives 2a, 4a, and 5); CY 1 to CY 11 (Alternative 4c)

Physical Component	Expected Timeframe
Compensatory mitigation	CY 1 through CY 3 (all alternatives)

CY = construction year; RTM = reusable tunnel material.

[a] Only the Lambert Road Batch Plant and Bethany Complex Batch Plant (Alternative 5) are listed separately as "Batch Plant" features. The Bacon Island Batch Plant is included in the Bacon Island Shaft feature. Both concrete batch plants at the Southern Complex (Alternatives 1, 2a, 2b, 2c, 3, 4a, 4b, and 4c) are included in the Southern Complex feature.

[b] Levee work at the intakes is included in the Intakes feature.

[c] The Southern Complex rail depot is included in the Southern Complex feature (Alternatives 1, 2a, 2b, 2c, 3, 4a, 4b, and 4c).

[d] Shafts at the intakes and Southern/Bethany Complex are included in the Intakes and Southern/Bethany Complex features, respectively.

23A.1.2 Activity Data

The Delta Conveyance Design and Construction Authority (DCA) developed project-specific construction assumptions (e.g., equipment operating hours, cubic yards of soil moved) for each of the physical project components. Construction assumptions for the compensatory mitigation sites were also developed. These assumptions define the activity inputs used to estimate construction emissions. The analysis also considers vehicle trip and vehicle miles traveled (VMT) data, as further discussed below in Section 23A.1.4.2, *Motor Vehicles*. Appendix 23B, *Air Quality and GHG Analysis Activity Data*, includes all underlying activity assumptions for the air quality and GHG analysis.

23A.1.3 Emission Sources

Table 23A-2 summarizes the emissions generating sources expected during construction of the project. Refer to Chapter 3, *Description of the Proposed Project and Alternatives*, Section 3.4, *Common Features of the Alternatives*, for additional information on the general construction approach and method.

Table 23A-2. Emissions Generating Activities during Project Construction

Source	Emissions Generating Process	Pollutants Analyzed
Heavy equipment	Equipment fuel combustion	ROG, NO_X, CO, PM2.5, PM10, DPM, SO_2, CO_2, CH_4, N_2O
Motor vehicles	Vehicle fuel combustion	Same as *heavy equipment fuel combustion*
	Tirewear and brakewear	Fugitive dust (PM10 and PM2.5)
	Vehicle travel	Fugitive dust (PM10 and PM2.5)
	Air conditioner losses	HFC
Locomotives	Locomotive fuel combustion	Same as *heavy equipment fuel combustion*
Marine	Vessel fuel combustion	Same as *heavy equipment fuel combustion*
Electricity consumption	Generation and transmission	ROG, NO_X, CO, PM2.5, PM10, SO_2, CO_2, CH_4, N_2O, SF_6
Circuit breakers	Fugitive losses	SF_6
Striping	Painting of parking lots and roads	VOC
Paving	Application of asphalt	VOC

Source	Emissions Generating Process	Pollutants Analyzed
Demolition	Mechanical dismemberment	Fugitive dust (PM10 and PM2.5)
	Debris loading	Fugitive dust (PM10 and PM2.5)
Land clearing	Scraping	Fugitive dust (PM10 and PM2.5)
	Bulldozing	Fugitive dust (PM10 and PM2.5)
	Truck loading	Fugitive dust (PM10 and PM2.5)
	Sequestration/carbon storage	CO_2, CH_4, and N_2O
Dredged and reusable tunnel materials	Conveyance transfer	Fugitive dust (PM10 and PM2.5)
	Stockpile wind erosion	Fugitive dust (PM10 and PM2.5)
	Truck and rail car loading	Fugitive dust (PM10 and PM2.5)
Concrete batching	Material processing	Fugitive dust (PM10 and PM2.5), TAC
	Stockpile wind erosion	Fugitive dust (PM10 and PM2.5)
	Upstream (lifecycle) activities	CO_2, CH_4, and N_2O
Wastewater treatment	Anaerobic decomposition	CH_4
Helicopters	Vehicle fuel combustion	Same as *heavy equipment fuel combustion*

ROG = reactive organic gases; VOC = volatile organic compounds; NO_X = nitrogen oxides; CO = carbon monoxide; PM10 = particulate matter; PM2.5 = particulate matter; SO_2 = sulfur dioxide; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxides; HFC = hydrofluorocarbons; SF_6 = sulfur hexafluoride; DPM = diesel particulate matter.

23A.1.4 Emissions Estimation

Each of the activities presented in Table 23A-2 was considered to evaluate the air quality and GHG effects during construction of the project. Emission rates for the various activities were calculated using a combination of emission factors and methodologies from the California Emissions Estimator Model (CalEEMod), version 2016.3.2; the Emissions FACtors model (EMFAC2017 and CT-EMFAC2017);[3] the U.S. Environmental Protection Agency's (EPA) *AP-42 Compilation of Air Pollutant Emission Factors* (AP-42); and other relevant agency guidance and published literature, as discussed further and cited below.

The California Department of Water Resources (DWR) has developed environmental commitments that would avoid or minimize potential air quality and GHG effects from construction of the project. Because environmental commitments are included as part of the project design, they are not considered mitigation, and are included as part of the project construction emissions estimate. Accordingly, an appropriate emission reduction factor was applied to the emission rate calculation for activities that would have emission controls, as specified by DWR through an environmental commitment. Appendix 3B, *Environmental Commitments and Best Management Practices*, presents the environmental commitments that are incorporated into the project design.

The following sections describe the quantification approach for each emissions source.

[3] CARB released EMAFC2021 on January 15, 2021; however, this version has not yet been approved by EPA. Accordingly, this analysis uses EMAFC2017, which was available at the time of notice of preparation and is the current EPA approved version of EMFAC.

23A.1.4.1 Heavy Equipment

Emission factors for diesel-powered heavy equipment (e.g., loaders, graders, bulldozers) were obtained from the CalEEMod (version 2016.3.2) User's Guide, which provides values per unit of activity (in grams per horsepower-hour) (Trinity Consultants 2017a:Table 3.5). Pursuant to Environmental Commitment EC-7: *Off-Road Heavy-Duty Engines* (refer to Appendix 3B), Tier 4 emissions rates were modeled, where established, instead of calendar year averages that are based on a mix of equipment meeting various engine tiers. Accessory equipment (e.g., trailers, clamshell bucket) with no engines or emissions-generating components were excluded from the analysis. Tunnel boring machines (TBM), tunnel fans, tunnel lights, and certain equipment would be electric and were included in the electricity analysis (see Section 23A.1.4.5, *Electricity Consumption*).

Equipment exhaust emissions were calculated using the CalEEMod emission factors and Equation 23A-1.

Equation 23A-1 $E_{phase} = \Sigma(Activity * EF_t * LF_t * HP_t) * UC$

Where:

E_{phase} = total exhaust emissions for the phase (pounds per day)
Activity = equipment activity (hours per day)
EF = engine emission factor (grams per horsepower-hour)
LF = engine load factor (unitless)
HP = engine horsepower (unitless)
UC = unit conversion from grams to pounds (0.002205)
t = equipment type (e.g., graders)

Environmental Commitment EC-7: *Off-Road Heavy-Duty Engines* also requires that off-road equipment utilize renewable diesel. Renewable diesel would reduce particulate matter and NOx emissions generated by Tier 0 to Tier 3 engines by 30% and 10%, respectively (California Environmental Protection Agency 2015:8). Accordingly, control efficiencies of 30% and 10% were applied to the quantification of PM10 and PM2.5 and NOx, respectively, for engines without Tier 4 emission standards. No reductions were applied to emissions quantified for Tier 4 engines pursuant to Environmental Commitment EC-7.

CalEEMod does not include emission factors for N_2O for off-road diesel equipment. Emissions of N_2O generated by each diesel-powered equipment piece were determined by scaling the CO_2 emissions quantified by Equation 23A-1 by the ratio of N_2O/CO_2 (0.000046) emissions expected per gallon of diesel fuel according to The Climate Registry (The Climate Registry 2020:Tables 2.1 and 2.7).

23A.1.4.2 Motor Vehicles

23A.1.4.2.1 Vehicle Fuel Combustion

Motor vehicles (e.g., pickup trucks, flatbed trucks) would be required for material and equipment hauling, on-site crew and material movement, and employee commuting. Exhaust emissions from on-road vehicles were estimated using the EMFAC2017 emissions model and vehicle activity data (trips and miles traveled per day). Running exhaust emission factors for on-site trucks are based on

emission rates at 5 miles per hour[4] (mph) for EMFAC's heavy-heavy duty truck (HHDT) and medium-heavy duty truck (MHDT) vehicle categories. Factors for off-site trucks and buses are based on emissions rates by five mph speed bin[5] for EMFAC's HHDT, MHDT, light-duty truck (LDT), and other bus (OBUS) vehicle categories, as applicable. Off-site employee commute vehicles were based on light-duty automobile (LDA) and LDT vehicle categories. Process exhaust (e.g., starting, idle) emissions factors were also derived from EMFAC2017 for each of the project vehicle categories.

Environmental Commitment EC-8: *On-Road Haul Trucks* (refer to Appendix 3B) requires all construction contractors to use diesel trucks that have model year engines manufactured or retrofitted ideally within the past 5 years of when the vehicles are brought to the individual construction sites, but no more than 8 years from overall project groundbreaking. The measure also encourages DWR construction contractors to use electric or hybrid-electric vehicles over diesel counterparts. While this commitment will reduce emissions from diesel haul trucks by requiring newer model year engines (or electric vehicles), because there is flexibility to use vehicles that are up to 8 years old from the start of construction, the exact project fleet mix is unknown. Accordingly, EMFAC's calendar year average emission factors were used to conservatively estimate emissions from haul trucks. This approach does not quantitatively capture the emissions benefits that will be achieved by Environmental Commitment EC-8, which will lead to use of newer and more electric vehicles for construction of the project compared to the calendar year fleetwide average.

Running emissions were calculated using the EMFAC emission factors and Equations 23A-2 and 23A-3.

Equation 23A-2 $E = \Sigma VMT_t * EF_t * UC$

Where:

E_{phase} = total running emissions (pounds per day)
VMT = daily VMT by air basin and speed (if applicable) (miles per day)
EF = running emissions factor by air basin and speed (if applicable) (grams per mile)
UC = unit conversion from grams to pounds (0.002205)
t = vehicle type (e.g., HHDT)

Equation 23A-3 $E = \Sigma Trip_t * EF_t * UC$

Where:

E_{phase} = Total process emissions (pounds per day)
Trip = daily trips by air basin (trips per day)
EF = process emissions factor by air basin (grams per trip)
UC = unit conversion from grams to pounds (0.002205)
t = vehicle type (e.g., HHDT)

[4] Emission factors are greatest at lower vehicle speeds. It is likely that vehicles will travel faster than 5 mph; however, to ensure emissions are not underrepresented, DWR conservatively elected to model all vehicle travel at the lowest vehicle speed for which emission factors are reported (5 mph).

[5] EMFAC provides speed-based emission factors in increments of 5 mph. For example, factors for vehicles traveling at 0 to 5 mph, 5 to 10 mph, and so on.

23A.1.4.2.2 Tirewear and Brakewear

Analysis estimated tirewear and brakewear emissions from on-road vehicles using the EMFAC2017 emissions model and activity data (miles traveled per day). Emission factors for each of the project vehicle categories were derived from EMFAC2017 using the same method as described above for vehicle fuel combustion. Equation 23A-2 was used to calculate resulting emissions (as shown in Section 23A.1.4.2.1, *Vehicle Fuel Combustion*).

23A.1.4.2.3 Vehicle Travel

When a vehicle travels over a road, the force of the wheels on the road can resuspend surface material that is entrained by vehicular travel. Entrained road dust contributes to airborne fugitive dust (PM10 and PM2.5). Emission factors for entrained road dust were calculated using the methodology found in Sections 13.2.1 and 13.2.2 of AP-42. Emission factors for on-site vehicles were calculated using Section 13.2.2 for unpaved roads (U.S. Environmental Protection Agency 2006a:Tables 13.2.2-1 and 13.2.2-2). Emission factors for off-site vehicles were calculated using Section 13.2.1 for paved roads (U.S. Environmental Protection Agency 2011:Table 13.2.1-1).

The equation for developing the unpaved road dust emission factors is shown as Equation 23A-4.

Equation 23A-4 $$EF = [((k * (s \div 12)^{a} * (S \div 30)^{d}) \div (M - 0.5)^{c}) - C] * ((N - P) \div N) * (1 - CE)$$

Where:

EF = emission factor (grams per mile)
k = empirical constant (grams per VMT)
s = surface material silt content (%)
M = surface material moisture content (%)
S = mean vehicle speed (mph)
C = emission factor for vehicle fleet exhaust, brakewear, and tirewear (grams per mile)
a = empirical constant (unitless)
c = empirical constant (unitless)
d = empirical constant (unitless)
N = number of days in the average period (365 days)
P = days per year with at least 0.01 inch of precipitation (days per year)
CE = control efficiency achieved by environmental commitment (%)

Constants a, b, and d are based on the particle size, and P and C vary by project location—Sacramento Valley Air Basin (SVAB), San Joaquin Valley Air Basin (SJVAB), and San Francisco Bay Area Air Basin (SFBAAB). Table 23A-3 defines the variables used for this calculation. The control efficiency is achieved through implementation of Environmental Commitment EC-11: *Fugitive Dust Control* (refer to Appendix 3B), which requires that all onsite travel routes be graveled and covered with chip-seal or treated with dust suppressants. The commitment also requires wheel washers, street sweepers, and other controls to reduce generation of road dust and track out onto public roads.

Table 23A-3. Variables for Unpaved Road Dust Emission Factor Calculation

Variable	PM10	PM2.5	Source
k (gram/VMT)	816.47	81.65	AP-42, Section 13.2.2 (U.S. Environmental Protection Agency 2006a:Table 13.2.2-2)
s (%)	8.5	8.5	AP-42, Section 13.2.2 (U.S. Environmental Protection Agency 2006a:Table 13.2.2-1)
C (gram/VMT)	0.107 (SVAB) 0.108 (SJVAB) 0.108 (SFBAAB)	0.045 (SVAB) 0.046 (SJVAB) 0.046 (SFBAAB)	EMFAC2017
a (unitless)	1.0	1.0	AP-42, Section 13.2.2 (U.S. Environmental Protection Agency 2006a:Table 13.2.2-2)
c (unitless)	0.2	0.2	AP-42, Section 13.2.2 (U.S. Environmental Protection Agency 2006a:Table 13.2.2-2)
d (unitless)	0.5	0.5	AP-42, Section 13.2.2 (U.S. Environmental Protection Agency 2006a:Table 13.2.2-2)
P (days/year)	58 (SVAB) 55 (SJVAB) 58 (SFBAAB)	58 (SVAB) 55 (SJVAB) 58 (SFBAAB)	Western Regional Climate Centers 2020a, 2020b, 2020c
CE (%)	84	84	Countess Environmental 2006:3

The equation for developing the paved road dust emission factors is shown as Equation 23A-5.

Equation 23A-5 $$EF = [k * (sL)^{0.91} * (W)^{1.02}] * (1 - P \div 4N) * UC$$

Where:

EF = emission factor (grams per mile)
k = empirical constant (pound per VMT)
sL = road surface silt loading (grams per square meter [g/m^2])
W = mean weight of all vehicles traveling on the road (tons)
P = days per year with at least 0.01 inch of precipitation (days per year)
N = number of days in the average period (365 days)
UC = unit conversion from pounds to grams (453.592)

Constant k varies depending on the particle size, and P varies by project location (air basin). Table 23A-4 defines the variables used for this calculation.

Table 23A-4. Variables for Paved Road Dust Emission Factor Calculation

Variable	PM10	PM2.5	Source
k (lb/VMT)	0.0022	0.00054	AP-42, Section 13.2.1 (U.S. Environmental Protection Agency 2011:Table 13.2.1-1)
sL (g/m^2)	0.1	0.1	CalEEMod default (obtained from the model)
W (tons)	2.4	2.4	CalEEMod (Trinity Consultants 2017a:Table 4.1)

Variable	PM10	PM2.5	Source
P (days/year)	58 (SVAB) 55 (SJVAB) 55 (SFBAAB)	58 (SVAB) 55 (SJVAB) 55 (SFBAAB)	Western Regional Climate Centers 2020a, 2020b, 2020c

Equation 23A-2 (as shown in Section 23A.1.4.2.1, *Vehicle Fuel Combustion*) was used to estimate the resulting road dust emissions based on the calculated emission factors.

23A.1.4.2.4 Air Conditioner Losses

Onboard air conditioning units can leak HFC during normal use. Therefore, unlike other pollutants, HFC are only emitted through the process of running loss (California Department of Transportation 2019:109). HFC emission factors were derived from the statewide total HFC vehicle emissions inventory and activity data from EMFAC2017. The California Department of Transportation (2019:109) reports that statewide calendar year 2017 vehicle HFC emissions were 49 grams per year from light-duty vehicles and 257 grams per year from heavy-duty vehicles. These inventories were divided by total statewide miles traveled (per EMFAC2017) for each vehicle class to obtain HFC emissions rates in terms of grams per mile that could be applied to the project activity data. The emission factors, which are based on 2017 fleet conditions, were held constant throughout the duration of construction. This approach is conservative given EPA's Significant New Alternatives Policy, which prohibits HFC use in light-duty vehicles manufactured after 2021 and heavy-duty vehicles manufactured after 2026 (California Department of Transportation 2019:109).

HFC emissions were quantified using Equation 23A-6.

Equation 23A-6 $E = \Sigma VMT_t * EF_t * UC$

Where:

E = HFC loss emissions (pounds per day)
VMT = daily VMT by vehicle type (miles per day)
EF = HFC emission factor (grams per mile)
UC = unit conversion from grams to pounds (0.002205)
t = vehicle type (light-duty or medium/heavy-duty)

23A.1.4.3 Locomotives

Tunnel segments, TBM components, materials, and equipment may be delivered to the Twin Cities Complex, Lower Roberts Island, and Byron Tract by railroad. Rail service would be provided by the Burlington Northern Santa Fe (BNSF) Railroad or Union Pacific Railroad (UPRR), depending on location. Locomotives would also be used on-site to transport construction materials and RTM to other Delta Conveyance construction sites, including moving RTM to the Southern Complex to construct the Southern Forebay embankments.

Emission factors for regulated criteria pollutants (hydrocarbons, NO_X, CO, and PM) were obtained from EPA (2009:Table 1). The emission factors are defined per unit of activity (in grams per horsepower-hour) by engine tier and by calendar year in terms of grams per gallon of diesel combusted. The emission factors for ROG and PM2.5 were calculated assuming ROG emissions are

equal to 1.053 times the hydrocarbon emissions and PM2.5 emissions are equal to 0.97 the PM10 emissions (U.S. Environmental Protection Agency 2009:4). SO_2 emission factors were calculated using Equation 23A-7 (U.S. Environmental Protection Agency 2009:5).

Equation 23A-7 $\mathbf{EF = (F_D * C * MW * S_C * UC_1) \div UC_2}$

Where:

EF = SO_2 emission factor (grams per horsepower-hour)

F_D = fuel density of 3,200 (grams per gallon)

C = fraction of fuel sulfur converted to SO_2 (97.8%)

MW = molar weight (2)

S_C = sulfur content (15 parts per million, per California Air Resources Board [CARB] and EPA requirements)

UC_1 = unit conversion (0.000001)

UC_2 = unit conversion from gallons to horsepower-hour (20.8)

Unlike criteria pollutants, there are no federal or state GHG standards for locomotives. Accordingly, emission factors for CO_2, CH_4 and N_2O are based on fuel-specific combustion rates for each pollutant, as defined in port inventories throughout the state (Starcrest Consulting 2019:Table 6.4).

All locomotives would be equipped with a single 4,300-horsepower engine. The operating engine load was calculated based on duty cycle averages for line-haul freight locomotives from EPA's Regulatory Support Document (RSD) (U.S. Environmental Protection Agency 1998a:Table 4-6 and Appendix B). The RSD was likewise used to define the average locomotive engine horsepower at idle. Resulting on-site locomotive emissions were calculated using EPA and GHG emission factors and Equation 23A-8. Pursuant to Environmental Commitment EC-9: *On-Site Locomotives* (refer to Appendix 3B), all on-site locomotives would operate Tier 4 or newer engines.

Equation 23A-8 $\mathbf{E_{phase} = \Sigma(Activity * EF * HP * LF) * UC}$

Where:

E_{phase} = total exhaust emissions for the phase (pounds per day)

Activity = engine activity (hours per day per locomotive)

EF = engine emissions factor (grams per horsepower-hour)

HP = engine horsepower (4,300 operating, 14 at idle)

LF = engine load factor (0.46 operating; 1 at idle)

UC = unit conversion from grams to pounds (0. 002205)

Locomotive exhaust emissions from UPRR and BNSF equipment and material deliveries were quantified using Equation 23A-9. The project inventory includes expected ton-miles traveled per day by phase. Because the fleet mix for UPRR and BNSF trains is unknown, calendar year average emission rates from EPA in terms of grams per gallon of fuel combusted were used for the off-site delivery trains. These emission factors were converted to grams per ton-mile traveled assuming U.S. freight railroads, on average, move 1 ton of freight more than 470 miles per gallon of fuel (Association of American Railways 2020:1). Resulting locomotive emissions were calculated using Equation 23A-9.

Equation 23A-9 $E_{phase} = \Sigma(Activity * EF) * UC$

Where:

E_{phase} = total exhaust emissions for the phase (pounds per day)
Activity = ton-mile traveled per day per locomotive
EF = engine emissions factor (grams per ton-mile)
UC = unit conversion from grams to pounds (0. 002205)

Under Alternatives 1, 2a, 2b, 2c, 3, 4a, 4b, and 4c, UPRR rail cars would be connected at the rail depot siding along Franklin Boulevard (Twin Cities Complex) and disconnected at the rail depot siding along Byron Highway (Southern Complex). Under the Eastern conveyance alignment (Alternatives 3, 4a, 4b, and 4c) and Bethany Reservoir conveyance alignment (Alternative 5), rail cars would also be unloaded at the Lower Roberts Island depot. There would be 10 to 15 on-site train trips per week for all alternatives, with trains idling approximately 30 minutes per trip at each siding location to connect and disconnect rail cars. Idle emissions associated with this activity were quantified using Equation 23A-8. Calendar year average emission rates from EPA in terms of grams per gallon of fuel were converted to grams per horsepower-hour using a conversion factor of 20.8 horsepower-hours per gallon of fuel (U.S. Environmental Protection Agency 2009:3).

23A.1.4.4 Marine Vessels

Marine vessels may be used to install riprap during the final intake construction phase and for preliminary field investigations. Engine parameters (horsepower, load factor) and emission factors for all vessels except worker transport vessels were obtained from the Sacramento Metropolitan Air Quality Management District's (SMAQMD) Harborcraft, Dredge and Barge Emission Factor Calculator. Worker transport vessels would operate a gasoline-powered (4-stroke) stern drive engine. Emission factors for this vessel were obtained from CARB's Pleasure Craft (PC2014) Model. Exhaust emissions were calculated using Equation 23A-10. Pursuant to Environmental Commitment EC-10: *Marine Vessels* (refer to Appendix 3B), all marine vessels used for preliminary field investigations would have model year 2010 or newer engines.

Equation 23A-10 $E_{phase} = \Sigma((Activity * EF * HP * LF)_m + (Activity * EF * HP * LF)_a) * UC$

Where:

E_{phase} = total exhaust emissions per phase (pounds per day)
Activity = engine activity (hours per day per vessel)
EF = engine emissions factor (grams per horsepower-hour)
HP = engine horsepower (1,167 main; 86 auxiliary)
LF = engine load factor (0.50 main; 0.31 auxiliary)
m = main engine
a = auxiliary engine
UC = unit conversion from grams to pounds (0.002205)

23A.1.4.5 Electricity Consumption

Construction of the project would require the use of electricity for lighting, tunnel ventilation, boring, and certain types of equipment. Operation of the batch plants would also consume

electricity. GHG emission factors from the generation and transmission of electricity were calculated using data from EPA's 2019 Emissions & Generation Resource Integrated Database (eGRID) and account for increases in the renewable energy mix due to the renewables portfolio standard and Senate Bill 100 (U.S. Environmental Protection Agency 2021).[6] The eGRID does not include complete emission factors for criteria pollutants. Accordingly, criteria pollutant emission factors for electricity were obtained from the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) model. Emissions were calculated using Equation 23A-11.

Equation 23A-11 **E = EF * MWh * UC**

Where:

E = annual emissions (pounds per year)
EF = electricity emission factor (grams per megawatt-hour [MWh])
MWh = electricity consumed per year (MWh per year)
UC = unit conversion from grams to pounds (0.002205)

23A.1.4.6 Circuit Breakers

Construction of the project would require the installation of electrical equipment, including power circuit breakers. This analysis assumes all circuit breakers would be insulated with SF_6-gas-insulated switchgear. This assumption is conservative because state regulations banning SF_6 circuit breakers after 2033 are forthcoming (California Air Resources Board 2020b). Moreover, DWR would pursue vacuum or very low-GWP gas insulated breakers as they become commercially available. Regardless, potential SF_6 emissions from the breakers were estimated based on the mass of each breaker and an assumed 1% by mass annual leak rate (17 California Code of Regulations § 95352), as shown in Equation 23A-12.

Equation 23A-12 **E = ER * CB * M * UC**

Where:

E = annual emissions (metric tons per year)
ER = SF_6 emission rate, per CARB regulation (1%)
CB = number of circuit breakers operating per year
M = breaker mass (90 pounds)
UC = unit conversion from pounds to metric tons (0.000453592)

23A.1.4.7 Striping

Volatile organic compounds (VOC) off-gassing emissions result from the painting of stripes, handicap symbols, directional arrows, and car space descriptions. The VOC emission factor for striping was calculated using the methodology found in the CalEEMod User's Guide (Trinity

[6] eGRID does not include emission factors for SF_6. Statewide SF_6 emissions in 2018, which was the latest year with data available as of the time of this analysis, were therefore used to identify an emission factor per MWh by dividing total SF_6 emissions by the total electricity generation in California (California Air Resources Board 2020a; California Energy Commission 2019).

Consultants 2017b:17). The equation for developing the VOC emission factor is shown as Equation 23A-13.

Equation 23A-13 $EF = C_{VOC} \div UC_1 * UC_2 \div C$

Where:

EF = emission factor (pounds per square foot)

C_{VOC} = VOC content (grams per liter)

UC_1 = unit conversion from pounds to grams (453.592)

UC_2 = unit conversion from gallons to liters (3.785)

C = constant, square feet (180)

The VOC contents (C_{VOC}) of paints are regulated by air districts. All three air districts with regulatory authority in the local air quality study area—SMAQMD, San Joaquin Valley Air Pollution Control District (SJVAPCD), and Bay Area Air Quality Management District (BAAQMD) have adopted rules that limit the VOC content of traffic maker coatings to 100 grams per liter (SMAQMD Rule 442, SJVAPCD Rule 4601, BAAQMD Regulation 8 Rule 3) (Sacramento Metropolitan Air Quality Management District 2015; San Joaquin Valley Air Pollution Control District 2020; Bay Area Air Quality Management District 2009).

VOC emissions were calculated using Equation 23A-14 (Trinity Consultants 2017b:17).

Equation 23A-14 $E_{phase} = EF * A_{PL} * P$

Where:

E_{phase} = VOC emissions for the phase (pounds per day)

EF = VOC emission factor (pounds per square foot)

A_{PL} = parking lot area constructed per day (square feet per day)

P = percent of area that is painted (6%)

23A.1.4.8 Paving

VOC off-gassing emissions result from asphalt paving of roads and parking lots. The VOC emission factor was obtained from the CalEEMod User's Guide (Trinity Consultants 2017b:17–18). VOC emissions were calculated using Equation 23A-15.

Equation 23A-15 $E_{phase} = EF * A_P$

Where:

E_{phase} = VOC emissions for the phase (pounds per day)

EF = VOC emission factor (2.62 pounds per acre)

A_P = daily area paved (acres per day)

23A.1.4.9 Demolition[7]

23A.1.4.9.1 Mechanical Dismemberment

Fugitive dust emission factors for dismemberment and collapse of a structure were calculated using Equation 23A-16, which is based on the methodology found in Section 13.2.4 of AP-42 and the CalEEMod User's Guide (Trinity Consultants 2017b:12).

Equation 23A-16 $$EF = k * (0.0032) * [(U \div 5)^{1.3} \div (M \div 2)^{1.4}] * (1 - CE) * UC$$

Where:

EF = emission factor (pounds per square foot)
k = particle size multiplier (pounds per ton)
U = mean wind speed (mph)
M = material moisture content (%)
CE = control efficiency achieved by environmental commitment (%)
UC = unit conversion from tons to square foot debris (0.0460)

Constant k varies depending on the particle size, and U varies by project location (air basin). Table 23A-5 defines the variables used for this calculation. The control efficiency is achieved through implementation of Environmental Commitment EC-11: *Fugitive Dust Control* (refer to Appendix 3B), which requires demolition sites be watered with adequate frequency for continued moist soil and to prevent visible dust from leaving work areas.

Table 23A-5. Variables for Mechanical Dismemberment Emission Factor Calculation

Variable	PM10	PM2.5	Source
k (lb/ton)	0.35	0.053	AP-42, Section 13.2.4 (U.S. Environmental Protection Agency 2006b:13.2.4-4)
U (mph)	6.6 (SVAB) 7.7 (SJVAB) 10.3 (SFBAAB)	6.6 (SVAB) 7.7 (SJVAB) 10.3 (SFBAAB)	Western Regional Climate Centers 2020d; University of Utah 2021
M (%)	2	2	CalEEMod User's Guide (Trinity Consultants 2017b:12)
CE (%)	36	36	Countess Environmental 2006:Table 3-7

Dust emissions from mechanical dismemberment were calculated using Equation 23A-17 (Trinity Consultants 2017b:12).

Equation 23A-17 $$E_{phase} = EF * SF$$

Where:

E_{phase} = emissions for the phase (pounds per day)
EF = emission factor (pounds per square foot demolished)
SF = floor area demolished per day (square feet per day)

[7] Emissions generated by site removal of debris are accounted for in the motor vehicles analysis discussed in Section 23A.1.4.2, *Motor Vehicles*.

23A.1.4.9.2 Debris Loading

Fugitive dust emission factors for debris loading were calculated using Equation 23A-18, which is based on the methodology found in the CalEEMod User's Guide (Trinity Consultants 2017b:13).

Equation 23A-18 $EF = k * EF_{L\text{-}TSP} * UC$

Where:

EF = emission factor (pounds per square foot)
k = particle size multiplier (unitless)
$EF_{L\text{-}TSP}$ = default factor for total suspended particles (0.058 pounds per ton)
UC = unit conversion from tons to square foot debris (0.0460)

Equation 23A-17 (as shown in Section 23A.1.4.9.1, *Mechanical Dismemberment*) was used to estimate the resulting debris loading emissions based on the calculated emission factors.

23A.1.4.10 Land Clearing

23A.1.4.10.1 Scraping

Fugitive dust emission factors from grading equipment passes were calculated using Equation 23A-19, which is based on the methodology found in Section 11.9 of AP-42 and the CalEEMod User's Guide (Trinity Consultants 2017b:8–9).

Equation 23A-19 $EF = [(a * S^a) * F * (As \div Wb) * (UC_1 \div UC_2)] (1 – CE)$

Where:

EF = emission factor (pounds per acre)
C = coefficient (unitless)
S = mean vehicle speed (mph)
a = empirical constant (unitless)
F = particle scaling factor
As = unitized acreage (1 acre)
Wb = blade width of the grading equipment (12 feet)
UC_1 = unit conversion from acres to square feet (43,560)
UC_2 = unit conversion from miles to feet (5,280)
CE = control efficiency achieved by environmental commitment (%)

Constants C, a, and F vary depending on the particle size. Table 23A-6 defines the variables used for this calculation. The control efficiency is achieved through implementation of Environmental Commitment EC-11: *Fugitive Dust Control* (refer to Appendix 3B), which requires graded and active work areas be watered with adequate frequency for continued moist soil and to prevent visible dust from leaving work areas. The commitment also requires the installation of wind breaks and prompt finishing and protection of all disturbed areas.

Table 23A-6. Variables for Scraping Calculation

Variable	PM10	PM2.5	Source
C	0.051	0.04	AP-42, Section 11.9 (U.S. Environmental Protection Agency 1998b:11.9-5)
S (mph)	7.1	7.1	AP-42, Section 11.9 (U.S. Environmental Protection Agency 1998b:11.9-9)
a	2	2.5	AP-42, Section 11.9 (U.S. Environmental Protection Agency 1998b:11.9-5)
F	0.6	0.031	AP-42, Section 11.9 (U.S. Environmental Protection Agency 1998b:11.9-5)
CE (%)	74	74	Countess Environmental 2006:Table 3-7

Dust emissions from scraping were calculated using Equation 23A-20.

Equation 23A-20 $E_{phase} = EF * A$

Where:

E_{phase} = emissions for the phase (pounds per day)
EF = emission factor (pounds per acre)
A = daily acres graded (acres per day)

23A.1.4.10.2 Bulldozing

Fugitive dust emission factors from bulldozing were calculated using Equation 23A-21, which is based on the methodology found in Section 11.9 of AP-42 and the CalEEMod User's Guide (Trinity Consultants 2017b:10).

Equation 23A-21 $EF = (C * s^a \div M^b * F) * (1 - CE)$

Where:

EF = emission factor (pounds per hour)
C = coefficient (unitless)
s = material silt content (%)
a = empirical constant (unitless)
M = material moisture content (%)
F = particle scaling factor
CE = control efficiency achieved by environmental commitment (%)

Constants C, a, and F vary depending on the particle size. Table 23A-7 defines the variables used for this calculation. The control efficiency is achieved through implementation of Environmental Commitment EC-11: *Fugitive Dust Control* (refer to Appendix 3B).

Table 23A-7. Variables for Bulldozing Calculation

Variable	PM10	PM2.5	Source
C	1.0	5.7	AP-42, Section 11.9 (U.S. Environmental Protection Agency 1998b:11.9-5)
s (%)	6.9	6.9	AP-42, Section 11.9 (U.S. Environmental Protection Agency 1998b:11.9-9)
a	1.5	1.2	AP-42, Section 11.9 (U.S. Environmental Protection Agency 1998b:11.9-5)
M (%)	7.9	7.9	AP-42, Section 11.9 (U.S. Environmental Protection Agency 1998b:11.9-9)
F	0.75	0.105	AP-42, Section 11.9 (U.S. Environmental Protection Agency 1998b:11.9-5)
CE (%)	74	74	Countess Environmental 2006:Table 3-7

Dust emissions from bulldozing were calculated using Equation 23A-22.

Equation 23A-22 $E_{phase} = EF * Activity$

Where:

E_{phase} = emissions for the phase (pounds per day)

EF = emission factor (pounds per hour)

Activity = equipment activity (hours per day)

23A.1.4.10.3 Truck Loading

Fugitive dust emission factors from loading and unloading overburden onto a truck were calculated following the same methodology as used for mechanical dismemberment (refer to Section 23A.1.4.9.1, *Mechanical Dismemberment*). The material moisture content (M) in Equation 23A-16 was revised to 12% to appropriately characterize overburden (U.S. Environmental Protection Agency 2006b:13.2.4-2). Additionally, the unit conversion (UC) was revised to convert tons to cubic yards (1.2641662) (Trinity Consultants 2017b:11). The control efficiency (CE) was set to 74% (Countess Environmental 2006:Table 3-7), which would be achieved by implementing Environmental Commitment EC-11: *Fugitive Dust Control* (refer to Appendix 3B). The commitment also requires all haul trucks and rail cars transporting sand and other loose materials on freeways, major roadways, and railways to be covered.

Dust emissions from truck loading were calculated using Equation 23A-23.

Equation 23A-23 $E_{phase} = EF * Activity$

Where:

E_{phase} = emissions for the phase (pounds per day)

EF = emission factor (pounds per cubic yard)

Activity = daily cut and fill (cubic yards per day)

23A.1.4.10.4 Sequestration/Carbon Storage

Construction of the project and compensatory mitigation sites would alter existing land uses, resulting in changes to present-day (baseline) GHG emissions or removals. Processes affecting present-day GHG emissions and removals on lands that will be affected by the project are associated primarily with agriculture. Along the alignments, there are mineral soils and organic and highly organic mineral soils. In areas where mineral soils predominate, GHG emissions and removals are related to the types of crops and management practices, such as fertilization.

The net GHG effect of land-use changes associated with construction of the central, eastern, and Bethany reservoir alignments and compensatory mitigation sites was quantified by calculating GHG emissions and removals relative to baseline conditions, which assumed that no significant land-use or management changes will be implemented beyond those already in existence at the time of the analysis. The project GHG emissions and removals over time were compared to the baseline scenarios. Given the dynamic temporal nature of land-based GHGs, annual emissions were projected through 2070 to capture the cumulative net GHG effect of the project. Attachments A and B to this appendix present the detailed methodology and results, which were developed by HydroFocus, Inc.

23A.1.4.11 Dredged and Reusable Tunnel Materials[8]

23A.1.4.11.1 Conveyance Transfer

Conveyors would move the RTM generated by tunnel launch shafts on the Southern Complex to an area within the inundation area of the Southern Forebay for drying and storage (i.e., stockpiles). Conveyors would also move a portion of the RTM at the Twin Cities Complex and on Lower Roberts Island and Bouldin Island. The drop of material at uncovered conveyor transfer points can generate particulate matter emissions. Environmental Commitment EC-11: *Fugitive Dust Control* (refer to Appendix 3B) requires all conveyors be fully enclosed. Therefore, the transfer of RTM along conveyor lines is not expected to produce any particulate emissions.

Fugitive dust emissions from adding RTM to stockpiles from a conveyor stacker were calculated following the same methodology as used for truck loading (refer to Section 23A.1.4.10.3, *Truck Loading*). RTM extracted from the tunnel launch shafts is expected to be wet during conveyance and at the final drop point, with an expected moisture content around 40%. Accordingly, the material moisture content (M) in Equation 23A-16 was revised to 40% to appropriately characterize the RTM at the drop point to the stockpile. The control efficiency (CE) was set to 0%.

23A.1.4.11.2 Stockpile Wind Erosion[9]

Stockpiles would be used to store RTM and other earthen materials. These stockpiles can generate particulate emissions as they are exposed to wind. The annual particulate matter emissions factor is

[8] Prior to transfer of dredged materials, dredging would occur at the intakes. This is a wet process, as the material would be dredged from below the waterline. Therefore, this process is not expected to produce any particulate emissions. Likewise, tunnel boring and extraction of RTM would occur below ground and would not result in ambient emissions.

[9] Prior to stockpiling, some material would be dried. All mechanical dryers will be enclosed within physical structures, pursuant to Environmental Commitment EC-11: *Fugitive Dust Control*. Therefore, this process is not expected to produce any particulate emissions.

calculated using Equation 23A-24, which is based on the methodology found in Section 9.3 of the Fugitive Dust Handbook (Countess Environmental 2006:9-8).

Equation 23A-24 $EF = 1.7 * (s \div 1.5) * (N[N-P] \div 235) * (f \div 15) * (1 - CE) * R$

Where:

EF = PM10 emission factor (pounds per acre per year)
s = silt content of the material (%)
N = number of days in the average period (365 days)
P = days per year with at least 0.01 inch of precipitation (days per year)
f = percent of time unobstructed wind speed is greater than 12 mph at pile height
CE = control efficiency achieved by environmental commitment (%)
R = ratio of total suspended particles to PM10 (unitless)

P varies by air basin and f varies by air basin and pile height. Tables 23A-8 and 23A-9 define the variables used for this calculation. The control efficiency is achieved through implementation of Environmental Commitment EC-11: *Fugitive Dust Control* (refer to Appendix 3B), which requires earthen storage piles be stabilized with an organic biopolymer. The commitment also requires the installation of wind breaks.

Table 23A-8. Variables for Stockpile Wind Erosion PM10 Emission Factor Calculation

Variable	PM10	PM2.5	Source
s (%)	9.8	9.8	Project area soil sampling
P (days/year)	58 (SVAB) 55 (SJVAB) 55 (SFBAAB)	58 (SVAB) 55 (SJVAB) 55 (SFBAAB)	Western Regional Climate Centers 2020a, 2020b, 2020c
f	See Table 23A-9		
CE (%)	90[a]		Countess Environmental 2006:Table 9-4
R	0.5	–	Countess Environmental 2006:9-8

[a] Control efficacy achieved by watering the storage pile area. Dust control achieved through use of biopolymers has been shown to achieve significantly greater reductions, with tunnel laboratory experiments showing a 100% reduction in the soil loss rate (Lemboye et al. 2021:1). Because EC-11: *Fugitive Dust Control* requires stockpiles be stabilized with an organic biopolymer, limiting the control efficacy to 90% is conservative.

PM10 emissions were calculated using Equation 23A-25. PM2.5 emissions were calculated assuming PM2.5 emissions are equal to 15% the PM10 emissions (Countess Environmental 2006:9-8).

Equation 23A-25 $E = EF_h * A_h$

Where:

E = PM10 emissions (pounds per year)
EF = emission factor (pounds per acre per year)
A = storage pile acres (acres)
h = pile height (feet)

Table 23A-9. Percent of Time Unstructured Wind Speeds Exceed 12 mph for the Stockpile Wind Erosion Emission Factor Calculation (%)

Pile Height	SVAB	SJVAB	SFBAAB
1 foot	<0.1	<0.1	0.5
2 feet	<0.1	0.1	6.1
3 feet	<0.1	0.4	13.2
4 feet	0.1	1.0	15.6
5 feet	0.5	1.7	21.4
6 feet	0.8	2.5	21.4
7 feet	1.1	3.2	24.6
8 feet	1.6	3.9	24.6
9 feet	2.2	4.8	28.1
10 feet	2.2	5.4	28.1
11 feet	3.1	6.0	28.1
12 feet	3.1	6.7	32.0
13 feet	4.4	7.4	32.0
14 feet	4.4	7.9	32.0
15 feet	4.4	8.6	32.0
16 feet	4.4	– [a]	35.9
17 feet	6.0	– [a]	35.9
18 feet	6.0	– [a]	– [a]
19 feet	6.1	– [a]	– [a]
20 feet	6.1	– [a]	35.9
21 feet	6.1	– [a]	35.9
22 feet	6.1	– [a]	– [a]
23 feet	8.4	– [a]	– [a]
24 feet	8.4	– [a]	– [a]
25 feet	8.4	– [a]	– [a]
26 feet	8.4	– [a]	40.5
27 feet	8.4	– [a]	40.5
28 feet	8.4	– [a]	40.5
31 feet	– [a]	– [a]	40.5
32 feet	– [a]	– [a]	40.5

Sources: San Joaquin Valley Air Pollution Control District 2018a; Sacramento Metropolitan Air Quality Management District 2019; University of Utah 2021.

[a] Stockpiles reaching this height would not be used.

23A.1.4.11.3 Truck and Rail Car Loading

Fugitive dust emission factors from loading and unloading dredged material and RTM onto a truck or rail car were calculated following the same methodology as used for truck loading (refer to Section 23A.1.4.10.3, *Truck Loading*). The RTM transported by truck and rail from Twin Cities to the Southern Forebay would be dried down to an average moisture content of 22%. Accordingly, the material moisture content (M) in Equation 23A-16 was revised to 22% to appropriately characterize the RTM. The control efficiency (CE) was set to 0%.

23A.1.4.12 Concrete Batching[10]

23A.1.4.12.1 Material Processing

Concrete required to construct the project would be manufactured at batch plants that store, convey, and discharge water, cement, fine aggregate, and coarse aggregate. Concrete would be provided to most construction sites from existing commercial concrete batch plants. New concrete batch plants would be used for this project if the construction site location would not allow pouring of the concrete within 90 minutes of loading the ready-mix truck at a commercial batch plant. Therefore, project-specific concrete batch plants are only placed at Lambert Road (for intake construction), Bacon Island (for shaft construction at Bacon and Mandeville Islands), Southern Complex, and Bethany Complex. Fugitive dust and metal emissions from concrete batching new temporary batch plants[11] were quantified using EPA's AP-42, Section 11.12 (2006c:Tables 11.12-2 and 11.12-8). AP-42 provides emissions factors per ton of material for each emission source. The particulate matter sources are sand transfer, aggregate transfer, cement unloading, cement supplement unloading, weight hopper loading, and truck mix loading. The metal sources are cement silo filing, cement supplement silo filing, and truck loading.

The equation for quantifying particulate matter and metal emissions is given as Equation 23A-26. Pursuant to Environmental Commitment EC-12: *On-Site Concrete Batching Plants* (refer to Appendix 3B), emission factors for "controlled" batching operations were used in estimating the emissions from this activity. PM2.5 emissions were calculated by assuming PM2.5 emissions are equal to 15% the PM10 emissions (Bay Area Air Quality Management District 2014:205).

Equation 23A-26 $E_{plant} = Br * \Sigma EF_m * MW_m * UC$

Where:

E_{plant} = emissions for the batch plant (pounds per day)

Br = batch rate (cubic yards concrete per day per plant)

EF = source emission factor (pounds per ton of material)

MW = material weight per cubic yard of concrete (pound per cubic yard concrete)

UC = unit conversion from pounds to tons (0.0005)

m = material (e.g., sand, aggregate)

The materials assumed in each emission source and their weights per cubic yard of concrete are shown in Table 23A-10.

[10] The motor vehicles, heavy equipment, and electricity consumption analyses discussed in this appendix account for emissions generated by material transport and operation of yard equipment and electricity consumption at on-site batch plants (refer to Sections 23A.1.4.1, *Heavy Equipment*, 23A.1.4.2, *Motor Vehicles*, and 23A.1.4.5, *Electricity Consumption*).

[11] A portion of concrete for the tunnel segments would be provided by three existing batch plants. These facilities are regulated and permitted to emit a maximum amount of criteria pollutants, including particulate matter. Therefore, fugitive dust emissions associated with concrete batching at existing facilities are not included in the analysis as these emissions have already been evaluated and accounted for in existing permit and environmental documents.

Table 23A-10. Concrete Batching Material Assumptions

Emission Source	Material	Pounds per Cubic Yard Concrete
Sand transfer	Sand	1,428
Aggregate transfer	Aggregate	1,865
Cement unloading	Cement	491
Cement supplement unloading	Cement supplement	73
Weight hopper loading	Aggregate and sand	3,293
Transit truck mix loading	Cement and cement supplement	564

Source: U.S. Environmental Protection Agency 2006c:Table 11.12-2.

23A.1.4.12.2 Stockpile Wind Erosion

Fugitive dust emission factors from wind erosion of aggregate and sand storage piles were calculated following the same methodology used for RTM stockpile wind erosion (refer to Section 23A.1.4.11.2, *Stockpile Wind Erosion*). The average batch plant stockpile height is expected to be 10 feet.

23A.1.4.12.3 Upstream Lifecycle Activity

The air quality and GHG analysis accounts for all emissions directly and indirectly generated by construction activities for which DWR has practical control and program responsibility. Emissions generated upstream (e.g., material manufacturing) and downstream (e.g., recycling) of construction, otherwise known as "lifecycle emissions," are not included in the analysis, consistent with guidance from the California Natural Resources Agency (2018:41–42). While the origin of most raw materials is not known, and thus an emissions analysis would be speculative, lifecycle emissions for cement and aggregate manufacturing, which is upstream of the concrete batching process, have been studied in various literature. Accordingly, for the purposes of disclosure, upstream CO_2 emissions resulting from cement and aggregate manufacturing were quantified using emission factors from Marceau et al. (2007:Tables E1b and G1b) and Equation 23A-27. It was assumed the tunnel segments would require a compression strength of 7,500 pounds per square inch (psi) and all other infrastructure would require a compression strength of 5,000 psi. The upstream emissions are presented for informational purposes only.

Equation 23A-27 $\mathbf{E = EF_{cs} * Br_{cs} * UC}$

Where:

E = CO_2 emissions (metric tons per year)
EF = upstream emission factor (pounds per cubic yard)
Br = batch rate (cubic yards per year)
UC = unit conversion from pounds to metric tons (0.000453592)
cs = compression strength

23A.1.4.13 Wastewater Treatment

Septic tanks would be constructed to treat wastewater flow from on-site restrooms at the intakes, Twin Cities Complex, Southern Complex, Bethany Complex, and Bouldin Island and Lower Roberts Island tunnel launch shaft sites. Septic systems use microbes to decompose wastewater anaerobically, which can produce fugitive CH_4. These emissions were quantified based on the expected volume of treated wastewater and Equation 23A-28 (Trinity Consultants 2017b:45).

Equation 23A-28 $E = Vol * BOD_5 * Bo * MCF_{septic} * UC_1 * UC_2$

Where:

E = annual CH_4 emissions (metric tons per year)
Vol = volume of wastewater (liters per year)
BOD_5 = concentration of dissolved oxygen (200 milligrams per liter)
Bo = maximum CH_4-producing capacity (0.6 kilogram CH_4/kilogram BOD_5)
MCF_{septic} = CH_4 correction factor for septic system (0.5)
UC_1 = unit conversion from milligrams to kilograms (0.000001)
UC_2 = unit conversion from kilograms to metric tons (0.001)

23A.1.4.14 Helicopters

Helicopters would be required for airborne magnetic surveys as part of preliminary field investigations and for installing towers along 8.3 miles of new 230 kilovolt transmission line to serve the Southern Complex for the central and eastern conveyance alignment alternatives. Emission factors per landing and take-off (LTO) and per operational cruising hour for a Bell 407, which is the expected helicopter type for the surveys, and a Hughes 500, which is the expected helicopter type for the transmission work, were obtained from the Federal Office of Civil Aviation (2015:16). Criteria pollutants and precursors generated by LTO were quantified using Equation 23A-29, and emissions generated from cruising were quantified using Equation 23A-30.

Equation 23A-29 $E = EF * LTO * UC$

Where:

E = exhaust emissions (pounds per day)
EF = engine emission factor (grams per LTO)
LTO = daily LTO (landings and takeoffs per day)
UC = unit conversion from grams to pounds (0. 002205)

Equation 23A-30 $E = EF * Hr * UC$

Where:

E = exhaust emissions (pounds per day)
EF = engine emission factor (grams per hour)
Hr = daily cruising time (hours per day)
UC = unit conversion from grams to pounds (0. 002205)

23A.1.5 Emissions by Alternative

The air quality analysis estimates emissions for nine project alternatives. The approach to construction and overall techniques are expected to be the same among all alternatives. However, there would be differences in the physical components constructed under each alternative. RTM quantities, concrete batching rates, electricity consumption, circuit breakers, and wastewater generation also differ among the alternatives. Appendix 23B, *Air Quality and GHG Analysis Activity Data*, identifies which components would be constructed under the various project alternatives. Emissions generated by each component were assigned to the corresponding alternative(s).

23A.1.6 Emissions by Air District and Air Basin

The project crosses three air basins—SFBAAB, SVAB, and SJVAB—and falls under the jurisdiction of four air districts—Yolo-Solano Air Quality Management District (YSAQMD), SMAQMD, BAAQMD, and SJVAPCD. Geographic information system (GIS) was used to identify the location of all construction activities. Emissions generated by construction of components that would occur exclusively within one air district were wholly assigned to that air district (e.g., intake construction in SMAQMD). Emissions estimates for components that span more than one air district were apportioned based on the location of construction activity. Appendix 23B, *Air Quality and GHG Analysis Activity Data*, identifies the location(s) of each construction component among the four air districts.

23A.1.7 Daily and Annual Emissions Estimates

The analysis assumes that project construction would occur over multiple phases. Daily criteria pollutant and GHG emissions generated by construction of each phase were quantified using the methods described above in Section 23A.1.4, *Emissions Estimation*. The daily estimates were converted to annual totals based on the detailed construction schedule and identified maximum daily emissions, based on concurrent construction activity, within the BAAQMD, YSAQMD, and SMAQMD, consistent with air district requirements. The highest daily emissions in each construction year were selected as the peak day for analysis purposes. This approach is conservative and based on available information; therefore, it is not necessarily representative of actual daily emissions that would occur during the construction period. Average daily emissions per year in the SJVAPCD were calculated by dividing annual emissions by the number of working days per year, consistent with SJVAPCD guidance (2018b:3).

23A.2 Operations & Maintenance

23A.2.1 Maintenance Activities

Maintenance would be conducted daily or at varying frequencies, depending on the type of activity. The following general activities would be needed to successfully maintain the project.

- **Daily**: Inspections, security checks, and operations oversight.
- **Weekly and bi-weekly**: Inspections, janitorial service, well measurements, and operability testing.
- **Monthly**: Inspections, cleaning, and operability testing.

- **Quarterly**: General maintenance, animal burrow filling, and weed management.
- **Bi-annual**: Pressure washing, group maintenance, operability testing, and debris and sediment removal.
- **Annual**: Inspections, general maintenance and repairs, jet washing and cleaning, operability testing and instrumentation calibration, refurbishment, lubrication, sediment removal, and surveying.
- **Long-term:** Various activities conducted every 2, 4, 5, 10, 15, and 30 years, including, but not limited to dewatering, repaving, recertification, special testing, and repairs.

Depending on the type of activity, project maintenance would generate emissions from heavy equipment, motor vehicles, marine vessels, truck loading (sediment removal), repaving, and circuit breakers. These activities would take place at the intakes, tunnel shafts, pumping plant, forebay, and control structures. The DCA developed project-specific assumptions (e.g., number of truck trips and miles, equipment operating hours) for all expected maintenance activities by project alternative. These data are provided in Appendix 23B, *Air Quality and GHG Analysis Activity Data*. Emissions were quantified using the same general methods as described in Section 23A.1.4, *Emissions Estimation*. The emissions intensity of maintenance activities was estimated under both 2020 and 2040 conditions. The 2020 analysis is presented in Chapter 23, *Air Quality and Greenhouse Gases*, and the 2040 analysis in Appendix 23F, *Air Quality and Greenhouse Gases 2040 Analysis*.

As discussed in Section 23A.1.6, *Emissions by Air District and Air Basin*, the project crosses three air basins and falls under the jurisdiction of four air districts. Maintenance emissions were assigned to an air district and basin based on the location of the site at which the maintenance activity would occur (e.g., intake maintenance in SMAQMD). Daily and annual emissions within each air district were quantified based on the frequency and duration of expected maintenance activities. The annual estimate includes emissions from all monthly, quarterly, bi-annual, and annual activities and conservatively assumes all long-term activities would occur in that same year. The daily estimates within YSAQMD, SMAQMD, and BAAQMD are based on an assessment of the maximum amount of maintenance that could theoretically occur in a single day. This approach is conservative and based on available information; therefore, it is not necessarily representative of actual daily emissions that would occur on a regular basis. Average daily emissions per year in the SJVAPCD were calculated by dividing annual emissions by the number of working days per year, consistent with SJVAPCD guidance (2018b:3).

23A.2.2 Operational SWP Pumping and Displaced Purchases of CVP Electricity

As discussed in Chapter 22, *Energy*, SWP and CVP system energy operations were analyzed for each alternative using the CalSim 3 model, LTGen post-processing tools, and the SWP power model in sequence. GHG emission factors from the generation and transmission of operational electricity were calculated using data from EPA's 2019 eGRID and account for increases in the renewable energy mix due to the renewables portfolio standard and Senate Bill 100 (U.S. Environmental

Protection Agency 2021).[12] The eGRID does not include complete emission factors for criteria pollutants. Accordingly, criteria pollutant emission factors for electricity were obtained from the GREET model. Emissions were calculated using Equation 23A-11 (above).

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[12] eGRID does not include emission factors for SF_6. Statewide SF_6 emissions in 2018, which was the latest year with data available as of the time of this analysis, were therefore used to identify an emission factor per MWh by dividing total SF_6 emissions by total electricity generation in California (California Air Resources Board 2020a; California Energy Commission 2019).

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Attachment 23A.1

HydroFocus, Inc. Construction Land Use Change Analysis

Effects on Greenhouse Gas Emissions and Removals Associated with DWR Delta Conveyance Project Land Use Changes

Prepared by HydroFocus, Inc.
Davis, California
February 4, 2022

For

ICF and Environmental Science Associates

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Effects on Greenhouse Gas Emissions and Removals Associated with DWR Delta Conveyance Project Land Use Changes

Introduction and Background

The State Water Project (SWP) relies on Delta channels to convey water. Two-thirds of California's water originates in the Sierra Nevada Mountains as snowpack, eventually flowing through the Delta, where it is delivered to more than 27 million Californians and 750,000 acres of farmland. Due to risk to continued conveyance via Delta channels due to sea level rise, earthquakes, and subsidence, the Department of Water Resources (DWR) is acting now to upgrade Delta infrastructure by planning for the Delta Conveyance Project.

The proposed Delta Conveyance Project includes constructing and operating new conveyance facilities in the Delta that would add to the existing SWP infrastructure. New intake facilities would be located in the north Delta to divert water. The new conveyance facilities include a tunnel to transport water from the new intakes to the existing pumping plants in the south Delta. Three tunnel alignments are being considered in this report[1] to assess changes in the GHG footprint due to these construction and land use changes: Alternative 2a, Alternative 4a, and Alternative 5. Each alternative will result in changes to current land use which will also result in changes to current greenhouse gas (GHG) emissions and/or removals. Cylindrical tee fish screens will be installed at the new intakes to minimize impacts to fish and other aquatic species.

There are two water-supply scenarios for the three alternatives: 7500 cubic feet per second (cfs) for Alternatives 2a and 4a, and 6000 cfs for Alternative 5. Each alternative requires varying numbers of pumping plants and tunnel sizes (DCA 2021e). For the 7500-cfs conveyance, DWR plans to provide water to users served by the Central Valley Project (CVP) via the Jones Pumping Plant (JPP). This will require three pumping plants, a tunnel with the largest inner radius of 38-ft relative to the other scenario flows, and one additional 7,900-ft long 20-ft inner radius tunnel to convey water from Banks Pumping Plant to the JPP for both Alternatives 2a and 4a.

The Department of Water Resources (DWR) is considering three possible main tunnel alignment distances between intakes along the Sacramento River in the north and to the Southern Complex and Bethany Complex. Each alignment includes a different number of tunnel shafts (Figure 1) along the conveyance tunnel for launch/reception and tunnel maintenance. Specifically,

[1] This is a revised report. The original report finalized in February 2021 was based on assumptions about the Delta Conveyance Project which upon subsequent review turned out to be erroneous. Thanks to DWR and ICF personnel, we incorporated the revised information and data into the revised analysis presented in this report.

- Alternative 2a includes 11 tunnel shafts and 41.5 miles of conveyance tunnel between intakes A, B, C, and the South Delta Pumping Plant (Figure 1-A).
- Alternative 4a includes 12 tunnel shafts and 44.0 miles of conveyance tunnel between intakes A, B, C, and the South Delta Pumping Plant (Figure 1-B).
- Alternative 5 includes 11 tunnel shafts and 45.0 miles of conveyance tunnel between intakes B, C, and the Bethany Reservoir Pumping Plant (Figure 1-C).

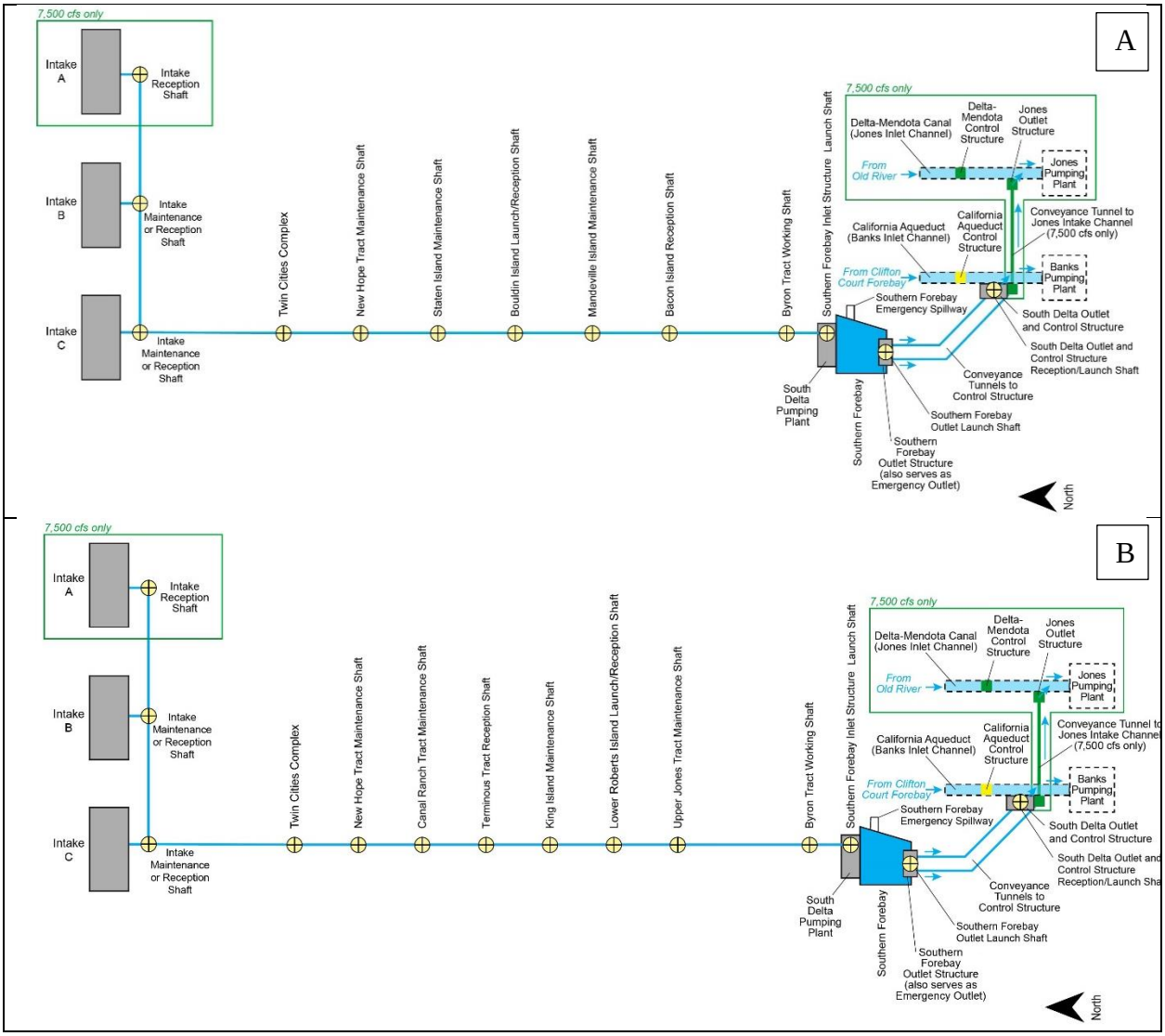




Figure 1. Alternatives 2a (A), 4a (B), and 5 (C) tunnel alignments and tunnel shaft names/locations. Adapted from DCA (2021e).

Processes Affecting Greenhouse Gas Emissions and Removals

Greenhouse gas emissions and removals on lands that will be affected by the Delta Conveyance Project are primarily agriculturally related and include carbon dioxide (CO_2) and nitrous oxide (N_2O). Emissions are losses of GHGs from soil to the atmosphere whereas removals refer to the removing of GHGs from the atmosphere such as in the case of carbon sequestration by plants. Along the alignments, there are mineral soils, organic soils, and highly organic mineral soils. In areas of predominantly mineral soils the main sources of GHG emissions and removals are related to crops and management practices such as fertilization and machinery use. Overall, agriculture on mineral soils in California is estimated to be a net remover of GHGs (Li et al. 2014). In contrast, on organic and highly organic mineral soils in the Delta, agricultural production results in net GHG emissions due to oxidation of organic matter (Deverel et al. 2016). The land alterations proposed for the Delta Conveyance Project, including crop removal and soil excavation and stockpiling, will alter GHG emissions and removals relative to present-day (baseline) GHG emissions and removals.

Objectives and Overall Approach

Our main objective was to quantify the net GHG effect of land-use changes and earthwork associated with the construction of the Delta Conveyance Project for the three alternatives.

Our overall approach was to estimate the GHG impact of the Delta Conveyance Project by calculating project-related GHG emissions and removals relative to the reference or baseline conditions[2]. For the development of the baseline scenario, we assumed that no significant land-use or management changes will be implemented. We projected those conditions to 2070. Baseline scenarios are not intended to be predictions of the future, but rather counterfactual constructions for comparison with project conditions.

[2] https://www.ipcc-data.org/guidelines/pages/glossary/glossary_b.html

The three main geospatial inputs for developing the baseline were land use, soil characteristics, and project constructability GIS layers. This geospatial data is presented in Figure 2, Figure 3, and Figure 4 for Alternatives 2a, 4a, and 5 respectively. Soils underlying the project features were classified as organic and highly organic mineral soils and mineral soils, based on the geospatial soil classification data. For project features overlaying organic and highly organic mineral soils, emissions due to aerobic microbial oxidation were calculated using an updated version of SUBCALC (Deverel et al. 2016). For project features overlaying mineral soils, we assumed that the main emissions and removals are caused by agriculture. Data presented by Li et al. (2014) were used to estimate biogeochemical GHG emissions and removals, while data presented by Schafer and Thompson (2015) for mineral soils were used to estimate emissions due to farming activities.

For project scenario estimates, construction will result in changes in GHG emissions and removals with respect to baseline. These changes can be temporary or permanent depending on the project feature. Changes in emissions and removals will result from the alteration of the oxidation rates of organic and highly organic mineral soils due to placement and capping in stockpiles and saturation, and the removal of crops that act as carbon sinks. For mineral soils, we assumed that crops will be removed, and the soil will be bare during construction. We also quantified emissions due to woody biomass removal at the beginning of construction.

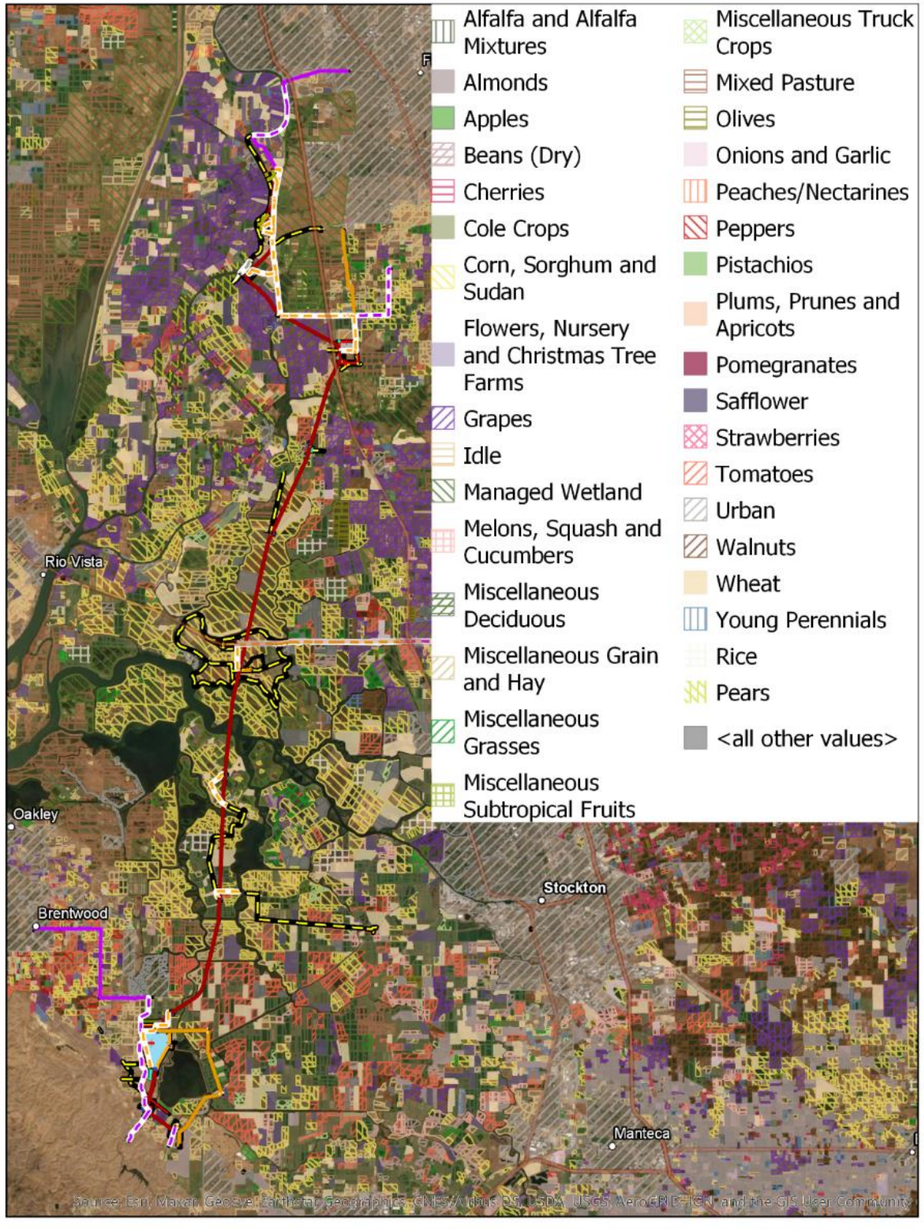
Three primary project-impact mechanisms were identified that will affect the rates of oxidation of organic and highly organic mineral soils: excavation, capping, and rewetting. Excavation refers to the removal of organic and highly organic mineral soils and storage in capped stockpiles. Capping refers to the covering of organic and highly organic mineral soils at features such as roads, stockpiles, and embankments, which limits the availability of oxygen for aerobic oxidation which results in a reduction of soil-organic-matter oxidation rates. For soils drained in the baseline scenario, excavation and capping will decrease oxygen availability for microbial oxidation, which would result in a reduced rate of GHG emissions relative to baseline. Rewetting creates anoxic conditions of the organic and highly organic mineral soils which would otherwise be exposed to aerobic conditions in the baseline scenario which limits aerobic oxidation and causes a reduction in GHG emissions.

For capping of excavated organic and highly organic mineral soils, the decrease in GHG emissions with respect to baseline was estimated as a function of the thickness of the cover based on work conducted by the US Geological Survey (Appendix A)]. The dimensions of organic and highly organic mineral soils stockpiles were obtained from the soil balance reports (DCA 2021c and DCA 2021d). Emissions due to removal of woody biomass prior to construction were quantified for organic and highly organic mineral soils.

After construction, land use for the project scenario is expected to change by impact category. For temporary surface impacts, we assumed, based on project documents, that land use after construction will be the same as the baseline scenario. For permanent surface impacts, we

assumed that project land uses will continue until 2070. For woody biomass on temporary surface impacts, we quantified carbon removals due to biomass regrowth after construction (IPCC, 2006). Woody biomass was assumed to be fully grown in 20 years after replanting.

After the baseline and project scenario were analyzed, we compared the project GHG emissions and removals to the baseline GHG emissions and removals to estimate the net GHG effect of the project. The net GHG effect of the project was calculated as the project scenario GHG emissions and removals, minus the baseline scenario GHG emissions and removals. Net GHG effects were aggregated spatially and temporally for Alternatives 2a, 4a, and 5 to estimate cumulative values. The temporal horizons used for the cumulative values calculations were 2040 and 2070. Figure 5 shows the general workflow the calculations.



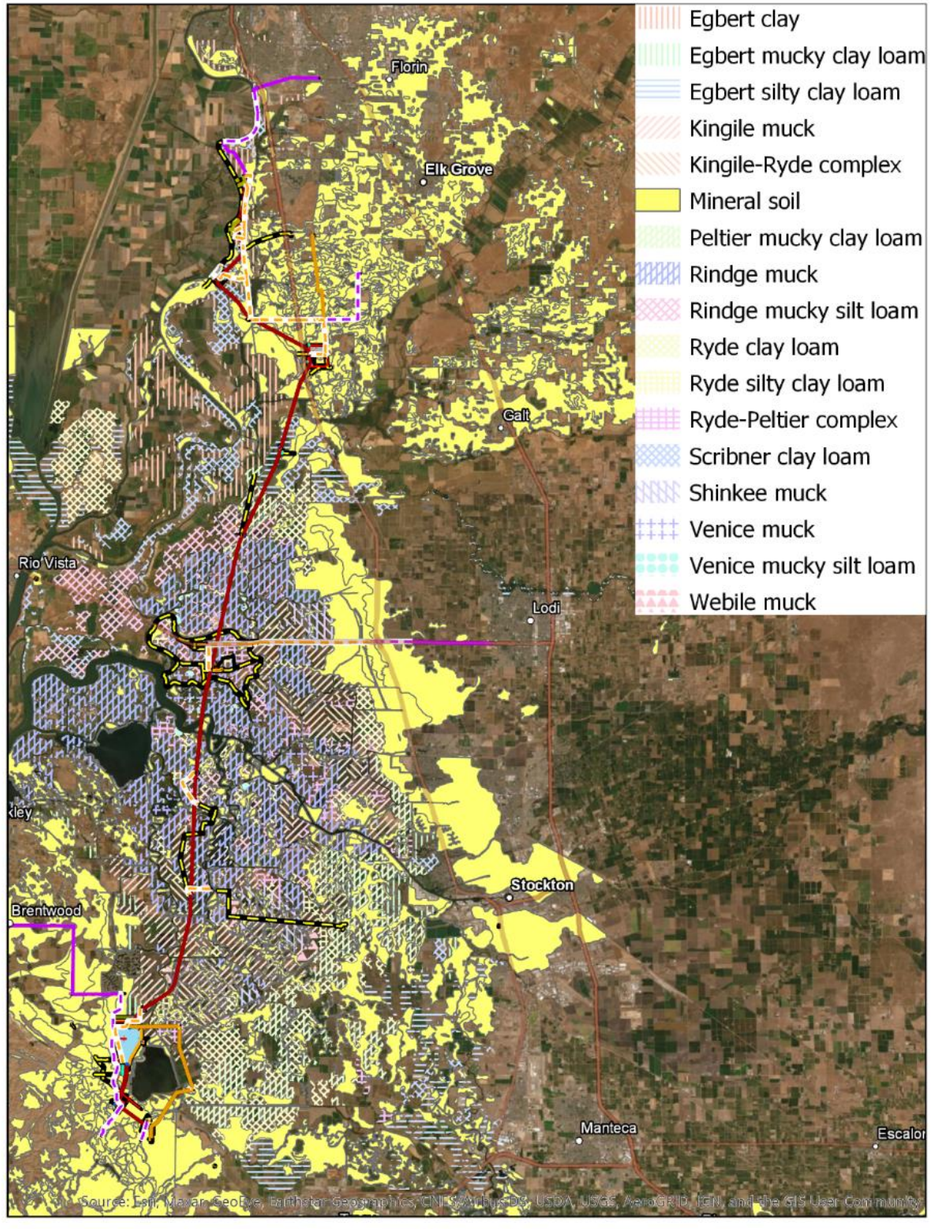
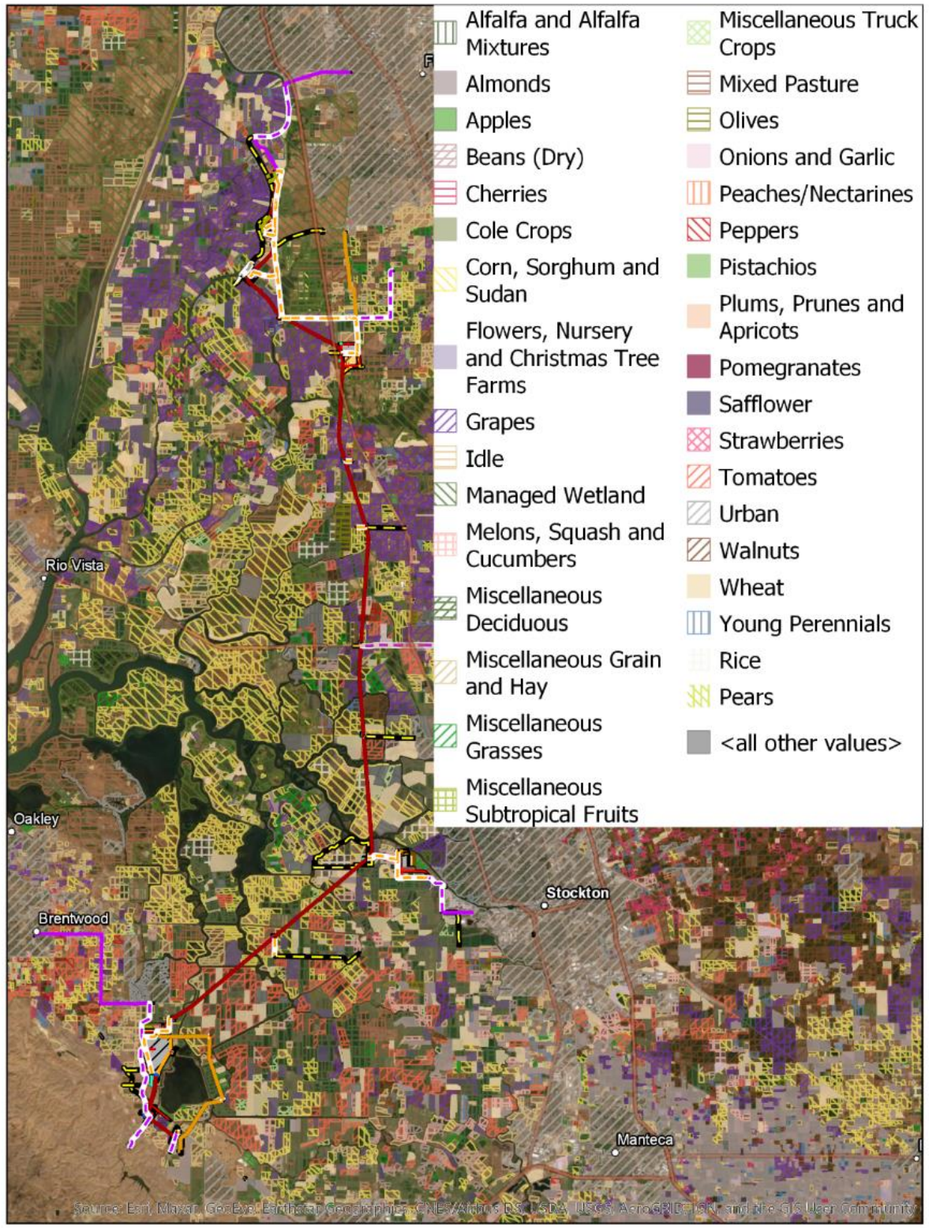


Figure 2. Alternative 2a Feature Locations. Land use is presented in the left figure and soil type in the right figure.



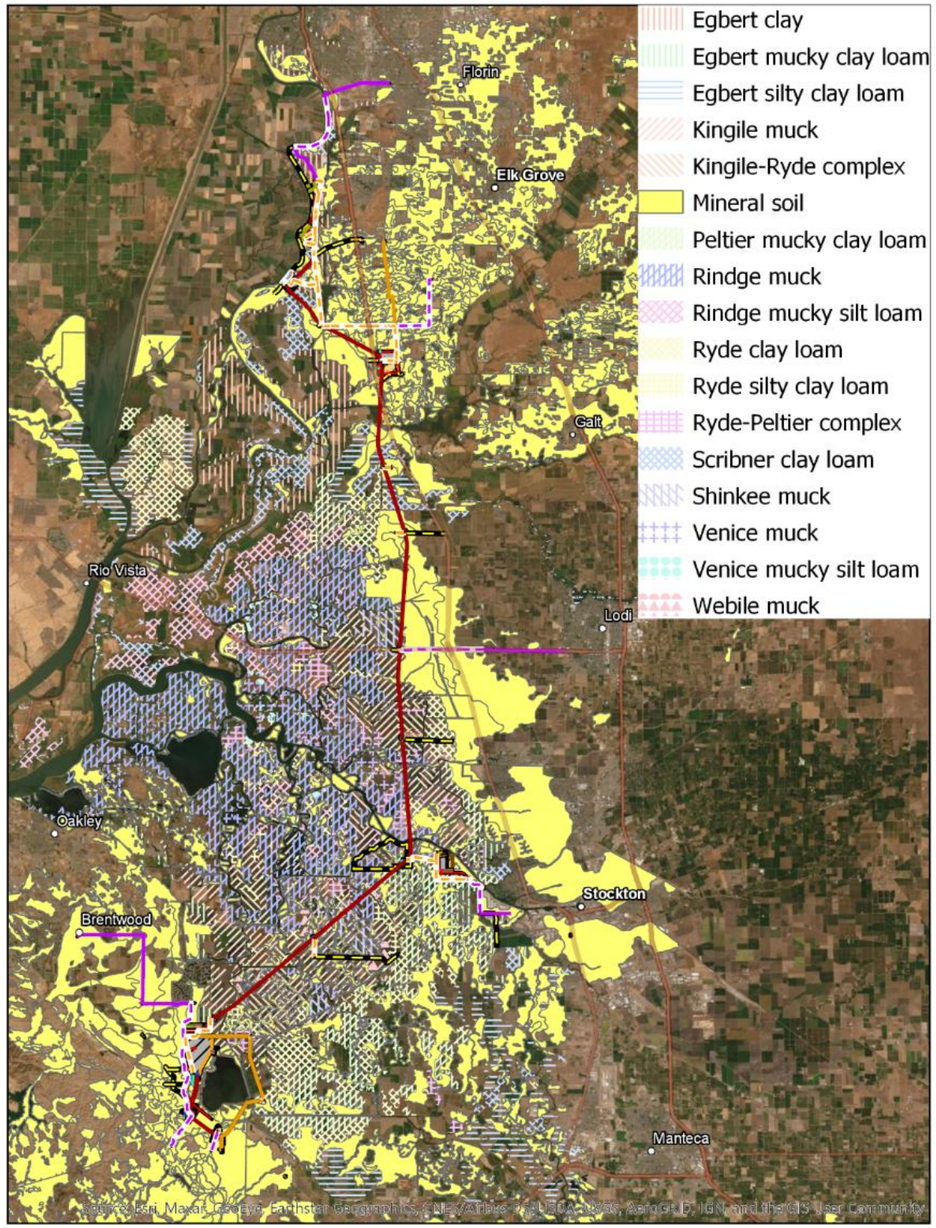


Figure 3. Alternative 4a Feature Locations. Land use is presented in the left figure and soil type in the right figure.

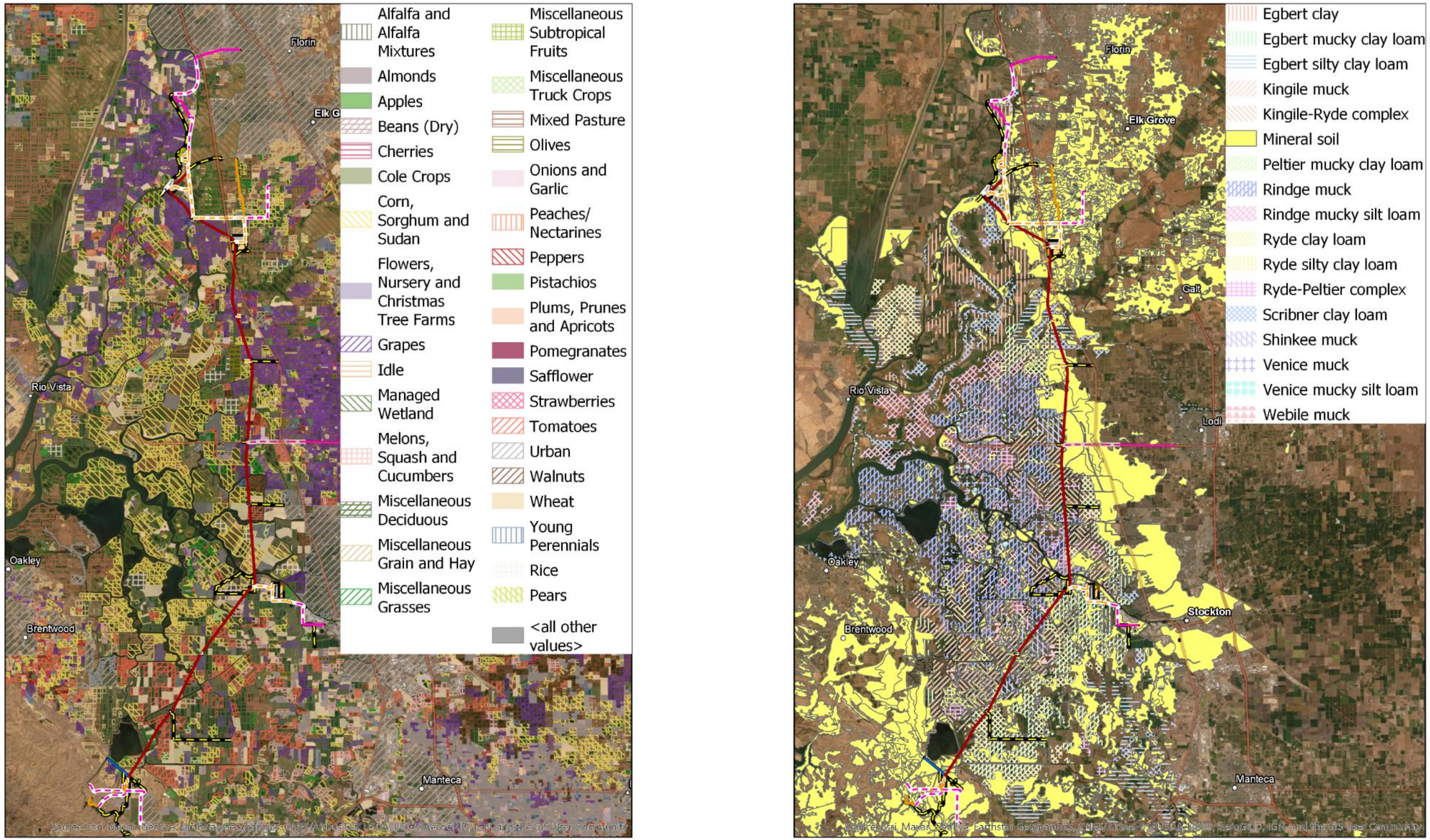


Figure 4. Alternative 5 Feature Locations. Land use presented is in the left figure and soil type in the right figure.

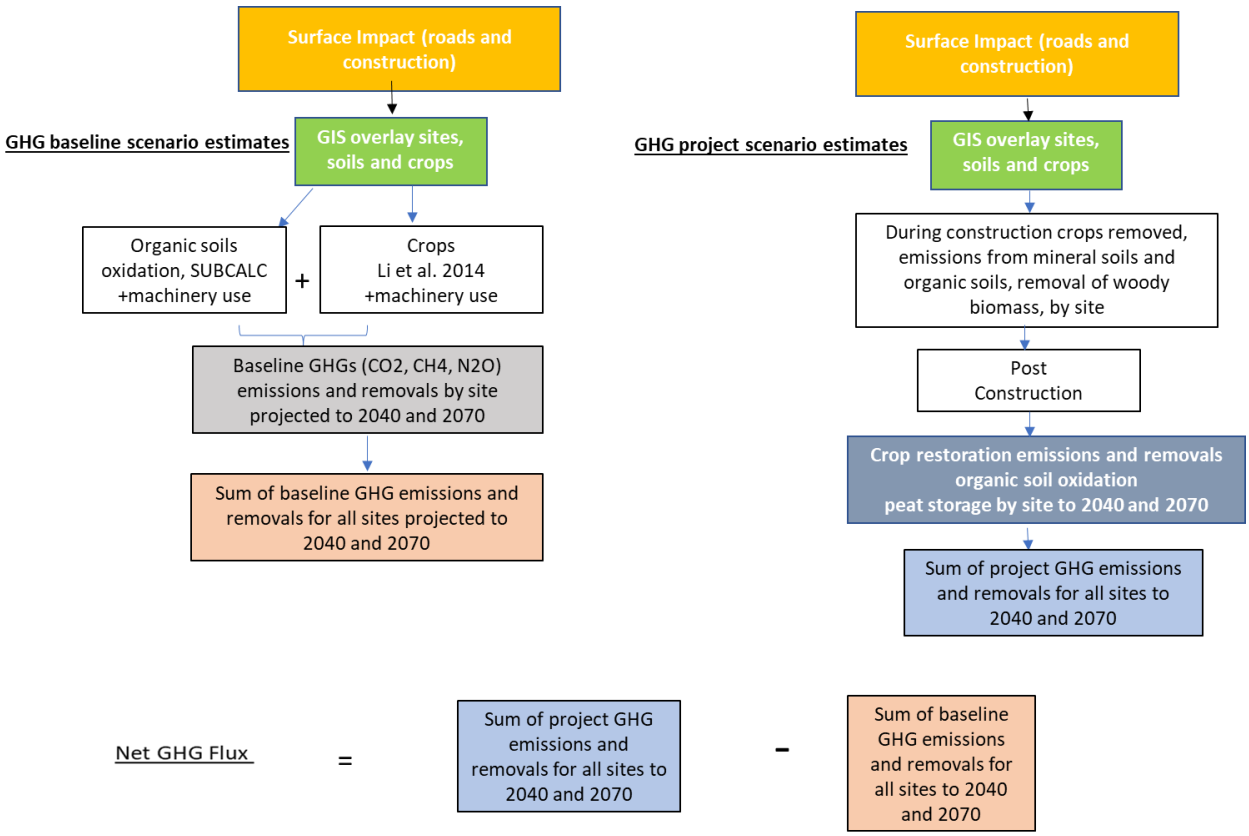


Figure 5. Flowchart for GHG emissions and removals, and net GHG effect calculations.

Area Description

For Alternative 2a, it is proposed that the central tunnel will underlie the Walnut Grove area, Staten, Bouldin, Venice, Mandeville, Bacon, Woodward, and Victoria islands to connect to the Banks and Jones Pumping plants. For Alternative 4a, it is proposed that the east tunnel underlie Glanville, New Hope, Canal Ranch, Brack, Terminous, and Rindge tracts and Roberts, Lower and Upper Jones and Victoria islands to connect to the Banks and Jones Pumping plants. For Alternative 5, it is proposed that the tunnel will follow the Alternative 4a tunnel alignment to Lower Roberts Island then veer south-west under Lower/Upper Jones, Victoria, Union, and Coney Islands to connect to the Bethany Complex (Figure 4).

Methods

GIS Data Processing

Quantifying GHG emissions and removals for the Delta Conveyance Project is a complex process, since emissions and removals and potential project effects depend on spatially variable factors, such as soil type, land use, and planned construction. To account for all these factors explicitly, we created a dataset with all the unique combinations of soil and land uses for every project feature for Alternatives 2a, 4a, and 5. This dataset was created by developing a GIS process in ARCGIS that overlays geospatial layers, while retaining the properties of the original layers and calculating the area of each unique combination of properties.

To setup this GIS process, we created GIS layers of the project features that retained the properties we needed for analysis for each alternative. These new geospatial datasets were based on layers of Constructability and Polygon Features provided by DCA. While constructability layers provided the overall footprint and impact category for project sites, the impact on organic and highly organic mineral soils depends on the local properties of the proposed construction features at each site, as described later in this report.

We combined the Polygon Features layers with the Constructability layers based on their Project Feature category. Project Feature categories included: the Forebay Emergency Spillway, Embankment, Inlet Structure, and Outlet Structure; Peat Storage; Shaft; Shaft Pad; and Topsoil Storage. Additional processing was required when merging the selected items from Polygon Features layers with Constructability because these layers contain joint polygons with intersecting areas. To avoid double counting and over estimation of GHG emissions and

removals, we removed the footprints of the Project Features items to be added to the Constructability layer before merging both layers.

Once the Constructability layers were modified as mentioned in the previous paragraphs, the next step was to overlay Constructability layers with land use. For this, we used the 2016 California Statewide Agricultural Land Use GIS layer (DWR, 2019a). Since this layer is not continuous within the project areas, we overlayed it with the Constructability layers by performing geospatial unions. Geospatial unions retain all the features of the original GIS layers. Therefore, after the unions were performed, we removed features in the land use layer, but not in the Constructability layer. Once we added land use to the Constructability layers, we overlaid them with soil type. We used the Web Soil Survey GIS layer (NRCS, 2021). Since the soil type layer is continuous, we performed a geospatial intersection to add the soil type attributes to the Constructability layers.

The output of the GIS process described above was a table containing all the unique combinations of project features, land use, and soil type for Alternatives 2a, 4a and 5. This table contains 3,838 rows and was processed in R Studio using the library tidyr (Wickham, 2021) as described in the following sections. This dataset was then pivoted to create one row for each year within the analyzed period (construction year 1 through 2070), for each unique combination of project feature, land use, and soil type.

Baseline conditions

For baseline conditions, we estimated GHG (CO_2, CH_4 and N_2O) emissions and removals for present-day conditions resultant from the oxidation of organic and highly organic mineral soils, agriculture on mineral soils (including fallowed/idle areas), farming activities, and managed wetlands. We assumed that managed wetland was the only land use to emit methane based on data presented in Hemes et al. (2019). We projected the present-day GHG emissions and removals for the counterfactual baseline scenarios to 2040 and 2070. Baseline GHG emissions and removals were calculated using the following equation

$$Baseline = OS_e + AC_e^{ms} - AC_r^{ms} + FA_e + WL_e \qquad (1)$$

Where:

OS_e: emissions from organic and highly organic mineral soils as metric tons of CO_2 equivalents (t CO_2-e)
AC_e^{ms}: emissions from agricultural crops on minerals soils as t CO_2-e
AC_r^{ms}: removals by agricultural crops on mineral soils as t CO_2-e
FA_e: emissions due to farming activities as t CO_2-e
WL_e: wetland emissions as t CO_2-e

Emissions are positive numbers and removals are negative numbers. Emissions and removals were calculated for each row of the dataset by multiplying emission rates per acre, by the area. The present-day emissions and removals were projected to 2070.

Emissions from organic and highly organic mineral soils

For GHG emissions from organic and highly organic mineral soils, we assumed that oxidation of organic matter is the predominant cause of emissions, and we utilized and updated version of the SUBCALC model (Deverel et al. 2016) and data for N_2O emissions from Delta organic and highly organic mineral soils as described in Deverel et al. (2017). The SUBCALC model accounts for the emissions and removals on organic and highly organic mineral soils in the Sacramento-San Joaquin Delta. Oxidation of organic and highly organic mineral soils is the primary cause of GHG emissions is based on data and analysis described in Deverel and Rojstaczer (1996) and Deverel and Leighton (2010). The SUBCALC modeling approach was used because it is peer reviewed and has been shown to accurately estimate CO_2 emissions determined by micrometeorological methods for organic Delta soils. The modified SUBCALC model is based on the published model and has been validated using recent measured GHG fluxes and subsidence on Delta soils. Methane is not emitted from Delta organic and highly organic mineral soils drained for agriculture but is emitted from wetlands (Hemes et al. 2019).

Deverel and Leighton (2010) originally used SUBCALC to integrate available data and quantify and simulate subsidence rates and causes. The SUBCALC model simulates aerobic microbial

oxidation of organic carbon, consolidation, wind erosion and burning. Present-day subsidence is primarily the result of oxidation and consolidation. The SUBCALC model simulates microbial oxidation of soil organic carbon to carbon dioxide using Michaelis–Menton enzyme kinetics in which the rate of soil organic-matter oxidation is limited by soil organic carbon content (Deverel and Leighton, 2010; Deverel et al. 2016). Deverel et al. (2016) calibrated SUBCALC with subsidence and carbon flux data for the Delta and the model was used to estimate CO_2 fluxes for organic soil and highly organic mineral soils throughout the Delta.

The updated SUBCALC model, in conjunction with GIS data, accounts for the spatial variability of peat thickness, soil organic matter, and depth-to-groundwater (DTW). The updated model calculates the total carbon substrate available for oxidation in the unsaturated portion of the soil profile. For each year of the simulation, the emitted carbon is removed from the substrate, the water table is lowered by the equivalent depth of subsidence to simulate drain deepening, and additional carbon is added to the unsaturated profile as underlaying peat is dewatered. When the water table falls below the bottom of the peat layer, no additional peat is added to the profile. The updated model also incorporates the expected increase in soil temperature in the Delta reported by Bradford et al. (2019) and the associated increase in emissions based on data for the relation of emissions and soil temperature presented in Deverel and Rojstaczer (1996).

SUBCALC needs as input organic matter, depth of the organic soil or highly organic mineral soil, and depth to groundwater. We estimated soil organic matter based on the mapped soil locations and organic matter data content provided in the Soil Survey Geographic Database (NRCS, 2021). We estimated peat thicknesses from Deverel et al. (2015) and the 2017 Delta LiDAR (DWR, 2019). Depth to groundwater was estimated based on Soil Survey data (NRCS, n.d.), and HydroFocus extensive database of water level measurements at drains and wells throughout the Delta. These data were organized in geospatial datasets of 90 ft resolution. To determine the per acre emissions rates for project sites on organic and highly organic mineral soils, we ran SUBCALC for each pixel of the combined geospatial datasets in map units corresponding to organic and highly organic mineral soils. We then calculated the total GHG emissions for the whole feature and normalized by the feature area to get the average metric tons of CO_2 per acre. Peat thickness and soil organic matter beneath the water table were confirmed and adjusted according to recent soil data at feature locations provided by the DCA and DWR.

For N_2O emissions resultant from the oxidation of organic soils and highly organic mineral soils, the approach described in Deverel et al. (2017) was used. Specifically, the relation of N_2O emissions to CO_2 emissions determined on Sherman and Twitchell islands (Teh et al. 2011; Morris 2014; Morris et al. 2017; Yang et al. 2016) was used to estimate the N_2O emissions due to the oxidation of Delta organic and highly organic mineral soils. We assumed that N_2O emissions due to nitrogen fertilizer application were insignificant relative to N_2O emissions resultant from the oxidation of organic and highly organic mineral soils based on data and calculations presented in Deverel et al. (2017). Estimated N_2O emissions due to fertilization of

organic and highly organic mineral soils described in Deverel et al. (2017) were less than 6% of the total N_2O emissions. All GHG emissions were expressed in t CO_2-e with an N_2O global warming potential value of 265 times the global warming potential of CO_2 on a 100-year timescale (Myhre et al. 2013). The uncertainty in the SUBCALC calculations is due primarily to the uncertainty in the spatial variability in soil organic matter content and depth to groundwater.

We used the updated SUBCALC results to obtain average emission rates per acre for organic and highly organic mineral soils for each project site and year of analysis. These per acre rates were joined to all the rows of the database with soils classified as organic and highly organic mineral soils. Soils classified as organic and highly organic mineral soils are presented in Table 1. Yearly per acre rates were multiplied by each row acreage to obtain yearly emissions in metric t CO_2-e.

Table 1. Organic and Highly Organic Mineral Soils.

Organic Soil - Highly Organic Mineral Soil Name (MUNAME)
Egbert Clay, Partially Drained, 0 To 2 Percent Slopes
Egbert Mucky Clay Loam
Egbert Silty Clay Loam, Partially Drained, 0 To 2 Percent Slopes
Kingile Muck
Kingile Muck, Partially Drained, 0 To 2 Percent Slopes
Kingile-Ryde Complex, Partially Drained, 0 To 2 Percent Slopes
Peltier Mucky Clay Loam, Organic Substratum, Partially Drained, 0 To 2 Percent Slopes
Peltier Mucky Clay Loam, Partially Drained, 0 To 2 Percent Slopes
Rindge Muck, Partially Drained, 0 To 2 Percent Slopes
Ryde Clay Loam, Partially Drained, 0 To 2 Percent Slopes
Ryde Clay Loam, Sandy Substratum, Partially Drained, 0 To 2 Percent Slopes
Ryde Silty Clay Loam, Organic Substratum, Partially Drained, 0 To 2 Percent Slopes
Ryde-Peltier Complex, Partially Drained, 0 To 2 Percent Slopes
Scribner Clay Loam, Partially Drained, 0 To 2 Percent Slopes
Shinkee Muck, Partially Drained, 0 To 2 Percent Slopes

Soil GHG emissions and removals and farming activities on mineral soils

To estimate baseline GHG emissions and removals due to agricultural crops on mineral soils, we used the results of California statewide modeling and field experiments for over 40 crops described in Li et al. (2014). Li et al. (2014) is the only comprehensive compendium of GHG emissions and removals for crops in California[3]. We aggregated the crops into 7 groups and estimated GHG emissions and removals on a per acre basis based on data presented in Li et al. (2014) and Shaffer and Thompson (2015) presented in Table 2. We used the estimated GHG emissions and removals for these crop groups in t CO_2-e per acre per year multiplied times the acreage provided in the GIS files. The uncertainty shown in Table 2 was used to estimate maximum and minimum values for each site for minerals soils.

[3] The California Air Resources Board has published GHG emissions and removals for agricultural crops as a whole, but not for individual crops.

Table 2. Greenhouse Gas Emissions (+) and Removals (-) For Crop Groups on mineral soils. For pasture and idle land, we assumed zero emissions.

Crop group	t CO2-e per acre per year	Farming Activities t CO2-e per acre per year (Shaffer and Thompson, 2015)	Total t CO2-e per acre per year (sum of columns 2 and 3)	Standard Deviation t CO2-e per acre per year
1. Trees and vines	-0.7	1.4	0.7	0.5
2. Pasture	0.2	-	0.2	4.1
3. Rice	4.8	2.1	6.9	3.9
4. Field crops (corn, safflower, sorghum, sunflower)	-2.4	1.5	-0.9	0.2
5. Miscellaneous Field Crops (small grains, dry beans, alfalfa, hay)	-4.2	1.7	-2.5	0.3
6. Vegetable Crops	1.9	2.7	4.6	0.6
7. Idle land	0.1	-	0.1	0.2

We estimated the live biomass accrued in permanent crops (trees and vines) using the approach described in the International Panel for Climate Change (IPCC, 2006) guidelines (Table 5.1 Default coefficients for above-ground woody biomass and harvest cycles in cropping systems containing perennial species for above-ground woody biomass in temperate climate regions) at 25.5 tons of carbon per acre. For wetlands, we used the GHG emissions described in Hemes et al. (2019) of 2.5 t CO2-e per acre year.

Project conditions

Project GHG emissions and removals were quantified similarly to the baseline emissions and removals, which were modified on an item-by-item basis depending on the type of soil, project feature, and impact category. Before the start of construction, GHG emissions and removals for the project scenario were assumed to be equal to baseline GHG emissions and removals for all soil types, land uses, and project features. Project GHG emissions and removals were calculated using the following equation

$$Project = OS_e + AC_e^{ms} - AC_r^{ms} + FA_e + WB_e - WB_r \qquad (2)$$

Where:

OS_e: emissions from organic and highly organic mineral soils as metric tons of CO_2 equivalents (t CO_2-e). This term includes emissions from organic and highly organic mineral soil stockpiles.
AC_e^{ms}: emissions from agricultural crops on minerals soils as t CO_2-e
AC_r^{ms}: removals by agricultural crops on mineral soils as t CO_2-e
FA_e: emissions due to farming activities as t CO_2-e
WB_e: emissions due to woody crops displacement as t CO_2-e
WB_r: removals due to woody biomass regrowth as t CO_2-e

Similar to baseline conditions (equation 1), project GHG emission and removal rates in metric tons of CO2-e per acre per year shown in Table 2 and as calculated by SUBCALC, were multiplied by the land-use areas for each site.

After the beginning of construction, the methodology for calculating project emissions depended on whether the soil was organic and highly organic mineral soil, or mineral. For organic and highly organic mineral soils, engineering conceptual drawings (DCA; 2021a, 2021b), and soil balances (DCA 2021c and DCA 2021d) were reviewed in detail. Based on this review, four main activities were identified to cause changes in GHG emissions and removals with respect to baseline. These activities are excavation and drainage, capping, wetting, and removal of woody biomass and are described below.

Excavation of organic and highly organic mineral soils and storage. We assumed that excavation of organic and highly organic mineral soils only occurs in features labeled as Shaft, Forebay Embankment, and Emergency Spillway. For shafts, excavation is necessary to reach tunnel depth. For the Forebay Embankment and Emergency Spillway, excavation of organic and highly organic mineral soils is necessary for foundation improvement. We assumed that levee improvements will not contribute to GHG emissions or removals differently than for baseline.

Excavation of organic and highly organic mineral soils causes two changes with respect to baseline emissions. First, in the area where the soil is excavated (e.g. in the footprint of a shaft), emissions stop in the area, because organic material is removed from the site. Therefore, for areas where organic and highly organic mineral soils are excavated, GHG emissions after the start of the project due to aerobic oxidation were set to zero. Second, excavated organic and highly organic mineral soils in storage piles emit GHGs (CO_2 and N_2O). Emissions from organic and highly organic mineral soils in piles are different than emissions of undisturbed soil due to the combined effect of drainage and capping. On one hand, drainage allows for oxygen diffusion which increases the rate of aerobic oxidation. On the other hand, capping of stockpiles reduces the rate of oxygen diffusion, which decreases the rate of aerobic oxidation.

We assumed a cover of 5 ft of topsoil on stockpiles to limit oxidation of organic material, as described on page 5 of the soil balance report (DCA, 2021c). The US Geological Survey (USGS) conducted an experiment in which peat soil columns were capped with mineral material in 1998 – 1999 (Lauren Hastings, former USGS Hydrologist, written communication to Steven Deverel, 1999). The results of these studies demonstrated that a mineral cap 2-feet thick on a

peat soil reduced CO_2 emissions about 35% (see Appendix A). Therefore, we assumed a linear decrease in CO_2 emissions with increasing cap thickness based on the USGS results. Hence, for the calculations of the GHG emissions we assumed that capping of the peat soil with a mineral layer 5-feet thick, will reduce oxidation by 88%. We employed SUBCALC (Deverel et al. 2016) and the relation of N_2O emissions to CO_2 emissions described in Deverel et al. (2017) to estimate CO_2 and N_2O emissions from the peat stockpiles and then reduced the estimated emissions by 88%. Organic matter contents of piles were estimated based on Web Soil Survey (NRCS, 2021) and bore logs provided by DCA for the excavated features closest to each pile. We used dimensions of stockpiles provided in Tables 3-1 and 3-2 of the soil balance report (DCA, 2021c).

Construction of features on top of organic and highly organic mineral soils, likely causes a capping effect analogous to the one described in the previous paragraph for stockpiles. For this capping, the feature provides a cover that limits the diffusion of oxygen through the soil, therefore limiting aerobic oxidation. We assumed that features labeled as Access Railroad, Access Road, Levee Access Road, Peat Storage, RTM Area, RTM Stockpile Area, Shaft Pad, and Topsoil Storage provided capping for organic and highly organic mineral soils. Emissions due to aerobic oxidation for these features were calculated by multiplying the baseline emissions by an emission factor ranging from zero to one based on the USGS work described in Appendix A. Emission factors were calculated using the following equation:

$$C_i = \max\left(0, 1 - \frac{h_i}{2} * 0.35\right) \qquad (3)$$

Where:
C_i: Emission factor for project feature i
h_i: Height of project feature i

We obtained heights for project features from engineering conceptual drawings (DCA; 2021a, 2021b). For roads, we assumed two feet of cover, which results in a 35% reduction of emissions ($C_i = 0.65$) (Appendix A). Based on equation 3, features with heights greater than six feet will result in a C_i of 0, or a 100% reduction of emissions calculated by SUBCALC. Therefore, for features labeled as Peat Storage, RTM Area, RTM Stockpile Area, Shaft Pad, and Topsoil Storage, we assumed no emissions due to oxidation of organic and highly organic mineral soils during project years.

Water saturation of organic and highly organic mineral soils will occur at the Forebay after construction due to flooding. Flooding the forebay will create anoxic conditions which will stop oxidation of organic and highly organic mineral soils. Therefore, we assumed that after the end of construction, no emissions due to organic and highly organic mineral soils oxidation would occur at the forebay.

Lastly, we assumed that in areas where the baseline land use includes woody crops, carbon stored in the removed biomass will be released to the atmosphere during the first year of

construction. Woody crops include trees and vines category in Table 2. Carbon stored in woody biomass was estimated based on IPCC (2006).

For mineral soils, changes in GHG emissions and removals with respect to baseline are expected due to changes in land use and removal of woody biomass. We assumed that during construction, crops were removed from all the project feature areas and the soil was left uncovered. Therefore, we classified the land use during these years as bare soil or idle land. The effect of crop removal with respect to baseline for mineral soils depends on the emissions and removals rates of the baseline land uses. For crops that sequester carbon, a change to idle land during project years results in a decrease in GHG removals. For crops that act as carbon sources, switching to idle land represents a decrease in GHG emissions with respect to baseline.

For impact categories labeled as Permanent Surface Impact, we assumed that the project scenario emissions would continue to 2070. For features labeled as Temporary Surface Impact, we assumed that land use returns to the baseline condition, and GHG emissions and removals are the same as the respective baseline year for each feature and land use, except woody crops. For woody crops, we assumed that removals from woody biomass regrowth would occur at a constant rate during the 20 years following the end of construction. Greenhous gas removals and emissions for the project scenario were aggregated spatially based on project features, and temporally based on two temporal horizons: 2040 and 2070.

Net GHG effect

Calculated GHG emissions and removals for both the baseline and project scenarios, were aggregated based on their DCA Feature Name category. We then calculated the net yearly GHG effect of the project as the difference between baseline and project yearly GHG emissions and GHG removals. The yearly net project GHG impacts were aggregated to estimate the cumulative effect to 2040 and 2070.

Results

Baseline GHG emissions and removals

We calculated present-day GHG emissions and removals for current land uses which are primarily agricultural. For each location where land use changes are proposed, we estimated the GHG emissions and removals associated with each land use for Alternatives 2a, 4a, and 5 as described above. The GHG emissions and removals are denoted as positive and negative numbers, respectively. The largest source of emissions are organic and highly organic mineral soils.

Alternative 2a

Table 3 shows the estimated present-day baseline emissions and removals expressed as positive and negative numbers, respectively, for the Permanent and Temporary Surface Impact sites for Alternative 2a. Overall, present-day land uses that will be temporarily and permanently impacted by the Project currently emit 5,594 t CO_2-e per year. The primary source of emissions are the organic and highly organic mineral soils, notably on Bouldin and Bacon islands.

Alternative 4a

Table 4 shows the estimated present-day GHG baseline emissions and removals expressed as positive and negative numbers, respectively, for the Permanent and Temporary Surface Impact sites for Alternative 4a. Overall, land uses that will be temporarily and permanently impacted by the Project currently emit 4,465 t CO_2-e per year. The primary source of emissions are the organic and highly organic mineral soils, notably on Lower Roberts Island.

Alternative 5

Table 5 shows the estimated present-day baseline emissions and removals expressed as positive and negative numbers, respectively, for the Permanent and Temporary Surface Impact sites for Alternative 5. Overall, land uses that will be temporarily and permanently impacted by the Project currently emit 3,628 metric tons CO_2-e per year. The primary source of emissions are the organic and highly organic mineral soils, notably on Lower Roberts Island.

Table 3. Estimated Present-day Average Annual Baseline Emission and Removal Rates for Alternative 2a.

DCA Feature Name	Land Use Codes	Area (ac)	Avg Baseline (tCO2-e/yr)
Access Railroad: Franklin Blvd	2, 8	21	3
Access Road: Bouldin I - Central	9	15	329
Access Road: Intake Haul Rd: I3 - I2	1, 4, 5, 8, 9	18	3
Access Road: Intake Haul Rd: I5 - I3	1, 3, 5, 8, 9	21	16
Access Road: Intake Haul Rd: Lambert - I5	1, 3, 4, 5, 8, 9	25	-8
Access Road: Lambert Road	8	0.02	0.001
Access Road: SForebay - North/Discovery Bay	2, 4, 8	18	-1
Access Road: Staten Island - Central	9	0.4	1
Access Road: Western Farms Ranch Road	2, 8	9	-12
Bacon_Mandeville Access Roads	3, 4, 8, 9	17	304
Bouldin Island RTM	9	226	1,107
Caltrans Road: Bouldin SR12 - Central	9	53	1,105
Intake A - 1,500 cfs - Cylindrical Tee Screen	1, 4, 5, 8, 9	165	212
Intake B - 3,000 cfs - Cylindrical Tee Screen	1, 8, 9	241	20
Intake C - 3,000 cfs - Cylindrical Tee Screen	1, 5, 8, 9	239	221
Lambert Road/Franklin Concrete Batch Plant #1	3, 8	8	-7
Lambert Road/Franklin Concrete Batch Plant #2	3, 8	8	-7
Levee Access Road: Bouldin Island - Central	8, 9	27	368
Park and Ride: Bethany	8	3	0.2
Park and Ride: Byron	8	2	0.2
Park and Ride: Charter Way	8	2	0.2
Park and Ride: Hood Franklin	7	4	10
Park and Ride: Rio Vista	1, 8	3	1
Shaft: Bacon Island - Central	9	15	185
Shaft: Bouldin - Central	9	89	1,230
Shaft: Mandeville Island - Central	4, 8, 9	14	-34
Shaft: New Hope Tract - Central	9	11	8
Shaft: Staten Island - Central	9	12	30
Shaft: Twin Cities Complex	2, 5, 8	361	520
Southern Complex on Byron Tract	2, 4, 8, 9	1,338	9
Southern Complex West of Byron Highway	2, 4, 8	364	18
Southern Complex West of Byron Highway - Alternatives 2a and 4a	1, 4, 8	111	-66
Twin Cities Complex RTM	2, 8	147	28
TOTAL	-	**3,588**	**5,594**

Legend
0 = Bare mineral soil
1 = Trees and vines (grapes, pears, cherries, citrus, walnuts, almonds)
2 = Pasture (mixed pasture, misc. grasses)
3 = Rice
4 = Field crops (corn, safflower, sorghum, sunflower)
5 = Miscellaneous field crops (small grains, dry beans, alfalfa, hay, wheat, misc. grain/hay)
6 = Vegetable crops (tomatoes, misc. truck crops, potatoes, and sweet potatoes)
7 = Idle crop (mineral soil)
8 = Managed wetland (2.5 MTCO2 e/ac/yr – Hemes, 2019)
9 = Urban
10 = Organic soil - highly organic mineral soil

Table 4. Estimated Present-day Average Annual Baseline Emission and Removal Rates for Alternative 4a.

DCA Feature Name	Land Use Codes	Area (ac)	Avg Baseline (tCO2-e/yr)
Access Railroad: Franklin Blvd	2, 8	21	3
Access Railroad: Lower Roberts Island	2, 3, 8, 9	29	60
Access Road: Canal Ranch Tract - Eastern	8	0.1	0.005
Access Road: Intake Haul Rd: I3 – I2	1, 4, 5, 8, 9	18	3
Access Road: Intake Haul Rd: I5 – I3	1, 3, 5, 8, 9	21	16
Access Road: Intake Haul Rd: Lambert – I5	1, 3, 4, 5, 8, 9	24.68	-7.619
Access Road: King Island - Eastern	9	0.1	0.2
Access Road: Lambert Road	8	0.02	0.001
Access Road: Lower Roberts - Eastern	1, 3, 4, 8, 9	27	123
Access Road: New Hope Tract - Eastern	1, 8	3	1
Access Road: SForebay - North/Discovery Bay	2, 4, 8	18	-1
Access Road: Upper Jones Tract - Eastern	5, 8, 9	6	22
Access Road: Western Farms Ranch Road	2, 8	9	-12
County Road: Clifton Court Rd	8	3	0.3
County Road: N Bruns Way	2, 4, 8	6	-6
County Road: Re-aligned Byron Hwy	2, 4, 8	23	-5
Intake A - 1,500 cfs - Cylindrical Tee Screen	1, 4, 5, 8, 9	166	212
Intake B - 3,000 cfs - Cylindrical Tee Screen	1, 8, 9	241	20
Intake C - 3,000 cfs - Cylindrical Tee Screen	1, 5, 8, 9	239	221
Lambert Road/Franklin Concrete Batch Plant #1	3, 8	8	-7
Lambert Road/Franklin Concrete Batch Plant #2	3, 8	8	-7
Levee Access Road: Lower Roberts - Eastern	3, 4, 5, 6, 8, 9	37	88
Lower Roberts Island	3, 4, 8, 9	24	109
Lower Roberts Island RTM	8, 9	95	857
Park and Ride: Bethany	8	3	0.2
Park and Ride: Byron	8	2	0.2
Park and Ride: Charter Way	8	2	0.2
Park and Ride: Hood Franklin	7	4	10
Shaft: Canal Ranch Tract - Eastern	1, 8	11	8
Shaft: King Island - Eastern	9	13	21
Shaft: Lower Roberts - Eastern	3, 4, 8, 9	257	2,005
Shaft: New Hope Tract - Eastern	1, 8	11	8
Shaft: Terminous Tract - Eastern	9	14	10
Shaft: Twin Cities Complex	2, 5, 8	231	495
Shaft: Upper Jones Tract - Eastern	5, 9	14	126

DCA Feature Name	Land Use Codes	Area (ac)	Avg Baseline (tCO2-e/yr)
Southern Complex on Byron Tract	2, 4, 8, 9	1,342	-130
Southern Complex on Byron Tract RTM	9	52	214
Southern Complex West of Byron Highway	2, 4, 8	364	18
Southern Complex West of Byron Highway – Alternatives 2a and 4a	1, 4, 8	111	-66
Twin Cities Complex RTM	2, 8	278	54
TOTAL	**-**	**3,736**	**4,465**

Legend
0 = Bare mineral soil
1 = Trees and vines (grapes, pears, cherries, citrus, walnuts, almonds)
2 = Pasture (mixed pasture, misc. grasses)
3 = Rice
4 = Field crops (corn, safflower, sorghum, sunflower)
5 = Miscellaneous field crops (small grains, dry beans, alfalfa, hay, wheat, misc. grain/hay)
6 = Vegetable crops (tomatoes, misc. truck crops, potatoes, and sweet potatoes)
7 = Idle crop (mineral soil)
8 = Managed wetland (2.5 MTCO2 e/ac/yr – Hemes, 2019)
9 = Urban
10 = Organic soil - highly organic mineral soil

Table 5. Estimated Present-day Average Annual Baseline Emission and Removal Rates for Alternative 5.

DCA Feature Name	Land Use Codes	Area (ac)	Avg Baseline (tCO2-e/yr)
Access Railroad: Lower Roberts Island	3, 8, 9	18	28
Access Road: Bethany Complex Kelso Road	4, 8	2	-3
Access Road: Bethany Complex North	1, 4, 8	9	-12
Access Road: Bethany Complex South	1, 8	9	5
Access Road: Bethany Reservoir Discharge Structure	8	21	2
Access Road: Canal Ranch Tract	8	0.08	0.007
Access Road: Intake Haul Rd: I5 – I3	1, 3, 5, 8, 9	21	16
Access Road: Intake Haul Rd: Lambert – I5	1, 3, 4, 5, 8, 9	25	-8
Access Road: King Island	9	0.1	0.1
Access Road: Lambert Road	8	0.02	0.001
Access Road: Lower Roberts Island	1, 3, 4, 5, 8, 9	34	138
Access Road: New Hope Tract	1, 8	3	1
Access Road: Union Island	9	0.05	0.2
Access Road: Upper Jones Tract	9	0.1	0.7
Bethany Complex: Aqueduct	1, 4, 8	138	-47
Bethany Complex: BRPP and Surge Basin	1, 2, 4, 8	237	-233
Bethany Complex: Discharge Structure	8	15	1
Intake B - 3,000 cfs - Cylindrical Tee Screen	1, 8, 9	242	20
Intake C - 3,000 cfs - Cylindrical Tee Screen	1, 5, 8, 9	239	221
Lambert Road/Franklin Concrete Batch Plant #1	3, 8	8	-7
Lambert Road/Franklin Concrete Batch Plant #2	3, 8	8	-7
Levee Access Road: Lower Roberts Island	3, 4, 5, 6, 8, 9	37	88
Lower Roberts Island RTM	3, 4, 8, 9	189	1,368
Park and Ride: Charter Way	8	2	0.2
Park and Ride: Hood Franklin	7	4	10
Shaft: Canal Ranch Tract	1, 8	11	7
Shaft: King Island	9	12	20
Shaft: Lower Roberts Island	3, 4, 8, 9	343	1,275
Shaft: New Hope Tract	1, 8	11	7
Shaft: Terminous Tract	9	13	9
Shaft: Twin Cities Complex	2, 5, 8	367	522
Shaft: Union Island	4, 8, 9	14	64
Shaft: Upper Jones Tract	4, 8, 9	11	98
Twin Cities Complex RTM	2, 8	209	41
TOTAL	-	**2,250**	**3,628**

Legend
0 = Bare mineral soil
1 = Trees and vines (grapes, pears, cherries, citrus, walnuts, almonds)
2 = Pasture (mixed pasture, misc. grasses)
3 = Rice
4 = Field crops (corn, safflower, sorghum, sunflower)
5 = Miscellaneous field crops (small grains, dry beans, alfalfa, hay, wheat, misc. grain/hay)
6 = Vegetable crops (tomatoes, misc. truck crops, potatoes, and sweet potatoes)
7 = Idle crop (mineral soil)
8 = Managed wetland (2.5 MTCO2 e/ac/yr – Hemes, 2019)
9 = Urban
10 = Organic soil - highly organic mineral soil

Project GHG emissions and removals and net project effects

We calculated the net effect of the proposed project by calculating the difference between the baseline scenario as described above to 2040 and 2070 (assuming no land use changes) and the project scenario emissions and removals estimated to 2040 and 2070. The project emissions or removals minus the baseline emissions or removals equals the net GHG effect:

Net GHG effect = (cumulative project emissions + removals) – (cumulative baseline emissions + removals)

Table 6 shows the baseline and project GHG emissions and removals and net GHG effect for Alternative 2a. The estimated cumulative net effect for this alternative is 17,002 t CO2-e to 2040 and -12,146 t CO2-e to 2070. There is a substantial effect of capping the organic soils relative to baseline. The larger baseline GHG emissions due to oxidation of organic soils relative to the project conditions in which these soils are capped results in a net GHG emissions reductions, notably on Bouldin Island. The net decrease in emissions to 2070 is mainly due to the saturation of organic soils underlaying the Southern Complex forebay caused by flooding, and the capping of peat soils on Bouldin Island.

Table 7 shows the baseline and project GHG emissions and removals and net GHG effect for Alternative 4a. The estimated cumulative net effect for this alternative is 35,299 t CO2-e to 2040 and 31,904 t CO2-e to 2070. In contrast to Alternative 2a, the higher emissions associated with this alternative are primarily related to the absence of organic soils and associated capping.

Table 8 shows the baseline and project GHG emissions and removals and net GHG effect for Alternative 5. The estimated cumulative net effect for this alternative is -59 t CO2-e to 2040 and -23,193 t CO2-e to 2070. The magnitude of emissions and removals for Alternative 5 is substantially lower than Alternatives 2a and 4a. Most of this difference is explained by the absence of the emissions associated with the Southern Complex, which is the most relevant feature for Alternatives 2a and 4a in terms of GHG emissions and removals.

(3)

Table 6. Cumulative baseline and project emissions and removals and net emissions for Alternative 2a.

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Access Railroad: Franklin Blvd	CY 1	44	131	43	130	-1	-1
Access Road: Bouldin I - Central	CY 2	5,095	14,787	3,921	11,218	-1,174	-3,569
Access Road: Intake Haul Rd: I3 – I2	CY 2	120	361	1,033	847	913	486
Access Road: Intake Haul Rd: I5 – I3	CY 2	277	831	289	437	12	-394
Access Road: Intake Haul Rd: Lambert - I5	CY 1	-116	-349	482	319	598	668
Access Road: SForebay - North/Discovery Bay	CY 1	-22	-67	15	-30	37	37
Access Road: Staten Island - Central	CY 2	16	49	13	38	-3	-11
Access Road: Western Farms Ranch Road	CY 1	-179	-538	-0.1	-102	179	436
Bacon_Mandeville Access Roads	CY 1	4,596	13,670	3,541	10,521	-1,055	-3,149
Bouldin Island RTM	CY 6	17,775	49,794	10,680	42,698	-7,095	-7,095
Caltrans Road: Bouldin SR12 - Central	CY 2	16,403	49,721	11,096	33,310	-5,307	-16,411
Intake A - 1,500 cfs - Cylindrical Tee Screen	CY 5	3,971	11,912	5,814	10,340	1,843	-1,572
Intake B - 3,000 cfs - Cylindrical Tee Screen	CY 1	2,185	6,554	17,997	12,480	15,812	5,926
Intake C - 3,000 cfs - Cylindrical Tee Screen	CY 1	9,164	27,492	6,994	15,451	-2,170	-12,041

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Lambert Road/Franklin Concrete Batch Plant #1	CY 1	-100	-299	8	12	108	311
Lambert Road/Franklin Concrete Batch Plant #2	CY 1	-101	-302	8	12	109	314
Levee Access Road: Bouldin Island - Central	CY 3	5,641	16,562	4,324	15,245	-1,317	-1,317
Park and Ride: Hood Franklin	CY 1	152	455	31	96	-121	-359
Park and Ride: Rio Vista	CY 1	13	40	88	95	75	55
Shaft: Bacon Island - Central	CY 6	3,003	8,322	2,279	5,620	-724	-2,702
Shaft: Bouldin - Central	CY 3	19,684	55,336	13,979	37,667	-5,705	-17,670
Shaft: Mandeville Island - Central	CY 5	-513	-1,539	-149	-634	364	905
Shaft: New Hope Tract - Central	CY 3	117	351	978	583	861	233
Shaft: Staten Island - Central	CY 3	474	1,336	361	985	-113	-351
Shaft: Twin Cities Complex	CY 1	7,807	23,420	1,462	17,058	-6,344	-6,362
Southern Complex on Byron Tract	CY 1	419	391	26,781	48,735	26,362	48,345
Southern Complex West of Byron Highway	CY 5	268	804	434	1,437	166	634
Southern Complex West of Byron Highway - Alternatives 2a and 4a	CY 5	-987	-2,961	-126	174	860	3,135
Twin Cities Complex RTM	CY 5	427	1,281	259	656	-168	-625

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Total	**-**	**95,631**	**277,545**	**112,633**	**265,399**	**17,002**	**-12,146**

Table 7. Cumulative baseline and project emissions and removals, and net emissions for Alternative 4a.

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Access Railroad: Franklin Blvd	CY 1	44	131	43	130	-1	-1
Access Railroad: Lower Roberts Island	CY 2	937	2,705	965	2,792	28	87
Access Road: Intake Haul Rd: I3 – I2	CY 2	120	361	1,033	847	913	486
Access Road: Intake Haul Rd: I5 – I3	CY 2	277	831	289	437	12	-394
Access Road: Intake Haul Rd: Lambert – I5	CY 1	-116	-349	482	319	598	668
Access Road: King Island - Eastern	CY 2	2	5	1	3	-1	-2
Access Road: Lower Roberts - Eastern	CY 1	1,903	5,520	1,629	4,216	-273	-1,305
Access Road: New Hope Tract - Eastern	CY 1	19	58	124	115	104	56
Access Road: SForebay - North/Discovery Bay	CY 1	-22	-67	15	-30	37	37
Access Road: Upper Jones Tract - Eastern	CY 1	343	973	215	627	-127	-347

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Access Road: Western Farms Ranch Road	CY 1	-179	-538	-0.1	-102	179	436
County Road: N Bruns Way	CY 5	-84	-251	-17	-1	67	250
County Road: Re-aligned Byron Hwy	CY 5	-76	-228	-4	-9	72	219
Intake A - 1,500 cfs - Cylindrical Tee Screen	CY 5	3,965	11,894	5,813	10,339	1,848	-1,555
Intake B - 3,000 cfs - Cylindrical Tee Screen	CY 1	2,186	6,558	18,008	12,491	15,822	5,933
Intake C - 3,000 cfs - Cylindrical Tee Screen	CY 1	9,175	27,526	6,994	15,452	-2,182	-12,074
Lambert Road/Franklin Concrete Batch Plant #1	CY 1	-100	-299	8	12	108	311
Lambert Road/Franklin Concrete Batch Plant #2	CY 1	-101	-302	8	12	109	314
Levee Access Road: Lower Roberts - Eastern	CY 1	1,367	3,967	971	3,571	-396	-396
Lower Roberts Island	CY 6	1,745	4,904	601	632	-1,144	-4,272
Lower Roberts Island RTM	CY 6	13,093	38,578	7,858	33,343	-5,235	-5,235

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Park and Ride: Hood Franklin	CY 1	152	455	31	96	-121	-359
Shaft: Canal Ranch Tract - Eastern	CY 3	117	352	1,009	562	891	210
Shaft: King Island - Eastern	CY 5	341	964	274	750	-67	-214
Shaft: Lower Roberts - Eastern	CY 2	31,727	90,233	31,057	88,012	-670	-2,221
Shaft: New Hope Tract - Eastern	CY 3	117	352	978	591	861	239
Shaft: Terminous Tract - Eastern	CY 6	148	445	1,285	968	1,136	523
Shaft: Twin Cities Complex	CY 1	7,424	22,272	1,257	16,070	-6,167	-6,202
Shaft: Upper Jones Tract - Eastern	CY 5	2,035	5,658	1,583	4,091	-452	-1,567
Southern Complex on Byron Tract	CY 1	-1,678	-5,869	29,119	51,989	30,797	57,858
Southern Complex on Byron Tract RTM	CY 5	3,238	9,636	1,081	7,479	-2,157	-2,157
Southern Complex West of Byron Highway	CY 5	268	804	434	1,437	166	634
Southern Complex West of Byron Highway - Alternatives 2a and 4a	CY 5	-987	-2,960	-126	175	860	3,135

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Twin Cities Complex RTM	CY 5	811	2,434	492	1,242	-320	-1,192
Total	**-**	**78,211**	**226,753**	**113,509**	**258,657**	**35,299**	**31,904**

Table 8. Cumulative baseline, project, and net emissions and removals for Alternative 5.

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Access Railroad: Lower Roberts Island	CY 1	430	1,259	352	1,036	-78	-223
Access Road: Bethany Complex Kelso Road	CY 1	-41	-124	-38	-121	3	3
Access Road: Bethany Complex North	CY 1	-174	-522	3	-108	176	414
Access Road: Bethany Complex South	CY 1	74	222	21	169	-53	-53
Access Road: Intake Haul Rd: I5 – I3	CY 2	277	831	289	437	12	-394

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Access Road: Intake Haul Rd: Lambert – I5	CY 1	-116	-349	482	319	598	668
Access Road: King Island	CY 2	2	6	2	5	-0.3	-1
Access Road: Lower Roberts Island	CY 1	2,106	6,208	1,831	4,880	-276	-1,328
Access Road: New Hope Tract	CY 1	19	58	124	115	104	56
Access Road: Union Island	CY 2	3	10	2	9	-1	-1
Access Road: Upper Jones Tract	CY 2	10	30	10.0	29	-0.2	-0.2
Bethany Complex: Aqueduct	CY 5	-704	-2,111	-155	-408	548	1,703
Bethany Complex: BRPP and Surge Basin	CY 3	-3,488	-10,463	-273	-913	3,215	9,551
Intake B - 3,000 cfs - Cylindrical Tee Screen	CY 1	2,195	6,586	18,075	12,508	15,880	5,923
Intake C - 3,000 cfs - Cylindrical Tee Screen	CY 1	9,164	27,492	6,994	15,451	-2,170	-12,041

Site Name	Construction Year (CY) Start	Cumulative Baseline to 2040 (tCO2e)	Cumulative Baseline to 2070 (tCO2e)	Cumulative Project to 2040 (tCO2e)	Cumulative Project to 2070 (tCO2e)	Cumulative Net Effect to 2040 (tCO2e)	Cumulative Net Effect to 2070 (tCO2e)
Lambert Road/Franklin Concrete Batch Plant #1	CY 1	-100	-299	8	12	108	311
Lambert Road/Franklin Concrete Batch Plant #2	CY 1	-101	-302	8	12	109	314
Levee Access Road: Lower Roberts Island	CY 5	1,360	3,945	1,120	3,706	-239	-239
Lower Roberts Island RTM	CY 5	20,897	61,559	9,779	50,441	-11,118	-11,118
Park and Ride: Hood Franklin	CY 1	152	455	31	96	-121	-359
Shaft: Canal Ranch Tract	CY 3	110	331	894	552	783	220
Shaft: King Island	CY 4	318	900	257	691	-61	-208
Shaft: Lower Roberts Island	CY 2	19,983	57,375	17,448	48,905	-2,535	-8,469
Shaft: New Hope Tract	CY 3	109	328	889	573	779	245
Shaft: Terminous Tract	CY 5	139	418	1,207	932	1,068	515
Shaft: Twin Cities Complex	CY 1	7,825	23,474	1,952	17,507	-5,873	-5,967

Site Name	**Construction Year (CY) Start**	**Cumulative Baseline to 2040 (tCO2e)**	**Cumulative Baseline to 2070 (tCO2e)**	**Cumulative Project to 2040 (tCO2e)**	**Cumulative Project to 2070 (tCO2e)**	**Cumulative Net Effect to 2040 (tCO2e)**	**Cumulative Net Effect to 2070 (tCO2e)**
Shaft: Union Island	CY 5	955	2,888	792	2,230	-163	-658
Shaft: Upper Jones Tract	CY 3	1,531	4,394	951	2,515	-581	-1,879
Twin Cities Complex RTM	CY 5	610	1,829	435	1,654	-175	-175
Total	**-**	**63,547**	**186,428**	**63,489**	**163,236**	**-59**	**-23,193**

Uncertainty

We estimated uncertainty by incorporating the range of estimated values for GHG removals and emissions for crops from Li et al. (2014) (see Table 1) and for oxidation rates for organic and highly organic mineral soils described in Deverel et al. (2016) for each site. The primary uncertainty in the estimation of soil organic matter oxidation rates is due to the spatial variability for key SUBCALC model inputs, soil organic matter content and depth to groundwater. Similarly, uncertainty in crop GHG emissions and removals estimates in Li et al. (2014) are due spatial uncertainty in key model inputs and spatial variability of measured data used for the statewide estimates. We were able to reduce the uncertainty by utilizing data for soil organic matter content provided by DWR. There is also model uncertainty of about plus or minus 11% where depth to groundwater and soil organic matter percentages are known. Considering the sources of uncertainty resulted in an overall average uncertainty in the mean annual per acre values for the net GHG shown in Table 8 of about plus or minus 30%.

Another source of uncertainty for projected emissions is the predicted future average soil temperature. To account for future warming trends, we incorporated the average increase in soil temperature in the Delta as modeled by Bradford et al. (2019) for the RCP 4.5 warming scenario. Bradford et al. modeled average soil temperature from 2010 to 2100 for both RCP 4.5 and 8.5 warming scenarios accounting for changes in soil moisture due to projected geographic shifts in precipitation and warming. Average modeled soil temperature within the legally defined Delta increases at approximately the same rate for both RCP 4.5 and 8.5 until about 2050 at which point the projections diverge. Thus, the most uncertainty arises in emissions projections after 2050.

Figure 6 below shows the results from Bradford et al. (2019) for the two potential warming pathways. By 2100, the average soil temperature is predicted to increase to 18.72ºC for RCP 4.5 and 20.40ºC for RCP 8.5. We used the RCP 4.5 scenario for this analysis as the most likely warming pathway, but it remains unclear which warming scenario will be realized in the coming decades. Average soil temperatures in the Delta could be higher than the projected temperatures used for our long-term analysis of project conditions, especially beyond 2070.

Beyond 2070, stockpiled peat will continue to oxidize at rates generally commensurate with the rates estimated during this study. Oxidation rates may be slightly greater than estimated with increased temperature associated with RCP 8.8 scenario. The timeframe for complete oxidation of the stored peat depends on the characteristics of the peat and the storage geometry and will range from several decades to over 100 years.

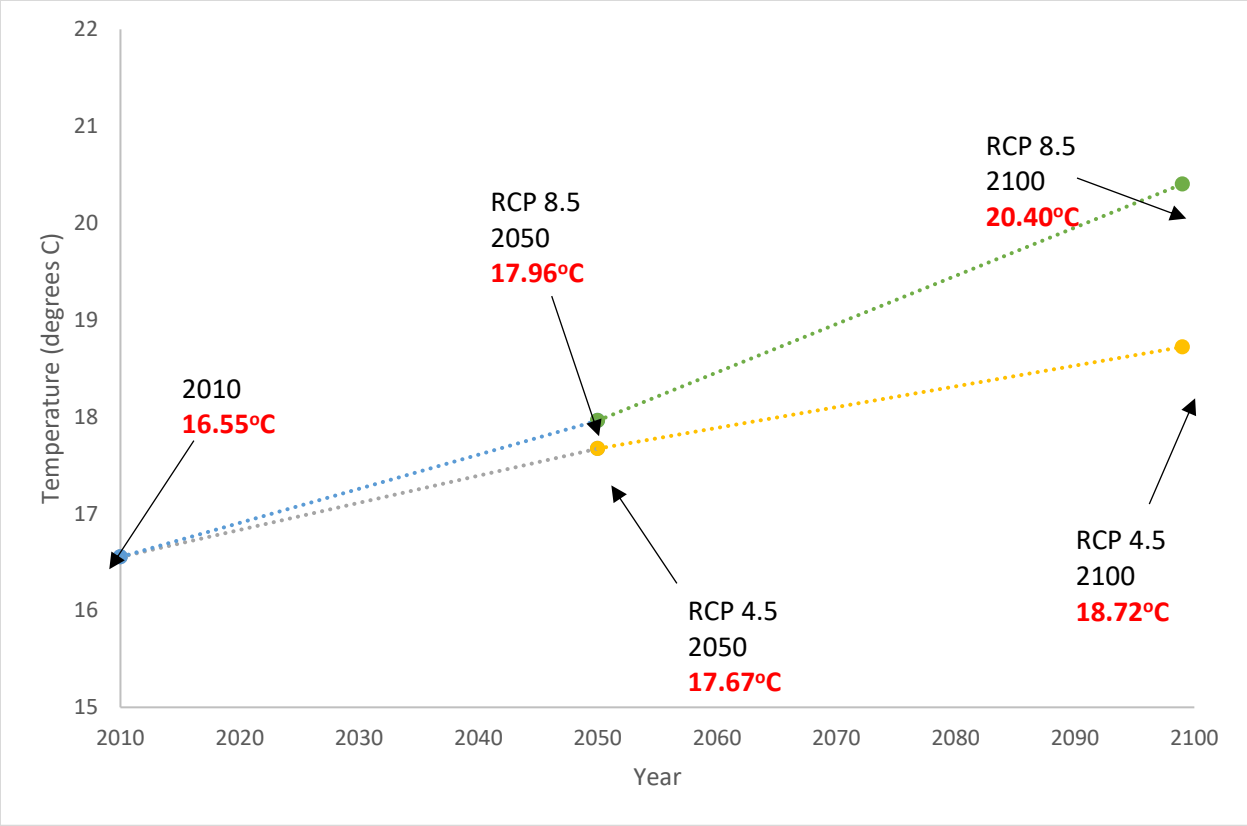


Figure 6. Estimated Delta soil temperatures from Bradford et al. (2019).

Summary

HydroFocus utilized available information for soils, land use and associated GHG emissions and removals, and modeling to estimate the net GHG effect of the land use changes and earth moving and storage along the proposed tunnel alignments for Alternative 2a, 4a, and 5. The overall objective was to quantify the net GHG effect due to land-use changes associated with the construction of the tunnels and appurtenances for these alternatives.

We estimated the GHG impact of the proposed project alignments by calculating GHG emissions and removals relative to the reference or baseline conditions using data from multiple sources, modeling, and GIS analysis. For baseline or reference conditions, we estimated GHG emissions and removals for present-day conditions resultant from the oxidation of organic and highly organic mineral soils, agriculture on mineral soils (including fallowed and idle areas), agricultural operations and a managed wetland. In the development of the baseline counterfactual scenarios to 2040 and 2070, we projected the present-day GHG emissions and removals into the future under the assumption that practices and processes that affect GHG emissions and removals will not change significantly without the proposed project.

Proposed project actions that will affect GHG emissions and removals relative to baseline conditions include organic and highly organic mineral soil excavation and storage, removal of crops, and dewatering, capping and saturation of organic and highly organic mineral soils. Crops will be removed temporarily or permanently. For permanent crops (trees and vines), there will be a removal of carbon accumulated in the woody biomass. When crops are replanted, the agricultural GHG removals and emissions will resume after the construction- activity timeframe specified in project documents.

We estimated that the average net cumulative GHG effect of land-use changes due to construction activities will range from a decrease of -59 to an increase of 35,299 t CO2-e to 2040. To 2070, the average net cumulative GHG effect will range from a decrease of -12,146 to an increase of 31,904 t CO2-e relative to baseline conditions for the three alternatives (Table 9). The increased emissions to 2040 result mainly from the removal of crops on mineral soils, such as alfalfa and wheat, and the removal of woody crops such as grapes and pears. This increase in emissions is offset to 2070 by the decrease in emissions with respect to baseline resulting from the capping of organic and highly organic mineral soils on Bouldin Island for Alternative 2a (CA), Lower Roberts Island for Alternatives 2a, 4a, and 5, and the flooding of the Southern Forebay for Alternatives 2a and 4a.

We estimated that the uncertainty in these estimates ranges from plus or minus 30%. The largest GHG effect was found for Alternative 4a. Effects of Alternative 2a and 5 are one order of magnitude lower than effects of Alternative 4a. The capping of organic and highly organic mineral soils provided by construction at Bouldin Island represents a significant benefit in decreasing emissions with respect to baseline for Alternative 2a. Alternative 5 is notably different to Alternatives 2a and 4a due to the absence of emissions associated with construction in the Southern Complex.

As indicated by the decrease in annual per acre values in Table 6, 7 and 8, cumulative net emissions will continue to decrease with time. This is due primarily to diminishing effects of peat oxidation and the long-term benefit resulting from project features that provided capping or wetting to organic and highly organic mineral soils. Also, the effects of temporary crop removal will disappear within 20 years after construction due to regrowth of permanent woody crops.

Table 9. Net emissions cumulative values and average rates for Alternatives 2a, 4a. and 5.

Alternative	Area (acres)	Cumulative Net Emissions 2040 (t CO2-e)	Cumulative Net Emissions to 2070 (t CO2-e)	Average emission rates up to 2040 (tCO2-e / acre / year)	Average emission/removal rates up to 2070 (tCO2-e / acre / year)
2a	3,588	17,002	-12,146	0.3	-0.1
4a	3,736	35,299	31,904	0.6	0.2
5	2,250	-59	-23,193	-0.002	-0.2

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Appendix A. US Geological Survey Experiments with Capping Peat Soils

It was hypothesized that capping of organic soils with mineral material would reduce diffusion of oxygen into the soil and thus reduce the rate of oxidation of organic carbon. The USGS evaluated the effects of capping surface organic soil on carbon loss. On Twitchell Island, USGS personnel collected 6 cylindrical cores, 2 feet deep and 6 inches wide. At the USGS laboratory in Sacramento, California, 2 feet of dried dredge material form the San Joaquin River was placed on three cores. Constant head devices employed to maintain water levels at two positions in the columns: first near the bottom and then midway in the organic layer. Plastic caps were placed on the columns and the headspaces were flushed continually with laboratory air, except during carbon flux measurements. Carbon fluxes were measured during 0.5-hour sampling periods. Headspace gas samples were collected with syringes at and analyzed the samples with a gas chromatograph.

Table A.1 shows average CO_2 fluxes for the two treatments and two water levels in the soil columns. Fluxes from the capped treatment were significantly lower than those from the uncapped treatment at both water levels ($p<0.001$). At the lowest water level, capping reduced CO_2 fluxes an average of 35%. At the middle water level, capping reduced fluxes by an average of 23%. Raising the water level from the bottom to midway in the organic layer reduced CO_2 fluxes by 83% in the capped and 86% in the uncapped treatments. The USGS did not detect methane fluxes in either treatment.

Table A.1. CO_2 emissions from uncapped and capped columns of surface organic soil from Twitchell Island.
[Values are mean ± standard error]

	CO_2 flux (tons carbon/acre/year)		
Water level	**Uncapped**	**capped**	**capped/uncapped**
Low	1.1 ± 0.18	0.72 ± 0.11	0.65
Middle	0.15 ± 0.013	0.12 ± 0.013	0.77

Attachment 23A.2
HydroFocus, Inc. Compensatory Mitigation Land Use Change Analysis

GHG Emissions and Removals Associated with Proposed Compensatory Mitigation for the Delta Conveyance Project

Prepared by HydroFocus, Inc.
Davis, California
December 9, 2021

For

ICF and Environmental Science Associates

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Introduction and Background

The State Water Project (SWP) relies on Delta channels to convey water. Two-thirds of California's water originates in the Sierra Nevada Mountains as snowpack, eventually flowing through the Delta, where it is delivered to more than 27 million Californians and 750,000 acres of farmland. Due to risk to continued conveyance via Delta channels due to sea level rise, earthquakes, and subsidence, the Department of Water Resources (DWR) is acting now to upgrade Delta infrastructure by planning for the Delta Conveyance Project. As part of this project, compensatory mitigation habitat is proposed for Bouldin Island and two areas near Interstate 5.

Overall Objective and Approach

The overall objective of this report is to quantify the net GHG effect of the proposed compensatory mitigation habitat on Bouldin Island and areas adjacent to Interstate 5 (I-5). These two compensatory mitigation projects may be built to offset potential impacts resulting from the construction and operation of the Delta Conveyance project (Project). The proposed mitigation projects are designed to compensate for habitats that may be impacted by the Project. This includes anticipated impacts to most terrestrial habitats and non-tidal wetlands (ESA, 2020). The areas near I-5 (Ponds 6, 7 and 8) are remnant borrow pits that supplied fill for the construction of I-5 during the late 1970s and heretofore denoted as I-5 Pond 6, and I-5 Ponds 7 and 8.

To estimate the net GHG effect of creating the proposed mitigation habitat, HydroFocus modeled GHG emissions and removals based on available data and the proposed land use changes. Specifically, we gathered and processed data, obtained model inputs and parameters for estimating baseline and projected project GHG emissions and removals for each of the three mitigation areas.

Area Description and Methods

Area descriptions

Bouldin Island

We estimated the net GHG effect of conversion from current land uses (baseline) to wetlands, grasslands, riparian forest, open water, and seasonal wetlands on a 989 acres mitigation area on Bouldin Island (Figures 1 and 2). The area of the three Bouldin sites proposed for mitigation is underlain by mineral and organic and highly organic mineral soils. The land is currently used primarily for agriculture.

Interstate-5 Ponds

The California Department of Water Resources owns the three ponds formally known as borrow pits near West Woodbridge Road and Highway 12: I-5 Pond 6, and I-5 Ponds 7 and 8. The three ponds, totaling approximately 345 acres, were excavated between 1974 and 1978 to provide fill for freeway construction. Currently, all three ponds are managed by the California Department of Fish and Wildlife (CDFW) as wildlife areas. They are located near the White Slough Wildlife Area (WSWA) and Woodbridge Ecological Reserve (ESA, 2020). The borrow pits are fed by groundwater and via periodic overland flow from precipitation, irrigation runoff, and high canal flows, creating three perennial ponds characterized by open water, vegetated banks, and relatively flat adjacent uplands. Mineral soils

underlie all three ponds. Existing habitats include seasonal wetlands and riparian, open water, grasslands, and berms.

Proposed mitigation for the three ponds includes compensatory habitat to offset negative impacts to wetlands and giant garter snake habitat that will occur from the Delta Conveyance Project. Pond 6 lies north of West Woodbridge Road, approximately 1.65 miles west of I-5 (Figures 3 and 4). The north edge of the site includes Hog Slough and its earthen levee, with an on-site water delivery ditch extending from a tide gate in the slough around the north and eastern edges of the property. Ponds 7 and 8 (Figures 5 and 6) lie directly south of West Cotta Road approximately 1 mile west of I-5. The area is underlain by shallow groundwater.

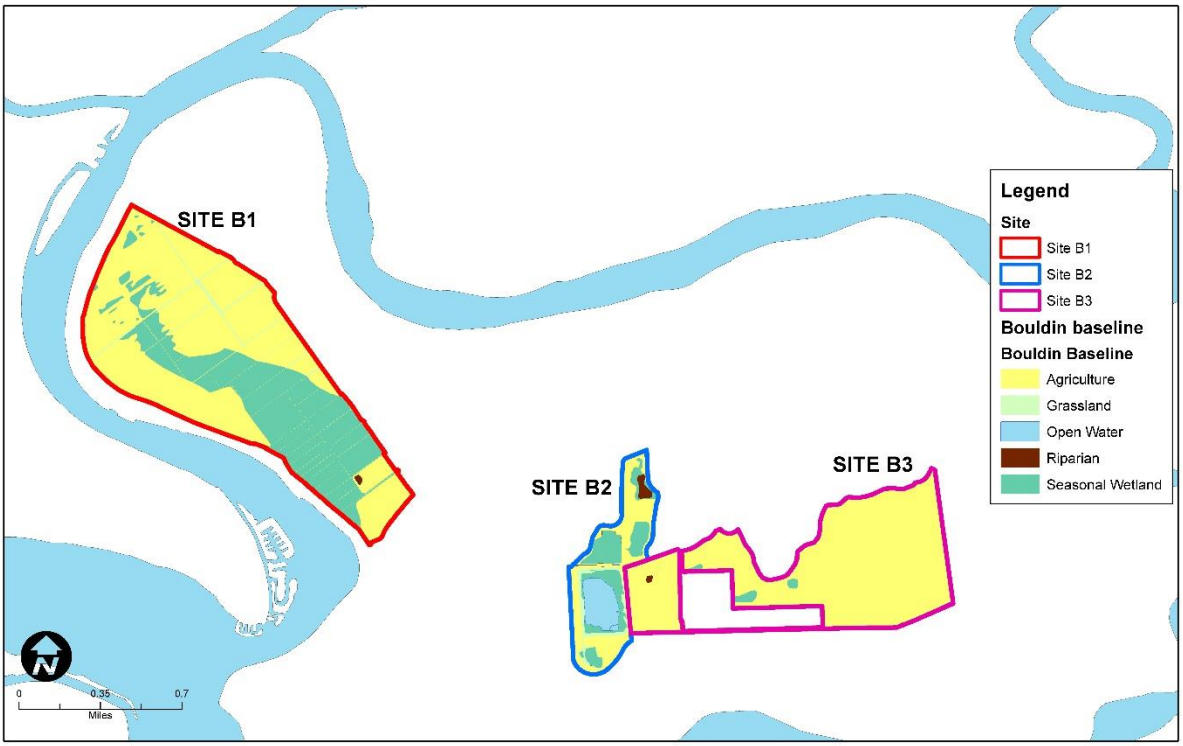


Figure 1. Bouldin Island present-day (baseline) land uses.

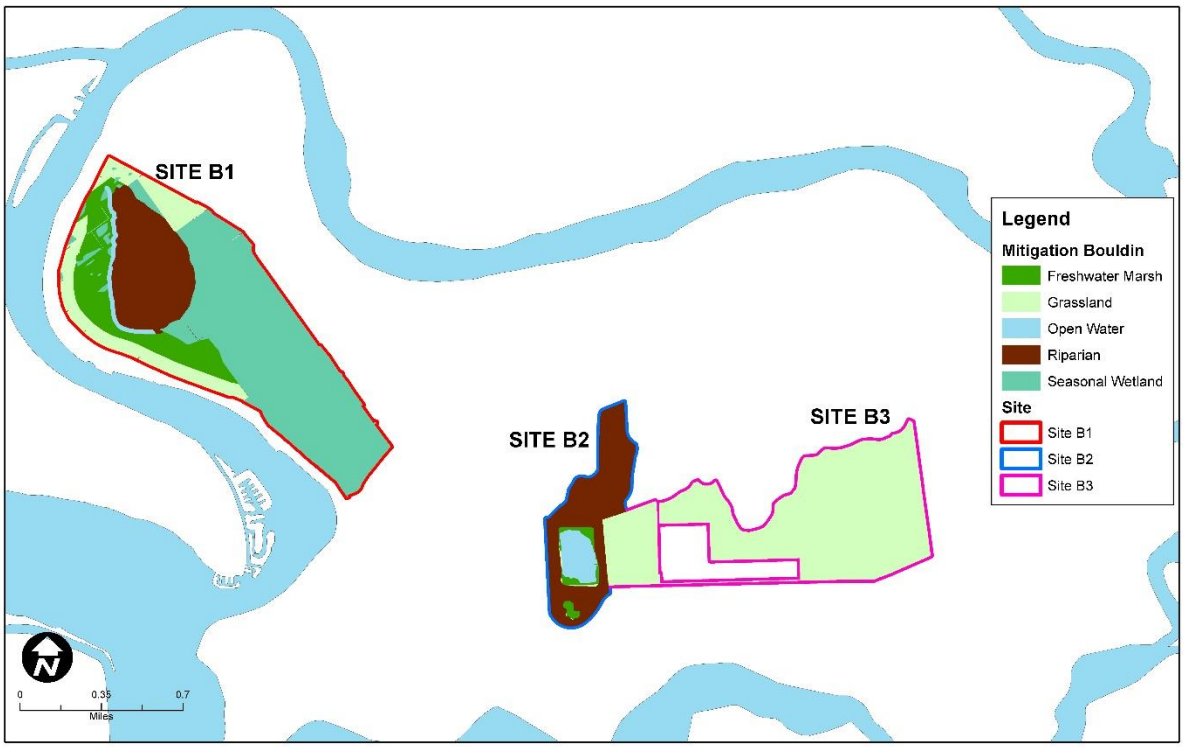


Figure 2. Bouldin Island proposed compensatory mitigation habitat.

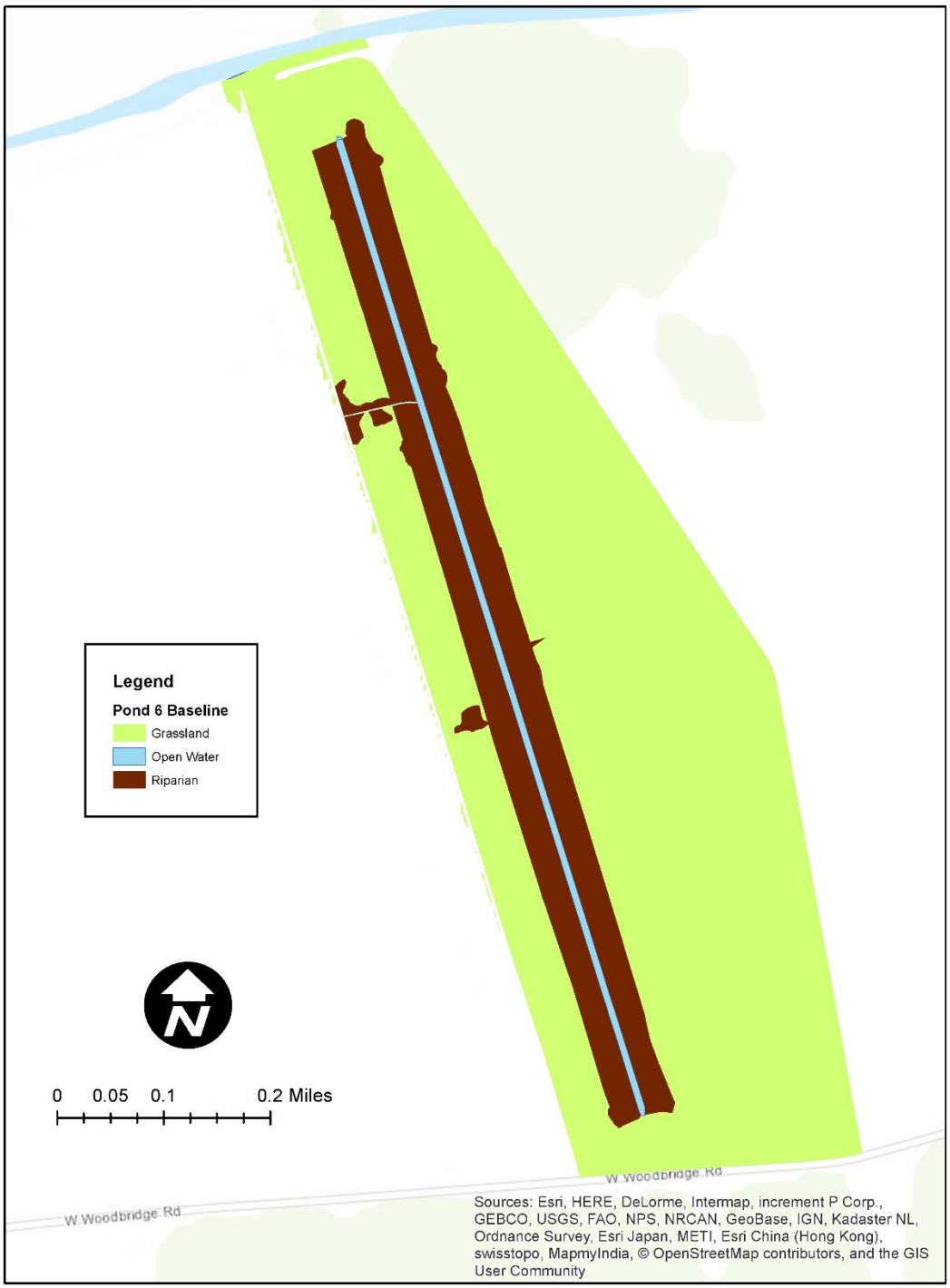


Figure 3. Interstate-5 Pond 6 present-day (baseline) land use.



Figure 4. Interstate-5 Pond 6 proposed mitigation habitats.

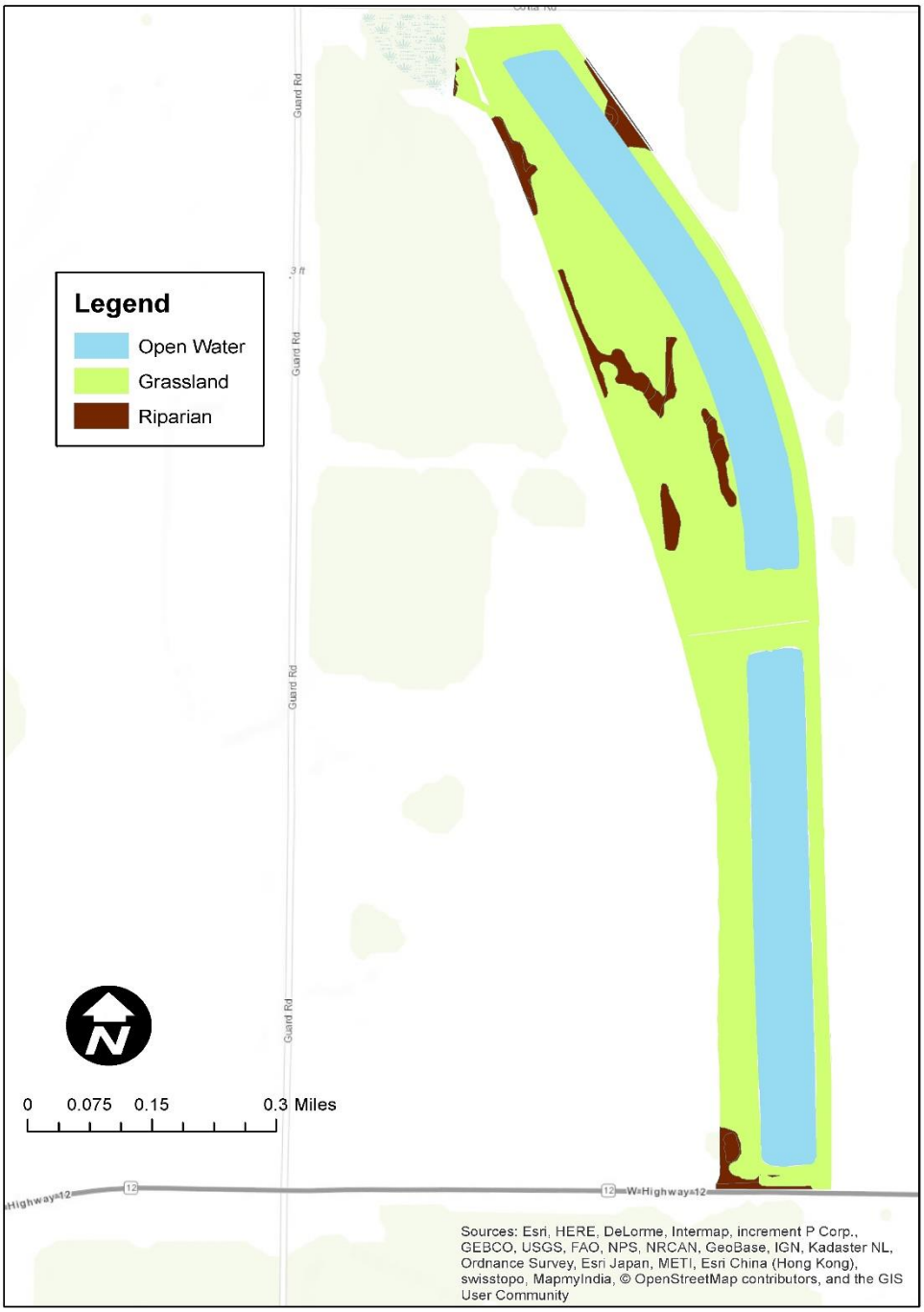


Figure 5. Interstate-5 Ponds 7 and 8 present-day (baseline) land use.



Figure 6. Interstate-5 Ponds 7 and 8 proposed mitigation habitats.

Methods

GIS and database description

To estimate GHG emissions and removals for baseline and project conditions, data were incorporated into the HydroFocus Geographic Information System (GIS). The HydroFocus GIS is an ARCGIS system which includes multiple shape files and data sources for the Sacramento-San Joaquin Delta. Shape files and data sources include delineations of the proposed restoration areas on Bouldin Island and the I-5 ponds, land use maps provided by Environmental Science Associates, GHG emissions and removals for agricultural land uses and fallowed (idle) soils (Li et al. 2014), mapped soil series[1], GHG emissions from organic and highly organic mineral soils and highly organic mineral soils (Deverel et al. 2016) and peat thickness shapefiles as described in Deverel et al. (2015).

Estimates of GHG Emissions and Removals

We estimated GHG emissions and removals for baseline or mitigation project conditions by calculating the net GHG flux as expressed in equation 1.

$$f_{COND} = \Sigma(f_{LU})_{OS} + \Sigma(f_{LU})_{MS} + e_{ag\ op} \quad (1)$$

Where f_{COND} is the net emission (+) or removal (-) rate for present-day conditions (baseline) or resulting from the proposed mitigation project (project condition). The subscripts OS and MS refer to organic and highly organic mineral soils and mineral soils, respectively. The LU subscript refers to land uses which include agriculture, seasonal wetland, freshwater marsh, riparian vegetation, grassland, and open water. The $e_{ag\ op}$ represents the emissions due to agricultural operations. Emission (+) and removal (-) rates are expressed in metric tons of CO_2 equivalents per acre per year (tCO_2-e $acre^{-1}$ yr^{-1}) multiplied by the area in acres. We used a N_2O global warming potential value (GWP) of 265 times the global warming potential of CO_2 of 1 on a 100-year timescale; GWP for methane (CH_4) was 25 (Myhre et al. 2013).

Bouldin Island

Bouldin Island Baseline Conditions

For baseline or reference conditions, we estimated GHG (CO_2, and N_2O) emissions and removals for baseline conditions resultant from the oxidation of organic and highly organic mineral soils and originating from mineral soils, and emissions due to farming activities. Land uses include agriculture (including fallowed/idle areas), seasonal wetlands, riparian vegetation, and grasslands. We estimated the baseline GHG flux as follows.

$$f_{BAS} = f_{OS} + f_{RIP_OS} + f_{AG_MS\ ag} + e_{ag\ op} + f_{SW_MS} + f_{GR_MS} + f_{RIP_MS} \quad (2)$$

Where:
f_{OS} are the emissions from organic and highly organic mineral soils for crops, seasonal wetlands, and grasslands,
f_{RIP_OS} are emissions from riparian vegetation on organic soil,

[1] websoilsurvey.nrcs.usda.gov

f_{AG_MS} are emissions/removals from crops on minerals soils,
$e_{ag\ op}$ are emissions due to farming activities,
f_{SW_MS} are net GHG flux from seasonal wetlands on mineral soils,
f_{GR_MS} are net GHG flux from grasslands on mineral soils,
f_{RIP_MS} are net GHG flux from riparian vegetation on mineral soil.

Calculation details for baseline emissions and removals for each soil and/or land-use type are described below.

Agriculture on organic soils

For baseline GHG emissions from organic and highly organic mineral soils, we utilized a modified version of the SUBCALC model (Deverel et al. 2016) and data for N_2O emissions from Delta organic and highly organic mineral soils as described in Deverel et al. (2017). The SUBCALC model accounts for the crop emissions and removals on organic and highly organic mineral soils in the Sacramento-San Joaquin Delta based on data and analysis described in Deverel et al. (2016), Deverel and Rojstaczer (1996) and Deverel and Leighton (2010). The SUBCALC modeling approach was used because it is peer reviewed and has been shown to accurately estimate CO_2 emissions for organic Delta soils used for agriculture. Recent improvements include model calibration with eddy covariance data and better characterization of Delta soil characteristics with recent data.

Deverel and Leighton (2010) originally used SUBCALC to integrate available data and quantify and simulate subsidence rates and causes. The SUBCALC model simulates aerobic microbial oxidation of organic carbon, consolidation, wind erosion and burning. Present-day subsidence is primarily the result of oxidation and consolidation. The SUBCALC model simulates microbial oxidation of soil organic carbon to carbon dioxide using Michaelis–Menton enzyme kinetics in which the rate of soil organic-matter oxidation is limited by soil organic carbon content (Deverel and Leighton, 2010; Deverel et al. 2016). Deverel et al. (2016) calibrated SUBCALC with subsidence and carbon flux data for the Delta and the model was used to estimate CO_2 fluxes for organic soil and highly organic mineral soils throughout the Delta.

For N_2O emissions resultant from the oxidation of organic soils and highly organic mineral soils, the approach described in Deverel et al. (2017) was used. Specifically, the relation of N_2O emissions to CO_2 emissions determined on Sherman and Twitchell islands (Teh et al. 2011; Morris 2014; Morris et al. 2017; Yang et al. 2016) was used to estimate the N_2O emissions due to the oxidation of Delta organic and highly organic mineral soils. We assumed that N_2O emissions due to nitrogen fertilizer application were insignificant relative to N_2O emissions resultant from the oxidation of organic and highly organic mineral soils based on a study described in Deverel et al. (2017), where they were less than 6% of the total N_2O emissions. The uncertainty in the SUBCALC calculations is due primarily to the uncertainty in the spatial variability in soil organic matter content and depth to groundwater. We thus estimated mean, high, and low values for emissions due to oxidation of soil organic matter based on the variability in soil organic matter content.

Seasonal wetlands on organic soils

Based on data presented for the Sherman Island seasonal wetland described in Hemes et al. (2019), and data for Twitchell Island in Deverel et al. (1998), we assumed that seasonal wetlands on organic soils and highly organic mineral soils will emit CO_2 and N_2O similarly to agriculture. This is due to drainage of these wetlands during spring, summer and fall which facilitates oxidation of the soil organic matter. Areas designated as seasonal wetlands within the proposed mitigation area on Bouldin Island are too

wet to farm due to poor drainage conditions (Deverel et al. 2015). Inability to adequately drain these areas for farming results in these areas behaving like seasonal wetlands.

Grasslands on organic soils

For grasslands on organic soils, we relied on data presented in (Teh et al.,2011) to conclude that there are net GHG emissions. We therefore used the SUBCALC model to estimate the emissions from existing grasslands on Bouldin Island on organic and highly organic mineral soils.

Riparian Vegetation on organic and mineral soils

To estimate carbon stored in soil and biomass for riparian vegetation, we used the tool described by Matzek et al. (2018). Matzek et al. (2018) defined different riparian vegetation groups. We assumed that willow scrub riparian forest adequately represents the current baseline riparian vegetation. We used the flux calculated from the annual change in carbon stocks of a 50-year-old willow scrub riparian forest as the baseline annual carbon flux. For organic soils, we added to the carbon losses from soils modeled by SUBCALC the carbon sequestered by the riparian vegetation in the ecosystem carbon pools (vegetation, dead vegetation mass, and forest floor). For mineral soils, we used the carbon sequestrated by all carbon pools (vegetation biomass, dead mass, forest floor and soil).

Agriculture on mineral soils

To estimate baseline GHG emissions and removals due to agricultural crop production on mineral soils, we used the results of California statewide modeling and field experiments for over 40 crops described in Li et al. (2014). Li et al. (2014) is the only comprehensive compendium of GHG emissions and removals for crops in California[2]. As shown in Table 1, we aggregated crops into 7 groups and estimated GHG emissions and removals on a per acre basis based on data presented in Li et al. (2014) and Shaffer and Thompson (2015). The estimated GHG emissions and removals for these crop groups in tCO_2-e $acre^{-1}$ yr^{-1} in Table 1 were multiplied times the acreage in the GIS files.

Grasslands on mineral soils

We assumed that grasslands would have an emission factor similar to pasture (Table 1). The uncertainty shown in Table 2 was used to estimate maximum and minimum values for each site for mineral soils.

Seasonal wetland on mineral soils

Based on extensive experience on Bouldin Island, we recognized that the areas delineated as seasonal wetlands are abandoned agriculture fields that are too wet to farm. Thus, for these areas, we used the emission rate for idle land in Table 1.

GHG emissions from farming activities

To estimate GHG emissions from farming activities, we used the estimated GHG emissions from Shaffer and Thompson (2015) (Table 1) for the crop types used in Bouldin, multiplied times the acreage of agricultural land (mineral and organic) in the GIS files. The GHG emission from farming activities was summed to the baseline emissions of the different land uses (as in Equation 2).

[2] The California Air Resources Board published GHG emissions and removals for agricultural crops but not for individual crops.

Table 1. Greenhouse gas emissions (+) and removals (-) For crop groups on mineral soils (from Li et al. 2014).

Crop group	tCO_2-e $acre^{-1}$ yr^{-1} (Li et al. 2014)	Farming Activities tCO_2-e $acre^{-1}$ yr^{-1} (Shaffer and Thompson, 2015)	Total tCO_2-e $acre^{-1}$ yr^{-1} (sum of columns 2 and 3)	Standard Deviation tCO_2-e $acre^{-1}$ yr^{-1}
1. Trees and vines	-0.7	1.4	0.7	0.5
2. Pasture	0.2	-	0.2	4.1
3. Rice	4.8	2.1	6.9	3.9
4. Field crops (corn, safflower, sorghum, sunflower)	-2.4	1.5	-0.9	0.2
5. Miscellaneous Field Crops (small grains, dry beans, alfalfa, hay)	-4.2	1.7	-2.5	0.3
6. Vegetable Crops	1.9	2.7	4.6	0.6
7. Idle land	0.1	-	0.1	0.2

Bouldin Island Project Conditions

For project conditions, the proposed compensatory mitigation on Bouldin Island includes permanently flooded wetlands, seasonal wetlands, grasslands, open water, and riparian habitat (Figure 2). Thus, the net GHG flux for project conditions ($f_{PR}J$) for the compensatory mitigation on Bouldin Island was estimated using equation 3 for each of the sites.

$$f_{PR}J = f_{WET} + f_{OW} + f_{SW_OS} + f_{RIP_OS} + f_{GR_OS} + f_{GR_MS} + f_{RIP_MS} \quad (3)$$

Where the GHG fluxes for the different land uses are permanently flooded wetlands (f_{WET}), seasonal wetlands (f_{SW}), grasslands (f_{GR}), open water (f_{OW}), and riparian habitat (f_{RIP}).

We estimated net fluxes for each land use/cover separately for mineral and organic soils (subscripts OS, and MS, respectively). The GHG emissions and removals expressed as fluxes in metric tons of CO_2 per acre per year were multiplied times the area in acres of each land cover type. We calculated project GHG emissions and removals (terms in equation 3) for each land use as follows.

- For permanently flooded wetlands, we used the mean annual GHG flux rate of multiple permanently flooded wetlands of different ages restored on Twitchell and Sherman Islands presented in Hemes et al. (2019).
- For seasonal wetlands and grasslands on organic soils, we used the SUBCALC model to simulate emissions. The rationale for this is described above for baseline conditions.

- For riparian vegetation on organic and highly organic mineral soils we added to the losses of CO_2 due to the oxidation of the organic matter modeled by SUBCALC the CO_2 sequestration due to the riparian vegetation described in Maztek et al. (2018) for mixed riparian forest in northern California. For mineral soils, we used all ecosystem carbon pools, including carbon stored in soils.
- For open water, we used GHG fluxes measured on open water in the Delta included in McNicol et al. (2017).
- For grasslands on mineral soils, we used the value for pasture in Table 1, as described for the baseline conditions.

Interstate-5 Ponds 6, 7 and 8

Due to the complexity of multiple baseline land uses, the absence of organic soils, and the current apparent degraded status of the habitats, we used a different approach to estimating the change in emissions for the I-5 ponds. We assessed the effect of the mitigation project on GHG emissions and sequestration by estimating and reporting each baseline for the proposed mitigation project conversion separately, which is consistent with IPCC (2006) guidelines. The basis for our approach is that the flux of carbon to or from the atmosphere due to a land use conversion is assumed to be equal to the change in carbon stocks between the current and new land use (at maturity).

This approach can be generalized and applied to all carbon pools (i.e., aboveground biomass, belowground biomass, dead wood, litter, and soils). Thus, the effect of land use changes on GHG emissions (-) and removals (+) can be expressed as the change in ecosystem carbon stocks (ΔC) before and after conversion from the baseline land use (LU1) to a new land use (LU2) and the annual GHG fluxes for the newly established land use. Ecosystem carbon stocks eventually reach steady state. We assumed this transition to a new equilibrium will occur linearly during a transition period T of 45 years. Thus, the change in ecosystem carbon stocks due to the conversion ($\Delta C_{conversion}$) can be expressed as:

$$\Delta C_{conversion} = \Delta C_{Biom} + \Delta C_{Soils.} = [(C_{Biom\ LU2} - C_{Biom_{LU1)}}) + (C_{Soil\ LU2} - C_{Soil_{LU1}})] \text{ x area} \quad (4)$$

The annual effect can be expressed as

$$\Delta C_{yr} = \Delta C\text{conversion} / T.$$

Where:
ΔC_{Biom} = the change in carbon stock in the biomass,
ΔC_{Soils} = the change in carbon stock in the soil,
$C_{Biom\ LU2}$ = carbon stock in the biomass for land use 2 (project),
$C_{BiomLU1}$ = carbon stock in the biomass for land use 1 (baseline),
$C_{Soil\ LU2}$ = carbon stock in the soil for land use 2 (project),
$C_{Soil\ LU1}$ = carbon stock in the soil for land use 1 (baseline),
T = transition period, set to 45 years (construction year 1 through to 2070).

Specific assumptions and methods for the land uses follow.

Grasslands

We assumed the restored grasslands would be improved relative to current conditions. Satellite images viewed by HydroFocus staff showed low vegetative cover. Therefore, we assumed that the current

condition is degraded relative to the proposed land use change. The proposed land use will increase biodiversity and productivity and accumulate carbon in the soil over the long term. When existing grasslands are replaced by a different land use, the changes in biomass carbon stocks following land use conversion were accounted for in the year of the conversion. For example, if open water replaced grasslands, the vegetation would be lost in the first year.

Grassland soil organic carbon (SOC) was calculated as:

$$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_I \quad (5)$$

Where:
The land use factor (F_{LU}) reflects presence of permanent grassland.
The management factor (F_{MG}) represents the status of the grassland (degraded or improved)
The input factor (F_I) is applied only to improved grasslands to account for possible additional management inputs.

Values for the terms in equation 5 were extracted from IPCC (2006). We used F_I =1.0 for improved grasslands. We used F_{LU} = 1.0, assuming all current and proposed grasslands are permanent. For restored grasslands, we used a management factor (F_{MG}) of 1.0 which is characteristic of non-degraded and sustainably managed grassland. For baseline grasslands, we used F_{MG} = 0.7 which represents conditions in which there is a long-term loss of productivity and vegetation cover as indicated by the imagery discussed previously. We assumed that when converting to grasslands from another land use such as ponds, 80% of the SOC_{REF} is reached during the first 20 years, and the total SOC_{REF} during the following 25 years (IPCC, 2006).

Ponds

For open water, we used the IPCC (2006) guidelines for flooded land (Chapter 7, and Appendix 3). We assumed a conversion to open water would not affect soil carbon of the previous land use because the anoxic conditions resultant from flooding will minimize oxidation of the organic carbon. However, anerobic conditions would result in CH_4 emissions. For warm temperate dry areas, the IPCC suggests a median CH_4 emissions value of 0.044 kg C ha^{-1} day^{-1} which corresponds to about 0.16 tCO_2-e $acre^{-1}$ yr^{-1} (IPCC, 2006). For the baseline ponded condition, we estimated soil carbon content as the average of the values of all current land uses based on the Soil Survey data. Also, biomass accumulations after flooding were set to zero. Due to the lack of water exchange with other water bodies, the aqueous flux of C was assumed to be insignificant.

Riparian vegetation

To estimate carbon stored in soil and biomass for riparian vegetation, we used the tool for riparian vegetation described by Matzek et al. (2018). Matzek et al. (2018) defined different riparian vegetation groups. We assumed that willow scrub adequately represents the current baseline riparian vegetation. We assumed that the proposed mitigation would improve the existing riparian vegetation to a more productive and diverse mixed riparian forest. Matzek et al. (2018) provided tables with annual carbon accumulation values for the different ecosystem pools for the first 100 years for each riparian vegetation type. We included the following carbon pools: trees, dead vegetation, forest floor, understory vegetation, and soil.

Freshwater wetland

We used reference values suggested by the IPCC wetland supplement for soil carbon and CH_4 emission of inland wetlands on mineral soils. For temperate climates, IPCC suggests CH_4 emissions of 235 kg CH_4 ha^{-1} yr^{-1} (2.4 tCO2-e $acre^{-1}$ yr^{-1}) and the value of 30 t C $acre^{-1}$ for the carbon in the soil pool. We assumed that the biomass produced in permanently flooded wetlands on mineral soil would not be significantly different from the biomass of permanently flooded wetlands on organic soils exemplified by the restored wetlands in the San Joaquin-Sacramento Delta. We therefore used 4.6 t C $acre^{-1}$ from Miller and Fujii (2010).

Table 2. Soil carbon stock and annual carbon stock reference values and methane fluxes for land uses in baseline and project conditions for the I-5 Ponds

Land use	Soil carbon stock (t C $acre^{-1}$)	Biomass carbon stock change (t CO_2-e $acre^{-1}$ yr^{-1})	Methane flux (t CO_2-e $acre^{-1}$ yr^{-1})	Reference
Grassland baseline	10.8	1.2	N/A	IPCC table 3.4.2 grassland chapter 6
Grassland project	15.4	1.2	N/A	IPCC table 3.4.2 grassland chapter 6
Lake/pond	11.5	0	0.2	IPCC flooded land. Appendix 3 of the 2006 IPCC guidelines
Wetland Freshwater	29.9	4.6	2.4	Miller and Fujii (2010), IPCC 2013 Wetland supplement, IWMS Chapter 5.
Riparian baseline (degraded)	1.0	29.4	N/A	Matzek et al. (2018)
Riparian project	4.7	30.6	N/A	Matzek et al. (2018)

Determination of GHG effects of f land use change Interstate-5 Ponds 6, 7 and 8

Because some portions of the mitigation area maintain the same land use, the proposed areas subject to land use change by the mitigation project are smaller than the total mitigation area. Therefore, in the portion of the mitigation area remaining "as is", the GHG emissions or removals are unaffected by the proposed project. These areas are excluded from the analysis of the effect of the mitigation project on GHG fluxes.

To estimate the effect of the mitigation project on the GHG fluxes we:

1. Determined acreage for each proposed land use conversion,
2. Determined soil and biomass carbon stock of the baseline and proposed mitigation land-uses (before and at the end of the transition period, T, respectively) for each land use conversion,
3. Determined the total carbon stock changes (soil + biomass) as the differences between carbon stocks of the baseline and proposed land use at the end of the transition period,
4. Determined the annual value of the total carbon stock changes (soil + biomass),
5. Added where appropriate the annual CO_2 and CH_4 fluxes to the annual carbon stock change and obtained the annual GHG flux per unit area in tCO_2-e $acre^{-1}yr^{-1}$,

6. Scaled the annual GHG flux value to the actual area of each conversion and calculated the total annual GHG flux for each project area and (tCO_2-e yr^{-1}),
7. Summed net changes in emissions (+) and removals (-) from construction year 1 to 2040 and 2070.

Results

Bouldin Island

Baseline

For the organic and highly organic mineral soils, baseline land uses consisted primarily of corn and safflower. Non-agricultural land uses included seasonal wetlands, fallow land, riparian vegetation, forested wetlands, and grassland. Table 3 shows the number of acres of the proposed mitigation land uses, the range of associated annual average baseline emissions per acre and the average annual total estimated range of total emissions (i.e., ranges per acre time the number of acres). Table 4 shows the baseline removal rates per acre and total baseline removals on mineral soils. Using medium emission and removal rates (Tables 3 and 4 columns titled "Medium"), we estimated the total present-day annual baseline emissions for the three proposed compensatory mitigation sites on Bouldin Island and the total mitigation area as equal to the sum of total baseline emissions on organic and highly organic mineral soils and removals on mineral soils or 8837 minus 379 which is equal 8,458 t CO_2 yr^{-1}.

Using the first year of construction as the start date, the estimated cumulative baseline emissions to 2040 are 129,173 tCO_2-e and cumulative baseline emissions for 2070 are 380,987 tCO_2-e.

Table 3. Average annual per acre and average annual total baseline emissions for organic soils and highly organic mineral soils of Bouldin areas associated with the proposed mitigation land uses (including emissions from farming activities).

Proposed mitigation		CO_2+ N_2O per acre (avg. annual.)			CO_2+N_2O total (avg. annual)		
	Acres	Low tCO_2-e	Medium tCO_2-e	High tCO_2-e	Low tCO_2-e	Medium tCO_2-e	High tCO_2-e
SITE B1							
Freshwater Marsh	19	33	36.7	40.1	627	697	762
Grassland	7	13.4	22.1	29.5	94	155	207
Lake/Pond	4	3.4	6.6	10.6	14	26	42
Riparian	75	9.0	13.6	18.4	675	1020	1380
Seasonal Wetland	126	11.5	16.3	21.2	1449	2054	2671
Total subject to LU change	231	12.4	17.1	21.9	2864	3950	5059
SITE B2*							
Freshwater Marsh	8	33.3	36.7	40.1	266	294	321
Riparian	75	14.1	19.9	25.6	1058	1493	1920
Total subject to LU change	83	16.0	21.5	27.0	1328	1785	2241
SITEB3							

Grassland	313	6.4	9.9	12.7	2003	3099	3975
Total subject to LU change	313	6.4	9.9	12.7	2003	3099	3975
BOULDIN totals							
Freshwater Marsh	27	33.1	36.7	40.1	893	991	1083
Grassland	319	6.6	10.2	13.1	2097	3253	4182
Lake/Pond	4	3.4	6.6	10.6	14	26	42
Riparian	150	11.6	16.8	22	1733	2513	3300
Seasonal Wetland	126	11.5	16.3	21.2	1449	2054	2671
TOTAL MITIGATIO AREA subject to LU change	627	9.9	14.1	18	**6186**	**8837**	**11278**

***** The baseline land use for open water habitat in Site B2 is a flooded borrow pit. The baseline emissions would be equal to the project emissions for this feature resulting in no net change in emissions. Therefore, the feature was omitted from the analysis.

Table 4. Annual per acre and total baseline removals for mineral soils associated with the proposed mitigation land uses on Bouldin Island (including emissions from farming activity).

Proposed mitigation		**CO_2+ N_2O per acre**			**CO_2+N_2O total**		
	Acres	**Low tCO_2-e**	**Medium tCO_2-e**	**High tCO_2-e**	**Low tCO_2-e**	**Medium tCO_2-e**	**High tCO_2-e**
SITE B1							
Freshwater Marsh	53	-1.9	-2.4	-2.9	-101	-127	-154
Grassland	62	-2.0	-2.5	-3.0	-124	-155	-186
Lake/Pond	6	-1.4	-1.8	-2.1	-8	-11	-13
Riparian	28	-1.7	-2.2	-2.6	-48	-62	-73
Seasonal Wetland	4	-1.7	-2.2	-2.6	-7	-9	-10
Total subject to LU change	153	-1.9	-2.4	-2.8	-290	-364	-436
SITEB2							
Riparian	17	-0.7	-0.9	-1.1	-12	-15	-19
Total subject to LU change	17	-0.7	-0.9	-1.1	-12	-15	-19
SITEB3	0	0	0	0	0	0	0
Total BOULDIN							
Freshwater Marsh	53	-1.9	-2.4	-2.9	-101	-127	-154
Grassland	62	-2.0	-2.5	-3.0	-124	-155	-186

Lake/Pond	6	-1.4	-1.8	-2.1	-8	-11	-13
Riparian	45	-1.4	-1.7	-2.1	-60	-77	-92
Seasonal Wetland	4	-1.9	-2.4	-2.9	-7	-9	-10
TOTAL Bouldin mitigation area subject to LU change	**170**	**-1.8**	**-2.2**	**-2.7**	**-300**	**-379**	**-455**

Proposed Mitigation

The proposed mitigation habitats, freshwater marsh, grassland, ponds, riparian, and seasonal wetlands, freshwater marsh, and riparian habitat, can contribute to offsetting the baseline emissions described above. Tables 5 and 6 show the estimated medium annual emissions (+) and removals (-) for the three proposed mitigation habitats sites. Using medium emission and removal rates (tables 5 and 6), we estimated the total annual project emissions for the proposed compensatory mitigation on Bouldin Island as equal the sum of total emissions on organic and highly organic mineral soils and removals on mineral soils (Table 5) (i.e., 7139 tCO_2-e from Table 5 minus 72 tCO_2-e from Table 6).

Table 5. Annual average project emissions for organic soils and highly organic mineral soils associated with the proposed mitigation land uses on Bouldin Island[3].

	Site B1		**Site B2**		**Site B3**		**Total Mitigation**	
Proposed mitigation	**Acres**	**Medium tCO_2-e**	**Acres**	**Medium tCO_2-e**	**Acres**	**Medium tCO_2-e**	**Acres**	**Medium tCO_2-e**
Freshwater Marsh	19	12	8	5	0	0	27	17
Grassland	7	144	<0.1	<0.1	313	2637	320	2781
Pond	4	16	0	0	0	0	4	16
Riparian	75	689	75	1168	0	0	150	1857
Seasonal Wetland	126	1863	0	0	0	0	126	1863
Total	**231**	**2724**	**83**	**1173**	**313**	**2637**	**627**	**6534**

[3] Even though riparian vegetation removes CO_2, the removal is counterbalanced by emissions from the oxidation of organic soils which results in a net annual emission.

Table 6. Annual project emissions and removals for mineral soils associated with the proposed mitigation land uses on Bouldin Island.

	Site B1		Site B2		Site B3		Total Mitigation	
Proposed mitigation	**Acres**	**Medium tCO_2-e**	**Acres**	**Medium tCO_2-e**	**Acres**	**Medium tCO_2-e**	**Acres**	**Medium tCO_2-e**
Freshwater Marsh	53	32	0	0	0	0	53	32
Grassland	62	12	0	0	0	0	62	12
Pond	6	24	0	0	0	0	6	25
Riparian	28	-81	17	-49	0	0	45	-129
Seasonal Wetland	4	-9	0	0	0	0	4	-12
Total	**153**	**-22**	**17**	**-49**	**0**	**0**	**170**	**-72**

Net GHG effect

We estimated the effects of the proposed compensatory mitigation habitat on GHG emissions and removals as the difference between baseline and project GHG emissions and removals to 2040 and 2070. Specifically, the overall average annual net effect (using medium values for emissions and removal rates) was estimated as -1,996 tCO_2-e yr^{-1}, the difference between baseline emissions (8,458 tCO_2-e yr^{-1}) and project emissions (6,462 tCO_2-e yr^{-1} from tables 3,4,5 and 6).

Using the first year of construction as the start date **we estimated the net emissions-reduction benefit of the proposed mitigation habitat at -29,566 tCO_2-e in 2040 and -90,193 tCO_2-e in 2070.** Most of the estimated benefit is due to the proposed construction of freshwater marsh which will stop emissions from oxidation of the organic and highly organic mineral soils. We estimated the uncertainty for the net effect at approximately plus or minus 50% primarily due to the spatial variability in soil characteristics that affect baseline emissions.

Climate Change Uncertainty

Additional uncertainty arises from expected increases in average global temperatures and concentration of atmospheric CO_2. In general, rising CO_2 concentrations are expected to increase plant productivity in the coming decades, but rising temperatures may also reduce yields. The projected impact varies by plant type and region. Lobell and Gourdji (2012) projected that global grain yields could increase 1.0-2.7% from higher CO_2, but also be reduced 4.0-0.3% from rising temperatures. Grasslands and pastures are expected to greatly increase primary productivity and, thus, more carbon sequestration. Cullen et al. (2009) reported a potential increase of 22-5-37.5% in pastures in Mediterranean climates resulting from both greater CO_2 and higher temperatures. Coomes et al. (2014) affirmed that trees would generally benefit from higher temperatures and possibly accumulate more woody biomass over time. Wetlands are also expected to increase overall methane emissions in response to warming (Gedney et al. 2019; Shindell et al. 2004; Gedney et al. 2004; Eliseev et al. 2008; Volodin 2008). For this analysis, we assumed that emissions under project conditions would stay constant for each year, as there is currently too much uncertainty around the specific impact of climate change on many of these systems in the Delta.

Interstate-5 Ponds

Pond 6

Of the 182 acres of proposed compensatory mitigation habitat, 171 acres will be subject to land use change with the mitigation project for Pond 6 will result in the following land use changes.

- Freshwater wetlands will increase by 36 acres.
- Grasslands will decrease by 15 acres.
- Open water will increase by 10 acres.
- Riparian habitat will decrease by 31 acres.

Specifically,

- 109 acres of current degraded grassland will be improved. Of the 15 acre decrease in grasslands
    - 8 acres will be converted to open water; and
    - 13 acres will be converted to freshwater wetlands.
- 5 acres of riparian habitat will be improved. Of the 31-acre decrease in riparian habitat
    - 26 acres will be converted to freshwater wetlands,
    - 4 acre will be converted to open water.

Using methods described above, we estimated net changes range from -0.2 to 2.6 t CO_2-e $acre^{-1}$ $year^{-1}$ where negative values are removals and positive values are emissions. The estimated overall annual net increase in emissions is 37.3 t CO_2-e during the first 20 years and 5.7 during the second 20 years. Using the first year of construction as the start date**, we estimated a net effect of increased cumulative emissions of 559 t CO_2-e to 2040 and 888 t CO_2-e in 2070.**

The primary uncertainty in our estimates is related to the annual net effect due to conversion of riparian areas to wetland. Specifically, estimates for riparian carbon sequestration contain a large degree of uncertainty (Maztek et al. 2020). For example, Maztek et al. (2020) related that high-end estimates of total C sequestration were more than double the low-end estimate and the range in the 95% confidence interval for a 20-year estimate covered nearly an order of magnitude.

Table 7. Estimated net annual changes (baseline – project) for Pond 6.

Land use change	Annual net effect per acre t CO_2-e $acre^{-1}$ $year^{-1}$	Annual net effect t CO_2-e $acre^{-1}$ $year^{-1}$	Overall Net effect
Existing grassland to wetland	0.5	6.7	emissions
Existing grassland to pond	0.4	3.2	emissions
Existing riparian to wetland	2.0	52.2	emissions
Existing riparian to grassland	1.2	4.4	emissions
Existing riparian to pond	2.6	4.4	emissions
Improved riparian	-0.4	-2.14	removal
Improved grassland	-0.3/-0.6	-31.6/-63.2 in the second 20-year period	removal
Total		37.3/5.7[4]	emissions

Ponds 7 and 8

Of the 162 acres of proposed compensatory mitigation habitat for Ponds 7 and 8, 134 acres will be subject to a change in land use. The mitigation will result in changes in land use as follows.

- Freshwater wetlands will increase by 59 acres.
- Grasslands will decrease by 22 acres, and the 60 acres of grasslands left will be enhanced.
- Open water will decrease to 30 acres.
- Riparian habitat will decrease by 6 acres to 2 acres.

Specifically,

- Of the 90-acre of existing grasslands
  - 60 acres will be enhanced,
  - 26 acres will be converted to wetlands,
  - 4 acres will be converted into a pond and,
  - 0.4 acres will be converted to riparian vegetation.
- Of the 8-acre of existing riparian habitat
  - 4 acres will be converted to enhanced grasslands,
  - 2 acre will be converted to enhanced riparian habitat,
  - 2 acres will be converted to wetlands and,
  - 0.6 acres acre will be converted to ponded area.
- Of the 60-acre of existing ponded area
  - 31 acres will be converted to wetlands and,
  - 3 acres will be converted to enhanced grasslands.

Table 8 shows the baseline land uses, grassland and riparian, and the associated soil and biomass carbon stock changes based on methods and references described previously.

[4] The 5.7 t CO_2-e/ year for the second 20 years results from increased soil sequestration by the grassland.

Overall, we estimated that there will be avoided annual emissions of -50.1 t CO_2-e/ year for the proposed mitigation for the first 20 years and -68.9 t CO_2-e/ year for the second 20 years. Using the first year of construction as the start date, **we estimate a cumulative net emission reduction of -751 t CO_2-e in 2040 and -2,724 t CO_2-e in 2070.** For Ponds 7 and 8, the largest source of uncertainty is due to grassland carbon removals. The literature indicates that this uncertainty is less than 20% (e.g., Bartholomée et al., 2018; Soussana et al., 2004)

Table 8. Estimated net annual changes (baseline – project) for Pond 7 and 8.

Project land use change	Annual net effect per acre t CO_2-e $acre^{-1}$ $year^{-1}$	Annual net effect t CO_2-e $year^{-1}$	Net effect
Existing grassland to wetland	0.5	12.84	emissions
Existing grassland to pond	0.4	1.60	emissions
Existing riparian to wetland	2.0	3.95	emissions
Existing riparian to grassland	1.2	4.43	emissions
Existing riparian to Pond	2.6	1.51	emissions
Existing riparian to wetland	2.0	3.95	emissions
Riparian improved	-0.4	-0.74	removals
Grassland improved 1-20 years	-0.3	-16.87	removals
Grassland improved 20-40 years	-0.6	-33.74	removals
Existing pond to wetland	-1.8	-57.37	removals
Grassland improved 1-20 years	-1.0	-3.38	removals
Grassland improved 20-40 years	-1.5	-5.33	removals
Total		-50.1/-68.9[5]	removals

[5] For the first and second 20 years respectively

Summary and Conclusions

We estimated the net GHG effect of the proposed compensatory mitigation on Bouldin Island and Interstate-5 ponds 6, 7 and 8 using available data and documented methods. For Bouldin Island, it is proposed that agriculture (baseline conditions) will be replaced by wetlands, riparian habitat, ponds, and grassland. For the Interstate-5 ponds, it is proposed that grasslands, riparian habitat, and ponds will be replaced by improved grassland, wetland, riparian, and open-water habitat.

We concluded the following.

The proposed mitigation project would reduce annual emissions from the mitigation area on Bouldin Island and the Interstate 5 ponds by an estimated 1,218 – 1,379 tons of CO_2 equivalents. This would result in a cumulative emission reduction of 29,566 tons of CO_2 equivalents by 2040 and 90,193 tons of CO_2 equivalents by 2070.

Bouldin Island

- The proposed land use changes on 796 acres would result in a net estimated reduction in annual emissions of about 1,996 tons of CO_2 equivalents.
- Between the first year of construction and 2040, the estimated cumulative effect is an emissions reduction of 29,566 tons of CO_2 equivalents.
- Between the first year of construction and 2070, the estimated cumulative effect is an emissions reduction of 90,193 tons of CO_2 equivalents.

Interstate Ponds

- The estimated effect of the Ponds 6, 7 and 8 is a net emissions reduction of 192 tons of CO_2 equivalents from the first year of construction to 2040 and 1,836 tons of CO_2 equivalents for the first year of construction to 2070.

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