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Memorandum

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subject *Ballona Wetlands Restoration Project*
Accounting Analysis of Greenhouse Gas Sequestration and Emissions from Wetlands

This memo applies an accounting framework for greenhouse gas (GHG) sequestration and emissions from wetlands for Alternative 1 of the Ballona Wetlands Restoration Project. We are providing this assessment for use in the Project EIR/EIS. The analysis quantifies future changes in GHG fluxes under sea level rise conditions for carbon dioxide (CO_2) and methane (CH_4). The changes in GHG fluxes are driven by changes in area of wetland habitat types, based off a previous habitat evolution analysis (ESA PWA 2012). This assessment is based on the 2013 Wetlands Supplement (IPCC 2013a) (which updates the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006)) and the Ventura County Climate Change Vulnerability Assessment (ESA PWA 2014). Note that emissions due to the restoration construction will be considered elsewhere in the EIR/EIS and are not included in this document.

Method

The three major GHGs from land cover are methane, carbon dioxide, and nitrous oxide (N_2O). Since N_2O emissions from wetlands are largely driven by agriculture, which is not a part of the Ballona Wetlands Restoration, it is not included in this analysis. CO_2 removals in coastal wetlands occur as biomass, dead organic matter, and soil carbon (IPCC 2013a). Dead organic matter is negligible for this analysis, since it is primarily important in woody wetlands (e.g. forested wetlands), where dead organic matter composes a large fraction of the aboveground carbon stock. Methane emissions occur in marshes when anaerobic conditions allow microbes to decompose organic matter and produce CH_4, such as in brackish marshes, but are limited in saline conditions. Since the project plans to restore brackish marsh, methane emissions are included in this analysis.

To analyze GHGs at Ballona under Alternative 1, each land cover type was assigned an aboveground biomass density, soil carbon sequestration factor, and methane emission rate (Table 1). The biomass and soil sequestration are GHG removals, while the methane is as an emission. When combined, the result is the net GHG flux. Each contributing factor is discussed below.

Aboveground Biomass
When vegetation is established, carbon is removed from the system to create biomass. If the vegetation type changes, the amount of biomass will change as well. The biomass densities provided in Table 1 were used to

calculate an aboveground carbon stock, assuming 47% of dry matter is carbon for all land covers. The carbon stock was then converted to CO_2 by multiplying by the ratio of molecular weights (44/12).

The biomass stock factors are based on measurements taken at Mugu Lagoon near Santa Barbara (Onuf 1987) and are assumed constant for all wetland types. Plant biomass surveys at Ballona are planned for summer 2014 and could be used to update this analysis at a later date. Additionally, it is assumed that the vegetation at Ballona would be established through natural recruitment and/or planted such that biomass would be fully grown by 2020 pending additional design information and actual initiation and phasing of the restoration. It may take a longer amount of time to implement the restoration and for vegetation to fully establish, which would shift sequestration to a later date.

Soil Sequestration

The soil carbon sequestration rate captures the below ground carbon stocks through time. When land is covered with vegetation, soil carbon increases over time according to the soil sequestration rate of the habitat, due to the incorporation of dead organic matter back into the soil. When a habitat converts to another habitat (e.g. from upland to salt marsh), aboveground biomass changes (may increase or decrease), due to the different type of vegetation, but soil sequestration continues. When salt marsh converts to mudflat, aboveground biomass is lost and soil sequestration halts, but soil carbon stored prior to the conversion remains sequestered within the mudflat. In contrast, when wetlands are diked or drained, the belowground carbon stock can be released as CO_2.

The change in soil sequestration was calculated by multiplying the average habitat area between time steps by the sequestration rate (Table 1) and the number of years between time steps, then summing this quantity for each previous time step, since soil sequestration is cumulative. The soil sequestration was converted from tonnes C to CO_2 equivalents by multiplying by the ratio of molecular weights (44/12). The biomass and soil sequestration were then combined to calculate the cumulative CO_2 equivalents sequestered (Table 2).

A soil sequestration factor for marsh habitats (Table 1) was calculated from Brevik and Homburg (2003) using a bulk density of 1455 kg/m^3, a soil carbon percentage of 1.28%, and an accretion rate of 0.32 mm/yr.

Methane Emissions

Methane emissions are produced when microorganisms in wet, poorly aerated soils, such as in freshwater marshes, decompose organic matter. However, high salinities reduce this methane production, so salt marsh is assumed to have negligible emissions (Jason Keller, Chapman University, unpublished, as cited in Elgin 2012). The IPCC recommends using an emission factor of 0 for salinities greater than 18 ppt and a factor of 193.7 kg CH_4/ha/yr for lower salinities (IPCC 2013a). Methane emissions were calculated for the brackish marsh habitat only, since all other regularly-flooded habitat types were considered saline. The average brackish marsh area between time steps was multiplied by the emission rate (Table 1) and the number of years between time steps, and each previous time step was added to the following, since emissions are cumulative. Methane has a 100-year Global Warming Potential (GWP) of 28 relative to CO_2, which means the effect of each tonne of CH_4 on the atmosphere in 100 years is 21 times greater than that of a tonne of CO_2. Table 3 presents the CH_4 emissions over time.

Net GHG Flux

To evaluate the net GHG sequestration, CH_4 was converted to CO_2 equivalents using the GWP and then subtracted from the sequestered CO_2 (Table 4).

Results and Discussion

By 2100, the Ballona Restoration under Alternative 1 is expected to sequester 16,050 tonnes CO_2 equivalents; without the restoration, habitat acreages would remain very similar to the existing conditions and would sequester

15,040 tonnes CO_2 equivalents. With restoration, the site would emit 2,420 tonnes CO_2 equivalents by 2100; without restoration, the site would emit 580 CO_2 equivalents due to less brackish marsh habitat. Cumulative GHG fluxes are shown in Figure 1 and Table 4. The restoration increases net GHG sequestration by creating more biomass through conversion of upland and salt pan habitats to the more densely vegetated salt marsh. However, the restoration also creates more brackish marsh, which will emit more methane than under the no project conditions. Until 2100, the sequestration over the site is greater than the effect of the emissions. By 2100, much of the marsh will have converted to mudflat and, because of the loss of the biomass, sequestration will decrease. This analysis does not consider sea level rise for the existing conditions since Area A would remain leveed off from the creek and Area B would continue to be managed. However, by 2100, there would be very little tidal signal in Area B under existing managed conditions, and it is likely that some or all of the existing marsh would convert to mudflat as well. As a result, this analysis is conservative in comparing the restored sequestration to the no-project scenario.

Carbon Stock and Sequestration

Sequestered CO_2 is shown over time in Figure 1 and Table 2. Under restored conditions, approximately 190 tonnes CO_2 equivalents would be removed from the atmosphere due to the change in biomass stock. Alternative 1 would create more salt marsh habitat in exchange for seasonal wetland, salt pan, and upland habitat. Both salt pan and upland habitat have lower biomass stock rates, so converting these habitats to salt marsh would result in denser vegetation and a GHG reduction.

As sea level rises, upland habitats would continue to convert to salt marsh, increasing carbon sequestration. However, as the marsh begins to convert to mudflat, biomass would disappear and soil sequestration would stop, slowing the total site sequestration.

To evaluate the upper end of carbon sequestration, the maximum values from Brevik and Homburg (2003) were used to calculate a higher soil sequestration factor. With a value of 1718 kg/m^3 for bulk density, 3.83% for soil carbon, and 2.6 mm/yr for accretion, a maximum soil sequestration factor of 1.71 is calculated. Use of this factor would more than double the total carbon sequestration (minus emissions) to 40,300 tonnes CO_2 equivalents from 13,630 tonnes. Table 5 presents the range of net sequestrations and emissions, where the upper end uses the high soil sequestration factor.

Methane Emissions

Changes in the cumulative CH_4 emissions are shown in Figure 1 and Table 3. Methane emissions increase linearly as the area of brackish marsh is not expected to increase with time.

The methane emissions factor assumes that no methane is emitted under saline conditions, while low salinity habitats emit more. However, the rate of emissions is highly uncertain. Additionally, the GWP of methane is currently being re-evaluated and may be greater than initially thought (GWP = 34 according to IPCC 2013b). Using this higher GWP, methane emissions could be as much as 2,940 tonnes of CO_2 equivalents by 2100, compared to 2,420 using the existing GWP. Table 5 presents the range of net sequestrations, where the lower end uses the higher GWP for methane.

Summary

Greenhouse gas accounting is highly variable, but can be used to estimate a range of sequestrations (or emissions). With Alternative 1, the Ballona wetlands are expected to prevent 13,100 to 40,300 tonnes of CO_2 (minus emissions) from entering the atmosphere by 2100. Because the restoration creates marshes and allows them to transgress upslope with sea-level rise, more carbon biomass aboveground and underground is created and sustained. As sea levels rise, the rate of sequestration would decrease due to the conversion of salt marsh to mudflat, but the carbon would remain sequestered in the soils. Although methane has a larger warming potential than CO_2, the amount of brackish marsh assumed for Alternative 1 is small enough that emissions do not outweigh the carbon sequestered in the salt marsh, even with conservative assumptions.

GHG Fluxes Under Alternatives 2-7

Initially, Alternatives 2 and 3 would sequester more carbon than Alternative 1 because they would have larger amounts of salt marsh in west and north Area B (as opposed to upland levee, which would sequester less carbon). However, with sea level rise, the tidal signal in the managed marsh would eventually shrink until vegetation was impacted and the habitat converted to mudflat. In Alternative 1 (and Alternative 2, to a lesser extent), the marsh would be able to migrate up the levee slope, and the upland would remain, sequestering carbon for a longer period of time than in Alternative 3 (and 2).

Alternative 3 would have less brackish marsh than in Alternative 1, so it would have lower methane emissions.

Alternatives 4 and 6 would have the same GHG fluxes as Alternative 1, since they only differ in the inclusion and location of the Visitors Center which has not been included in this analysis. Alternatives 5 and 7 would be similar to Alternative 8, the no project scenario, since no habitats would be converted in any of these alternatives. The no restoration scenario is discussed above in relationship to Alternative 1.

Table 1. Ballona Habitat Areas, Reduction Factors, and Emission Factors

	Ballona Habitat Areas[1]					Biomass Stock Factors			Carbon Reduction Factors		Methane Emission Factors	
Habitat type	**Existing (ha)**	**Restored (ha)**	**2030 (ha)**	**2050 (ha)**	**2100 (ha)**	**Biomass Stock (tonnes dry matter/ha)**	**Notes**	**Aboveground carbon stock[5] (tonnes C/ha)**	**C Removal Rate (tonnes C/ha/yr)**	**Notes**	**CH_4 Emission Rate (kg Ch_4/ha/yr)**	**Notes**
Subtidal	14.2	11.7	12.1	12.5	19.4	0	Assumed unvegetated	0	0	Assumed unvegetated	0	Assumed unvegetated
Mudflat	8.5	21.9	23.9	36.0	57.9	0	Assumed unvegetated	0	0	Assumed unvegetated	0	Assumed unvegetated
Low salt marsh	3.6	17.8	22.7	20.6	11.7	0	Assumed unvegetated because cordgrass is uncommon in this system	0	0	Assumed unvegetated because cordgrass is uncommon in this system	0	Assumed unvegetated because cordgrass is uncommon in this system
Mid salt marsh	7.3	41.7	38.9	34.8	44.9	5.5[2]		2.6	0.60[5]		0[7,8]	Assumed 0 for saline conditions
High salt marsh	16.6	11.3	10.9	11.3	8.9	5.5[2]		2.6	0.60[5]		0[7,8]	Assumed 0 for saline conditions
Brackish marsh	1.2	5.3	5.3	5.3	5.3	5.5[2]		2.6	0.60[5]		193.7[8]	
Salt pan	8.9	7.7	7.7	7.7	5.7	0.4	Assumed 7% cover	0.2	0.04	Assumed 7% cover	0[8]	Assumed 0 for saline conditions
Transition zone	0.0	20.2	21.9	25.5	5.7	5.5	Assumed equal to other wetlands	2.6	0.60[5]		0[8]	Assumed 0 for saline conditions
Seasonal wetland	34.8	1.6	1.6	1.2	1.2	5.5[2]		2.6	0.60[5]		0[8]	Assumed 0 for saline conditions
Upland	115	71	65	55	49	1.6[4]	Assumed grassland for warm temperate – dry regions	0.8	0.09[6]	Assumed value for non-rice annual cropland	0	Assumed dry

1. ESA PWA 2012
2. Onuf 1987, Figure 31: Mean biomass of salt marsh plants in Mugu Lagoon (1977-1981)
3. IPCC 2006, V4 Chap 6- p6.29 & Table 6.4
4. Aboveground carbon stock = carbon fraction , 0.47 * area
5. Brevik and Homburg 2003.
6. Kroodsma and Field 2006
7. Elgin 2012
8. IPCC 2013a, Table 4.14, 0 for saline conditions

Table 2. Cumulative CO_2 Equivalents Sequestered

	Cumulative CO_2 equivalents sequestered (tonnes CO_2 equivalents)				
Habitat type	**Existing (2012)**	**Restored[1] (2020)**	**2030**	**2050**	**2100**
Subtidal	0	0	0	0	0
Mudflat	0	0	0	0	0
Low salt marsh	0	0	0	0	0
Mid/high salt marsh	0	950	2,050	4,130	9,700
Brackish marsh	0	100	210	440	1,020
Salt pan	0	10	20	50	100
Transition zone	0	370	850	1,920	3,450
Seasonal wetland	0	10	40	100	230
Upland	0	130	330	710	1,550
Total	**0**	**1,560**	**3,510**	**7,350**	**16,050**
Total w/o restoration	**0**	**1,370**	**3,080**	**6,500**	**15,040**
Net Total (w/ restoration – w/o restoration)	**0**	**190**	**430**	**850**	**1,010**

1. Assumes vegetation is planted, so biomass is instant in 2020

Table 3. Cumulative CH_4 Emissions

	Cumulative CH_4 emissions				
Habitat type	**Existing (2012)**	**Restored (2020)**	**2030**	**2050**	**2100**
Total brackish marsh (tonnes CH_4)	0	5	15	36	87
Total brackish marsh (tonnes CO_2 equivalent)	**0**	**140**	**430**	**1,000**	**2,420**
W/o restoration (tonnes CO_2 equivalent)	**0**	**50**	**120**	**250**	**580**
Net Total (w/ restoration – w/o restoration) (tonnes CO_2 equivalent)	**0**	**90**	**310**	**750**	**1,840**

Table 4. Net Greenhouse Gas Emissions and Reductions

	Net Cumulative Greenhouse Gas Emissions and Reductions (tonnes CO_2 equivalent)				
Habitat type	**Existing (2012)**	**Restored (2020)**	**2030**	**2050**	**2100**
Subtidal	0	0	0	0	0
Mudflat	0	0	0	0	0
Low salt marsh	0	0	0	0	0
Mid/high salt marsh	0	950	2,050	4,130	9,700
Brackish marsh	0	-50	-210	-550	-1,400
Salt pan	0	10	20	40	100
Transition zone	0	370	850	1,920	3,450
Seasonal wetland	0	10	40	100	230
Upland	0	130	330	710	1,550
Total w/ Restoration	0	1,420	3,080	6,350	13,630
Total w/o Restoration		1,310	2,960	6,250	14,470
Net Total (w/ restoration – w/o restoration)		110	120	100	-840*

Note: Negative values indicate methane emissions or a decrease in habitat type under restoration
* Assumes managed marsh can be maintained as marsh through 2100. With sea level rise, the tidal signal in the managed marsh would likely become so muted that the vegetation could not survive and would convert to mudflat, which would reduce the amount of carbon that could be sequestered.

Table 5. Range of Net Greenhouse Gas Emissions and Reductions

	Net Cumulative Greenhouse Gas Emissions and Reductions (tonnes CO2 equivalent)			
Habitat type	**Restored**	**2030**	**2050**	**2100**
Subtidal	-	-	-	-
Mudflat	-	-	-	-
Low salt marsh	-	-	-	-
Mid/high salt marsh	2,200	2,050 to 5,400	4,130 to 11,380	9,700 to 27,120
Brackish marsh	200	-310 to 100	-770 to 190	-1,920 to 420
Salt pan	30	20 to 60	40 to 130	100 to 270
Transition zone	700	850 to 2,030	1,920 to 5,040	3,450 to 9,730
Seasonal wetland	600	40 to 700	100 to 870	250 to 1,250
Upland	130	330	710	1,550
Total	3,860	3,000 to 8,600	6,100 to 18,300	13,100 to 40,300

Note: Negative values indicate emissions

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Figure 1. Greenhouse Gas Emissions and Sequestrations at Ballona Wetlands

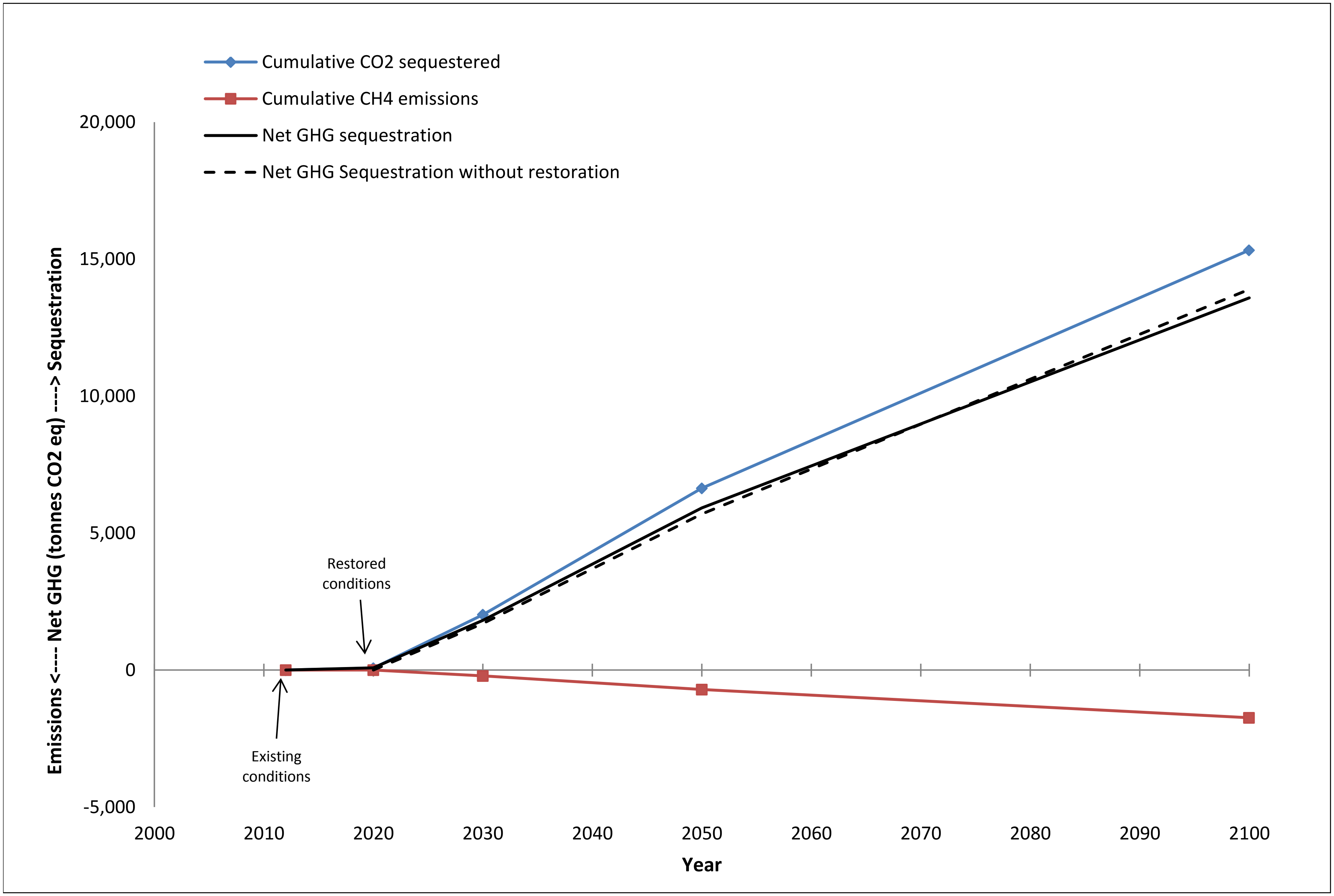

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Figure 1

Greehouse Gas Emissions and Sequestration at Ballona Wetlands