NW1: Carbon Sequestration in Rangelands

Brief Summary:
This control measure would increase carbon sequestration in rangelands across the Bay Area by providing technical and research assistance to local governments, regional agencies and private owners of rangelands.

Purpose:
Encouraging good soil management and enhancement practices will increase the uptake and sequestration of carbon dioxide (CO_2) by the soils and vegetation of these habitats.

Source Category:
Area sources - rangelands

Regulatory Context & Background:
Nearly 2.8 million acres in the Bay Area, approximately two-thirds of the region's land mass, are undeveloped lands. Forested and woodland areas make up nearly 50 percent, grasslands over one-third and shrub lands composed of chaparral and coastal shrub make up the remaining nearly 15 percent. Approximately two-thirds of these undeveloped areas (some 1.9 million acres) function as rangelands, lands that produce vegetation suitable for livestock grazing.

Some 70 percent of the rangelands in the Bay Area (about 1.35 million acres) are privately owned. In addition, approximately 26 percent of the rangelands (nearly 500,000 acres) are permanently protected from development through conservation easements, or through outright purchase of a property for conservation purposes.

To understand the role rangelands play in carbon sequestration, it is critical to understand the carbon cycle, the role of soils in this cycle, and what carbon sequestration is. Carbon is found in all living organisms on Earth and exists predominately as plant biomass, soil organic matter, and CO_2 in the atmosphere and dissolved in seawater. Carbon sequestration is the storage of carbon in oceans, soils, vegetation, and geologic formations. Although oceans store most of the Earth's carbon, soils contain approximately 75 percent of the carbon pool on land, three times more than the amount stored in living plants and animals. Through photosynthesis, plants absorb and store atmospheric carbon as they grow. Some portion of this carbon migrates from plant roots into the surrounding soil in other organic forms; this carbon can remain in the soil, i.e., become sequestered in the soil, to varying degrees depending on how the soil and vegetation is managed. As such, rangelands, and other ecosystems such as forestlands, play a critical role in sequestering carbon at a global scale.

In agricultural systems, the amount and length of time carbon is stored is determined predominately by how the soils are managed. One practice that has been found to increase carbon storage is the addition of organic matter, and compost in particular, to agriculture and/or rangeland soils. The addition of compost results in the slow release of fertilizer to the soils as the compost decomposes, and improved soil moisture conditions; both result in increased plant production. In turn, more plant growth leads to more CO_2 being removed from the atmosphere through photosynthesis and thus more CO_2 being transferred (i.e., sequestered) through the plant to the soil as roots and detritus.

The Marin Carbon Project (MCP) has conducted extensive studies of the effects of organic matter soil amendment. MCP is a consortium of the leading agricultural institutions and producers in Marin County, university researchers, county and federal agencies, and nonprofit organizations seeking to understand and demonstrate the potential of enhanced carbon sequestration in Marin's agricultural and rangelands soils. Beginning in 2006, MCP launched an intensive research effort to determine if the application of compost on grazed rangelands could increase the land's carbon-sequestering ability.

Results from MCP's work indicate that a single application of a half-inch layer of compost on grazed rangelands significantly increases plant growth (by 40 to 70 percent), and increases soil water holding capacity. Modeling results further indicate that soil carbon sequestration could increase by at least 0.4 metric tons (MT) per acre annually for 30 years without re-application. Scaling up from MCP's results indicates that applying compost at this rate on 50 percent of the rangeland area in California could offset 42 million metric tons (MMT) of CO_2e annually, an amount equivalent to the annual GHG emissions from energy used by the commercial and residential sectors in California.

Other studies have confirmed that amending rangelands and other managed lands with compost and other organic materials increases carbon sequestration of these lands. For example, studies in California coastal and valley grasslands found that adding compost resulted in annual sequestration rates after three years ranging from 0.2 to 1.7 MT CO_2e per acre. Scaling up to 5 percent of California's rangeland, these sequestration rates would mitigate between 0.7 and 4.7 MMT CO_2e annually. A recently released study (Ryals et. al, 2015) based on field data and modeling indicates that sequestration rates ranged from 0.51 to 0.67 MT CO_2e per acre annually when assessed over a 10-year time period and 0.25 to 0.38 MT CO_2e per acre annually over a 30-year time period. Some of the variability noted was ascribed to the carbon-to-nitrogen ratio of the amendments (amendments with lower carbon-to-nitrogen ratios resulted in higher sequestration rates over time) and the application rates (i.e., single or multiple applications). Nevertheless, in all cases all compost amendment scenarios analyzed led to net GHG sinks that persisted for several decades.

Implementation Actions:
The Air District will:

- Include off-site mitigation of GHG emissions through carbon sequestration projects using the MCP GHG reduction protocol in Air District CEQA guidance and comments, and the CAPCOA GHG Reduction Exchange or other third-party protocols approved for use by the Air District.
- Work with the MCP, resource conservation districts, and local farms to apply compost amendments on grazed grasslands and rangelands across the Bay Area.

- Develop climate action plan guidance and/or best practices on soil management for local agencies and farmers and their associations to maximize GHG sequestration on rangelands.

Emission Reductions:

Pollutant*	2020	2030
CO_{2e}	16,667	57,500

** CO_{2e} is reported in metric tons/year (100 yr GWP)*

Emission Reduction Methodology:
Table 1 displays the total amount of carbon that would be expected to be sequestered (as a range in MMT CO_2e) on rangelands if various percentages of rangelands in the nine-county Bay Area (total of approximately 1.9 million acres) received soil amendments. These estimates are based on extrapolations of the results from the studies described above.

Table 1. Expected range of total carbon sequestration (MMT CO_2e) with soil amendment over specific time period

	Percent of total rangeland in Bay Area amended			
	10%	25%	50%	100%
Over 3 years	0.1 – 0.9	0.3 – 2.4	0.7 – 4.7	1.4 – 9.5
Over 10 years	1.0 – 1.3	2.4 – 3.2	4.9 – 6.4	9.8 – 12.8
Over 30 years	1.4 – 2.2	3.5 -5.4	7.0 – 10.8	14.1 – 21.7

Emissions reductions were determined by using the midpoint value of the 10 percent of total rangeland amended indicated in the Table above and assumed that 1 percent of all rangelands were amended by 2020 and 5 percent by 2030. For 2020, the midpoint value of total expected carbon sequestered over three years (0.5 MMT CO_2e) was divided by 10 (equal to 1 percent of all rangelands), while for 2030, the midpoint value of total expected carbon sequestered over 10 years (1.15 MMT CO_2e) was divided by 2 (equal to 5 percent of all rangelands). Both values were then converted into a per-year estimate of CO_2e reductions by 2020 and 2030.

Exposure Reduction:
This measure will reduce CO_2 in the atmosphere by sequestering CO_2 into rangelands and other managed agricultural lands.

Emission Reduction Trade-Offs:
Adding compost to rangelands can result in the release of other GHGs, nitrous oxide (N_2O) in particular, from these same amendments. Ryals et al. (2015) found that amendments with lower carbon-to-nitrogen ratios, which resulted in higher sequestration rates, also experienced greater N_2O fluxes. In addition, multiple smaller compost additions resulted in lower cumulative N_2O emissions, but also a time lag in sequestration. These results demonstrate that there is a trade-off between maximizing carbon sequestration and minimizing N_2O emissions following addition of soil amendments. Therefore, potential increases in the emission of these other GHGs should be considered when managing agricultural lands for carbon sequestration.

Cost:
Cost estimates will be further developed during program implementation.

Co-Benefits:
Removing CO_2 from the atmosphere is only one significant benefit of enhanced carbon storage in soils. Improved soil and water quality, decreased nutrient loss, reduced soil erosion, increased water conservation, and greater crop production may result from increasing the amount of carbon stored in agricultural soils. In addition, diverting manure, yard and food wastes to composting systems can lead to significant GHG offsets.

Issues/Impediments:
Successful implementation of this measure would require adequate availability of appropriate sources of composting material.

Sources:

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NW2: Urban Tree Planting

Brief Summary:
The control measure promotes the planting of trees in urbanized settings to take advantage of the myriad benefits provided by these trees, including: shading to reduce both the "urban heat island" phenomenon and the need for space cooling, and the absorption of ambient criteria air pollutants as well as carbon dioxide (CO_2).

Purpose:
The purpose of this control measure is to reduce criteria pollutants and GHGs by promoting the planting of trees in urban settings. These efforts will also serve to mitigate the urban heat island phenomenon and lower cooling and heating energy costs.

Source Category:
Area sources – urban trees

Regulatory Context & Background:
In urban areas, where buildings and paved surfaces have replaced the natural landscapes, solar energy is absorbed into roads and rooftops, causing the surface temperature of urban structures to increase and radiate heat. These higher temperatures in turn lead to higher overall ambient air temperatures, a phenomenon known as the "urban heat island." The average ambient temperature of an urban center can be 2-5 degrees Fahrenheit higher than surrounding areas. This difference can be more pronounced at night as urban infrastructure continues to slowly release heat well into the evening, with a potential temperature increase over surrounding areas of as much as 22 degrees Fahrenheit (USEPA 2015).

The resulting higher temperature caused by the urban heat island has numerous effects with air quality implications, including:

- With increased temperatures, there is increased demand for cooling-related energy use in commercial and residential buildings. The increased electricity generation required to meet the increased demand for energy leads to increased emissions of numerous pollutants at power plants, including SO_2, CO, NO_x, and PM, as well as CO_2.
- The increased temperatures in these settings can accelerate the formation of smog, as ozone precursors (i.e., NO_x and VOCs) react with increased temperatures to produce ground level ozone.

Numerous studies have shown that increasing the tree canopy in an urban setting can provide various environmental and economic benefits, including ameliorating the urban heat island effect. Details on these benefits are provided below.

Carbon sequestration

Trees absorb CO_2 from the atmosphere during photosynthesis and store this carbon as biomass.[1] The rate at which carbon is absorbed, and then released through decay and decomposition, varies based on numerous factors, including tree species and local environmental conditions. It is estimated that U.S. urban trees and forests store 2,358.4 million metric tons (MMT) CO_2 and sequester a net total of 69.3 MMT CO_2 per year (Nowak et al. 2013a). This same analysis estimated that California urban trees store 115.1 MMT CO_2 and sequester nearly 4.3 MMT CO_2 annually. An analysis of street trees in California (a subset of all urban trees) indicates that California's 9.1 million street trees store 7.78 MMT CO_2 and sequester 567,758 MT CO_2 annually (McPherson et al. 2014). At a more local scale, net sequestration by the 6.6 million urban trees in the San Francisco Bay Area was calculated at 696,686 MT CO_2 annually (McPherson et al. 2010). Even finer scale studies found that Berkeley's 36,485 municipal trees sequestered 3,025 MT CO_2 annually and that the approximate 669,000 trees in the San Francisco urban forest sequester some 19,067 MT CO_2 annually (Nowak et al. 2007, McPherson et al. 2010).

Reduction in Pollution Concentrations

Trees reduce ambient concentrations of criteria pollutants as well. Trees absorb pollutants such as ozone, NO_2 and SO_2 primarily through leaf stomata as well as on plant surfaces and bark pores. In fact, the U.S. EPA has recognized tree planting as a measure for reducing ozone in state implementation plans. Trees affect ambient concentrations of PM by intercepting small airborne particles, which deposit on trees' leaves, twigs and bark.

Table 1 summarizes the findings from various analyses and modeling studies of the rate of annual ambient pollution removal of various criteria pollutants by urban trees. As indicated in the table's note, these studies use the percent of the urban landscape covered by trees (i.e., percent tree cover) in their calculations of the emission reductions achieved by these trees.

Table 1. Metric tons of air pollution removal by urban trees annually

	O_3	*PM_{10}*	*$PM_{2.5}$*	*NO_2*	*SO_2*	*CO*	*Source*
Conterminous United States	523,000		27,000	68,000	33,000		Nowak et al. 2014
	305,100	214,900		97,800	70,900	22,600	Nowak et al. 2006
San Jose	305	243		188	28	34	
San Francisco	80	107		63	12	15	
	83	84		45	13	11	Nowak et al. 2007
			5.5				Nowak et al. 2014, Nowak 2014

The percent of tree cover in each study varied as follows: from 11.9 percent (Nowak et al. 2007) to 27 percent (Nowak et al. 2006) to 34.2 percent (Nowak et al. 2014) to 36.1 percent (Nowak 2014 and Nowak et al. 2014).

[1] This discussion distinguishes between the amount of carbon trees absorb from the atmosphere each year ("to sequester") and the amount of carbon that is contained in the trees' biomass ("to store").

Lastly, urban trees can lead to lower evaporative emissions. Specifically, by shading asphalt surfaces and parked cars, trees serve to reduce hydrocarbon emissions (i.e., ozone precursors) from gasoline that evaporates from leaky tanks and hoses.

Reduction in Ambient Temperatures

One of the functions performed by trees in urban settings that is most easily recognizable is the shade these trees provide to outdoor areas, buildings and urban structures such as sidewalks and parking lots. This shade has the direct effect of lowering ambient temperatures; these lower temperatures result in less ozone formation. Moreover, trees directly cool the air through transpiration – the evaporation of water from plants.

Energy Savings

If appropriately placed around buildings, trees can lower the energy demands for heating and cooling from these buildings, leading to energy savings. Specifically, the lower temperatures resulting from shade trees can reduce the energy demands to cool structures on hotter days. These energy savings are particularly critical when they occur at the hottest time of the day and thus reduce peak energy consumption. In addition, trees can provide for energy savings in the winter. Specifically, by reducing wind speed, trees can mitigate the infiltration of outside air into interior spaces. In this manner, trees can lower the heat loss from cool winter winds, resulting in heating savings.

The energy savings provided by trees throughout the year can be substantial. A study of all of California's 177 million trees found that these trees reduce annual electricity used for cooling by 6,407 gigawatt hour (GWh), enough energy to power 730,000 homes (McPherson and Simpson 2001). Similarly, California's 9.1 million street trees are estimated to save 684 GWh of electricity annually, equal to the amount of energy required to air condition 530,000 households in California each year (McPherson et al. 2015). Similarly, the 6.6 million existing urban trees in the San Francisco Bay Area are estimated to provide annual energy savings valued at $327 million (reported in McPherson et al. 2010). Likewise, an analysis of the 36,485 municipal trees in Berkeley found a citywide annual energy savings of $553,066 ($15.16/tree), 17 percent from winter heating and 83 percent from summer air conditioning (McPherson et al. 2010). Specifically, annual electricity use for air conditioning was reduced by 3,469 megawatt hour (MWh) ($12.58/tree) and annual savings of natural gas for heating was 7,209 million British thermal units (MBtu) ($2.58/tree).

Implementation Actions:

The Air District will:

- Develop or identify an existing model municipal tree planting ordinance and encourage local governments to adopt such an ordinance.
- Provide assistance to local governments to increase tree canopy by assisting in identifying and securing incentive funds that are available for the planting of trees.
- Include tree planting recommendations in Air District's guidelines for local plans and CEQA review.

- Provide information via technical guidance, best practices, outreach materials, presentations and workshops to local government planning and public works staff on how to maximize air quality, GHG and public health benefits from municipal tree planting programs.

Emission Reductions:
Due to the level of uncertainty in terms of the impact this program may have on number of trees planted, emission reductions have not been estimated.

Emission Reduction Methodology:
N/A

Exposure Reduction:
Tree planting in urban settings would serve to reduce ambient concentrations of numerous criteria pollutants as well as sequester CO2. Additionally, studies have demonstrated that access to trees within an urban setting is a direct reflection of income.[2] Increasing urban trees in low income communities, therefore, may not only reduce cooling expenses of residents and improve air quality, but may also reduce disparity.

Emission Reduction Trade-Offs:
It is important to take into account that trees can also contribute to emission increases. For example, some trees emit biogenic volatile organic compounds (BVOCs) that can contribute to ozone formation. The contribution of BVOC emissions from city trees to ozone formation depends on complex geographic and atmospheric interactions, and differs considerably across tree species, and has not been studied in most cities (McPherson et al. 2010). Additional research would need to be conducted to identify the tree species that are most beneficial to air quality overall. It is also important to consider that trees also emit particles such as pollen and particles captured on plant surfaces can be re-suspended into the air. In addition, equipment used for tree planting and maintenance (e.g., vehicles, chain saws, chippers) release CO_2.

Cost:
An analysis of small, medium and large broadleaf trees and a coniferous tree in the Northern California Coast Region (which covers large portions of the nine-county Bay Area) found that the benefits conveyed by trees outweigh the costs of maintaining these trees. Table 2 presents the average annual benefits, costs and net benefits per tree for a 40-year period (McPherson et al. 2010).

Table 2. Average annual benefits, costs and net benefits per tree for a 40-year period

	Average Annual:		
Tree type	**Benefits**	**Costs**	**Net Benefits**

[2] "Ecosystem services and urban heat riskscape moderation: water, green spaces, and social inequality in Phoenix, USA." By G. Darrel Jenerette, Sharon L. Harlan, William L. Stefanov, and Chris A. Martin. Ecological Applications, Vol. 21 No. 7, October 2011.)

			(Benefits – Costs)
Small broadleaf	$41 to $51	$10 to $17	$31 to $34
Medium broadleaf	$57 to $71	$11 to $24	$46 to $47
Large broadleaf	$115 to $135	$13 to $28	$102 to $107
Conifer	$161 to $176	$15 to $33	$142 to $143

The largest portion of the benefits results from increased property value and energy savings; additional benefits are derived from reduced storm water runoff, lower levels of air pollutants and reduced ambient CO_2. The majority of costs are associated with tree planting, pruning and removal.

Co-Benefits:
Trees in urban settings provide for numerous additional benefits – ranging from environmental to economic to psychological and social. For example, trees:

- Improve water quality by reducing storm water runoff, a major source of pollution entering wetlands, streams and the San Francisco Bay.
- Reduce flood risk and recharging groundwater supplies by capturing storm water.
- Provide wildlife habitat in the built environment.
- Prolong the life of sidewalks and pavement by reducing the daily heating and cooling and thus expansion and contraction of asphalt.
- Have been found to increase property values - research suggests that people are willing to pay 3 to 7 percent more for properties with ample trees versus few or no trees.
- Provide social and psychological benefits by beautifying the landscape, promoting social interactions, providing stress relief and noise reduction, contributing to public safety and providing pleasure to humans.

It is also important to consider the additional benefits associated with planting native and/or drought-tolerant or drought-resistant trees. Specifically, since native plants have evolved in and with the local environment, they tend to be better adapted to local conditions (e.g., soil type, rain regime) and less susceptible to pest and diseases than non-native trees. As such, they require little long-term maintenance if they are properly planted and established. In addition, native trees provide food and habitat for native wildlife, birds, bees and butterflies; these animals in turn play key roles in the local ecosystem. Drought-tolerant and -resistant trees (whether native or not) require far less water than exotic trees, especially once established. Encouraging water-wise landscaping will become increasingly important as a result of the altered weather patterns expected with climate change.

Issues/Impediments:
Due to the voluntary nature of this measure, significant impediments to implementation are not anticipated.

Sources:

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NW3: Carbon Sequestration in Wetlands

Brief Summary:
This control measure would increase carbon sequestration in wetlands in the San Francisco Bay by providing technical and research assistance, policy support, and incentive funding to local governments and regional agencies to ensure the preservation and restoration of wetlands.

Purpose:
Ensuring the preservation and restoration of wetlands in the Bay Area will (1) reduce the emissions of CO_2 that results when wetlands are destroyed and/or degraded, and (2) increase the uptake and sequestration of atmospheric CO_2 within these habitats when they are re-established and protected.

Source Category:
Area sources - wetlands

Regulatory Context & Background:
The development and urbanization of the nine-county Bay Area, in particular since the mid-1850s following the Gold Rush, has affected and changed nearly all the region's natural habitats. Among the most severely affected were the wetlands that once ringed the San Francisco Bay. By the 1960s, filling of shallow areas of the San Francisco Bay had reduced the Bay's size by one-third and destroyed 90 percent of the Bay's tidal marsh.

The Save San Francisco Bay Association (now Save the Bay) was established in 1961 to stop unregulated filling of San Francisco Bay and to open up the Bay shoreline to public access. This movement helped support the establishment in 1969 of the San Francisco Bay Conservation and Development Commission (BCDC) as a permanent state agency to regulate shoreline development and increase public access. BCDC has jurisdiction over the open water, marshes and mudflats of greater San Francisco Bay, the first 100 feet inland from the shoreline around the Bay as well as managed wetlands that have been diked off from the Bay.

Efforts by governmental agencies and non-profit groups have been on-going across the Bay to preserve and restore wetlands. Of particular note, in the 1990s, in response to the growing recognition of the importance of wetlands, nine state and federal agencies and dozens of concerned scientists came together to produce a guide for restoring and improving the wetlands and adjacent habitats of San Francisco Bay in order to establish a long-term vision for a healthy and sustainable baylands ecosystem. This effort was called the San Francisco Bay Area Wetlands Ecosystem Goals Project (Goals Project 1999).[1] Among the key recommendations of the Goals Project was to increase the total area of tidal marsh across the

[1] An update to the 1999 Goals Project report was released in 2015 (Goals Project 2015). This updated report synthesizes the latest science, including advances in the understanding of climate change, and provides new recommendations for achieving healthy baylands ecosystems. The habitat acreage goals set in 1999 remain the same.

Bay from 40,000 acres to about 95,000 to 105,000 acres, requiring the restoration of large areas of diked habitats such as salt ponds, managed marshes and agricultural flatlands. Re-establishing extensive areas of tidal marsh would have major environmental benefits, including improving the Bay's natural filtering system and enhancing water quality, increasing primary productivity of the aquatic ecosystem, and reducing the need for flood control and channel dredging. In addition, Goals Project 2015 specifically addresses the carbon sequestration benefits that would result from restoration of these wetlands.

The scientific foundation for the protection and re-establishment of wetlands across the Bay provided by the Goals Project in 1999 has served to guide wetlands restoration and enhancement around the Bay for well over a decade. For example, the San Francisco Bay Joint Venture, a partnership organization that works to protect, restore and enhance wetlands in the Bay Area, has completed over 150 wetland habitat projects resulting in the conservation of over 70,000 acres of habitat. Additional wetlands restoration projects have taken place, in particular in the South and North Bay regions, or are planned on lands purchased by government agencies such as the U.S. Fish and Wildlife Service, the California Department of Fish and Game and the California Coastal Conservancy, and by private organizations and land trusts. Overall, since the Goals Project report was published in 1999, over 12,000 acres of tidal marsh and wetlands have been restored, and nearly 30,000 more are now under way (Goals Project 2015).

Fundamental to the successful re-establishment of wetlands is attracting significant funding for land acquisition and restoration as well as maintenance and protection of re-established wetlands. Efforts to secure funding for restoration included the passage of AB 2954 in 2008 which established the San Francisco Bay Restoration Authority (Restoration Authority) as a regional body with the power to raise and allocate local resources for the "restoration, enhancement, protection, and enjoyment of wetlands and wildlife habitat in the San Francisco Bay and along its shoreline." In June 2016, a $12 per year parcel tax placed on the ballot by the Restoration Authority (the "San Francisco Bay Clean Water, Pollution Prevention, and Habitat Restoration Program," also known as the Clean and Healthy Bay Ballot Measure) was approved by the required two-thirds majority of voters in all nine counties of the Bay Area. The measure is expected to generate approximately $25 million per year and $500 million over its 20-year life to protect and restore the San Francisco Bay.

There is existing federal and state funding for wetlands restoration projects in the Bay Area. Specifically, the United States Environmental Protection Agency's (EPA) San Francisco Bay Water Quality Improvement Fund (SFBWQIF) has been available since 2008. This Fund has invested almost $16 million in 26 projects to restore over 4,000 acres of wetlands around the Bay; these projects have leveraged additional funds from partner agencies and organizations, resulting in $100 million being invested in San Francisco Bay and its watersheds since 2008. In addition, the new Wetlands Restoration for Greenhouse Gas Reduction Grant Program, administered by the California Department of Fish and Wildlife, granted its first awards to 12 projects throughout California (one in the Bay Area) in April 2015. This Program allocates Greenhouse Gas Reduction Funds (GGRF) from California's Cap-and-Trade proceeds to restore wetlands that sequester GHGs and provide other ecological benefits in mountain meadow ecosystems, the Sacramento-San Joaquin Delta and coastal wetlands.

In addition, in late 2015, a new protocol for wetland carbon finance was approved by the Verified Carbon Standard. Specifically, the Wetlands Restoration and Conservation project category provides a framework for accounting for emission reductions in mangroves, tidal and coastal wetlands, marshes, seagrasses, floodplains, deltas, and peatlands among others tidal wetlands and seagrass restoration. These groundbreaking requirements are the first for crediting restoration and conservation activities across wetland ecosystems.

Implementation Actions:
The Air District will:

- Collaborate with other local, regional, state and federal agencies to protect, restore and enhance existing wetlands that provide carbon sequestration value in the Bay Area.
- Develop or identify guidance based on acceptable quantification methods for local climate action plans on estimating GHG sequestration associated with wetlands restoration and protection.
- Partner with other local and regional agencies to apply the Wetlands Restoration and Conservation methodology or other applicable third-party protocols to potential carbon offset projects.
- Include offsite mitigation strategies for GHG emissions through carbon sequestration from wetland restoration and preservation in CEQA guidance and comments.
- Identify federal, state and regional agencies, and collaborative working groups that the Air District can assist with technical expertise, research or incentive funds to enhance carbon sequestration in wetlands around the Bay Area.
- Provide technical assistance as needed for SFBWQIF and GGRF projects.
- Assist agencies and organizations that are working to secure the protection and restoration of wetlands in the San Francisco Bay to reach the Goals Project recommendation of 100,000 acres.

Emission Reductions:

Pollutants*	2020	2030
CO_{2e}	90,000	90,000

**criteria pollutants are reported in lbs/day; CO_{2e} is reported in metric tons/year (100 yr GWP)*

Emission Reduction Methodology:
Emissions reductions achieved based on sequestration potential of wetlands and the recommended area of wetlands to be restored. It is estimated that every acre of healthy salt marsh captures and converts at least 0.87 metric tons (MT) of CO_2 into plant material annually (Save the Bay 2007). Therefore, if full restoration of the 100,000 acres recommended by the Goals Project is achieved, it would be expected that nearly 90,000 MT of CO_2 would be sequestered annually.

Exposure Reduction:
This measure will reduce CO_2 in the atmosphere by sequestering CO_2 into wetlands.

Emission Reduction Trade-Offs:
The creation, restoration and maintenance of wetlands can result in criteria and GHG emissions associated with on-road vehicles and off-road heavy equipment that may be used to restore and or maintain the wetlands.

Cost:
The main costs for this control measure will be funding for the acquisition, planning and maintenance of restoration projects. Save The Bay's 2007 report, "Greening the Bay," estimated that it would cost $1.43 billion over 50 years to fully restore the over 36,000 acres of shoreline property that had already been acquired and awaiting restoration to tidal wetlands at that time. The report did not estimate the costs of acquiring and restoring the remaining 20,000 acres or so to reach the 100,000-acre goal. Overall, most of the expenses are a one-time investment, with more than 80 percent needed for planning, construction and monitoring of the restoration projects. Once restored, tidal marshes require little maintenance with expenses focused on ongoing operations and maintenance, security, public access facilities and protecting other infrastructure at restored marshes.

Co-Benefits:
Restoring and preserving wetlands not only ensures increased capture and storage of carbon by these areas, but also provides a multitude of environmental co-benefits from these areas:

- Protection and buffer from floods, erosion and sea-level rise as these area act as sponges, slowing down and soaking up large quantities of runoff and water from rain storms and high tides;
- Habitat for over 500 species of fish and wildlife;
- Improved water quality by trapping and filtering out pollutants and toxins;
- Open Space and Recreation for visitors to and residents of a highly urbanized Bay Area; and
- Economic Benefits from tourism, fishing, and recreation opportunities in and around wetlands.

In addition, it is critical to note that wetlands provide economic benefits that are not reflected in the costs outlined in the section above. Specifically, Save the Bay's report noted that wetlands produce $4,650 per acre in flood control and dredging cost savings compared to engineered dams, reservoirs and channels and, since they purify water so well, they are often used for tertiary treatment by municipal sewage plants.

Issues/Impediments:
The major issue/impediment to restoring and preserving wetlands for all the associated environmental benefits, including carbon sequestration, is adequate funding. Wetland restoration requires long-term, consistent funding for acquisition, planning, on-the-ground construction, and operations and maintenance.

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