CHAPTER 7: LOCAL CLIMATE CHANGE ASSESSMENT

7.0 Introduction

Climate change is a relatively new and extremely significant issue for water resource management. Only recently has there been a political consensus acknowledging the overwhelming scientific evidence for the existence of climate change as well as the primary role of human activities as a contributing factor to climate change. This chapter begins with an overview of the evidence of global climate change due to recent increases in greenhouse gases (GHGs). It then discusses the two sides of climate change, mitigation and adaptation. It summarizes current scientific information about ongoing global climate change, in terms of general projections of large-scale climate change, and approaches of assessing climate change implications at the local scale. The chapter then outlines general climate change issues from the water resource management perspective, and identifies characteristics of the region to consider when assessing potential impacts, both primary and secondary, of climate change at the local scale. Finally, the chapter discusses the implications of climate change with regard to local forests and watersheds, the role of forests in climate change, and a discussion of the California Climate Action Registry and potential carbon credits for forestland owners.

7.1 Overview of the evidence for global climate change

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as “any change in climate over time, whether due to natural variability or as a result of human activity” (IPCC, 2007). The energy balance of the earth’s climate system is altered by changes in the atmospheric abundance of greenhouse gases and aerosols, solar radiation and land surface properties. The IPCC (2007) reported:

> Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentrations are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture.

7.1.2 The greenhouse effect

Greenhouse gases (GHGs) affect climate by increasing the “greenhouse effect.” As GHGs concentrate in the Earth’s atmosphere, they trap heat by blocking part of the long-wave energy that the Earth normally radiates back to space; the resulting change in atmospheric energy balance affects both weather and climate (California Climate Action Registry, 2007).

7.1.3 Observed long-term changes

Scientists began measuring atmospheric CO_2 late in the nineteenth century. The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005 (IPCC, 2007). This increase is attributed to human activities, especially the burning of fossil fuels (coal, oil, natural gas) which have been locked within the earth’s crust for millions of years, and the clearing and burning of forests. Huge swaths of temperate forests in the northern hemisphere were cleared for agriculture in the 19^{th} and early 20^{th} centuries. In recent decades, large areas of the Amazon rain forest have been cleared for agriculture and cattle grazing.

The IPCC (2007) documented an unequivocal warming of the climate system, evidenced by observed increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level. Carbon dioxide (CO_2) is the most important anthropogenic greenhouse gas. The concentration of CO_2 in 2005 exceeded by far the natural range over the last 650,000 years, as determined from ice cores. The primary source of the increased CO_2 since 1750 results from fossil fuel use.

The carbon dioxide content of the atmosphere has steadily increased since the beginning of the industrial revolution. Samples of air, captured in core samples from the glacial ice of Greenland show no change in CO_2 content until about 300 years ago.

From 1850 to 1998, approximately 270 (+ 30) gigatons of carbon (GtC) have been emitted as carbon dioxide (CO_2) into the atmosphere from fossil fuel burning and cement production. About 136 (+ 55) GtC has been emitted as a result of land-use change, predominantly from forest ecosystems. This has led to an increase in the atmospheric content of carbon dioxide of 176 (+ 10) Gt C. Atmospheric concentrations increased from about 285 to 366 ppm (i.e., by ~28%), and about 43% of the total emissions over this time have been retained in the atmosphere. The remainder, about 230 (+ 60) Gt C, is estimated to have been taken up in approximately equal amounts in the oceans and the terrestrial ecosystems. Thus, on balance, the terrestrial ecosystems appear to have been a comparatively small net source of carbon dioxide during this period.

Observed long-term changes in climate include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones (IPCC, 2007).

Other general observations include (IPCC, 2007):

- Widespread changes in extreme temperature have been observed over the last 50 years. Cold days and nights have become less frequent, while hot days, hot nights and heat waves have become more frequent.
- The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapor.
- An average global temperature increase of approximately 1.4 degrees C has been observed in the last 50 years.

Despite the large increases in CO_2 in the atmosphere resulting from these activities, scientists have calculated that it is only about half of what they would expect from the amount of fossil fuel consumption and forest burning. There is some evidence that the missing CO_2 has been incorporated by increased growth of forests, especially in North America, and the increased amounts of phytoplankton in the oceans.

7.1.4 Abrupt climate change

Since publication of the 2007 IPCC report, the Climate Change Prediction Program of the U.S. Department of Energy's Office of Biological and Environmental Research (OBER) launched another study known as IMPACTS or Investigation of the Magnitudes and Probabilities of Abrupt Climate Transitions (U.S. Department of Energy, 2008).

IMPACTS is analyzing four factors that could hasten the “tipping point” toward irreversibility of global warming. These four factors include:

- Instability among marine ice sheets, particularly the West Antarctic ice sheet;
- Positive feedback mechanisms in subarctic forests and arctic ecosystems, leading to rapid methane release or large-scale changes in the surface energy balance;
- Destabilization of methane hydrates (vast deposits of methane gas caged in water ice), particularly in the Arctic Ocean; and
- Feedback between biosphere and atmosphere that could lead to megadroughts in North America.

The scientists will study these factors using a series of models, which they are building. The purpose is to predict more accurately how large-scale change may happen due to certain forcing mechanisms on a scale of years to decades, rather than centuries.

7.1.5 The carbon cycle

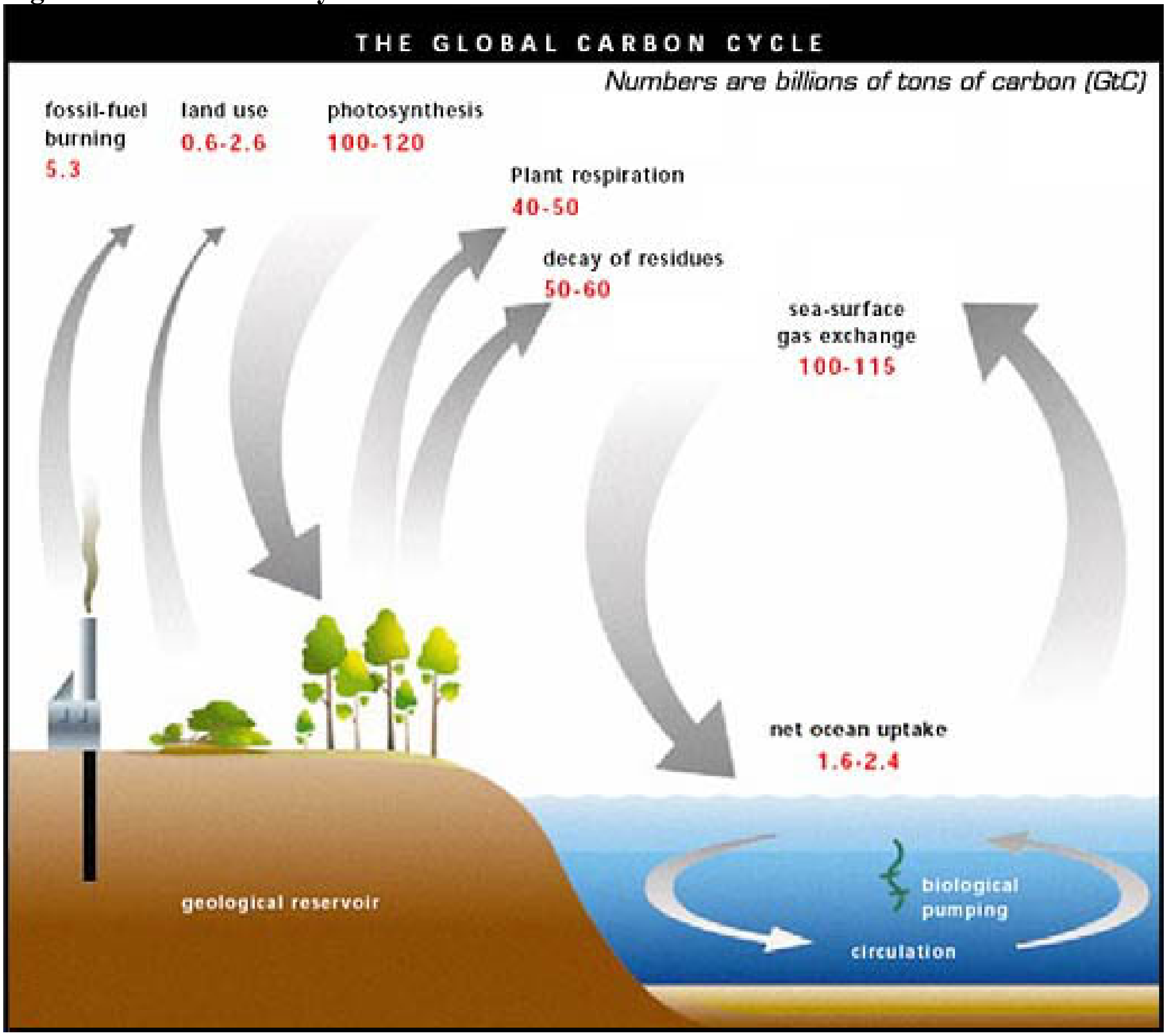
Carbon is an element found in all life forms, as well as in the atmosphere, the oceans, in minerals and fossil fuels stored in the earth’s crust. Just as there is a finite amount of water, which constantly moves through the hydrologic cycle, there is a finite amount of carbon, which moves through the carbon cycle. The carbon cycle works through a series of complex processes, including photosynthesis, respiration, combustion, and metabolism, as shown in Figure 7-1.

The Earth stores great quantities of carbon in the atmosphere, forests, soils, fossil fuels, and oceans. The earth’s reservoirs of carbon are found in the following major sinks:

- As organic molecules in living and dead organisms throughout the biosphere
- As the gas carbon dioxide in the atmosphere
- As organic matter in soils
- In the earth’s crust as fossil fuels and sedimentary rock deposits such as limestone, dolomite, and chalk
- In the oceans as dissolved atmospheric carbon dioxide and as calcium carbonate shells in marine organisms.

Although natural transfers of carbon dioxide are approximately 20 times greater than those due to human activity, they are in near balance, with the magnitude of carbon sources closely matching those of the sinks. The additional carbon resulting from human activity is the cause of the rise in atmospheric carbon dioxide concentration over the last 150 years.

Figure 7-1. The carbon cycle



Source: Oak Ridge National Laboratory

7.1.6 Restoring balance to the carbon cycle

Restoring balance to the global carbon cycle requires scaling back emissions of carbon dioxide into the atmosphere, and increasing carbon storage in natural carbon sinks.

Scaling back emissions primarily entails burning fewer fossil fuels. Slowing deforestation is another way to reduce emissions. When trees are cut and burned and the land converted to agriculture, the carbon stored in the forests and in the underlying soils is released to the atmosphere. This is estimated to be happening at roughly 1.6 gigaton (Gt) C/yr, producing an amount of carbon equal to approximately 20-25% of the total annual human-induced CO_2 emissions. Therefore, forest protection is a key component of any overall strategy to reduce atmospheric CO_2 concentrations.

Increasing carbon storage in natural carbon sinks can be done through land use change and forestry activities. When degraded lands are restored, carbon is removed from the atmosphere and stored in the biomass of trees through photosynthesis.

7.2 The two aspects of climate change: Mitigation and adaptation

Once the existence of climate change and its human causes are acknowledged, policy makers are left to address two looming aspects of climate change, mitigation and adaptation. Mitigation addresses the question, "How does society reduce its emissions of greenhouse gases to levels that will slow and eventually reverse the trend of global warming?" Scientific evidence suggests that policies with positive outcomes must be put into place shortly throughout the world in order to mitigate the levels of GHGs and to avert a global catastrophe. The other aspect of climate change, known as adaptation, addresses the question, "How does society prepare for the inevitable and increasing impacts to its citizens, its water resources, its infrastructure, and its natural landscapes?" The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007).

Clearly, both mitigation and adaptation must be addressed in tandem. No matter how successful society's efforts are at reducing GHG emissions, levels are already so high in the atmosphere that the impacts of climate change will be with us for many generations (IPCC, 2007).

7.2.1 District planning to date for climate change mitigation and adaptation

In April 2008, the District initiated and co-sponsored with other local public water agencies a local forum entitled "Tools for Addressing Climate Change and Local Water Resources" (SLVWD et al., 2008). Internationally acclaimed water experts spoke at the forum to address the following questions:

1. What are the potential impacts of climate change on local water resources?
2. How can local water resource managers plan for these potential impacts?
3. How can local water agencies reduce their carbon footprints?

Shortly following this well-attended forum, the District Board of Directors approved a climate change resolution that commits the District to address both aspects of climate change, mitigation and adaptation. DVDs of the forum are available at county libraries and on request at the District office.

In terms of mitigation, the Board's climate change resolution commits the District to reducing GHGs to levels defined in California law AB32. In compliance with the resolution, the District inventoried and reported in 2008 its greenhouse gas emissions for 2006 and 2007 to the California Climate Action Registry (CCAR). The CCAR accepted these reports in 2009, and the reports are publicly disclosed on CCAR website (CCAR, 2009). The inventory estimates the District's total GHG emissions at 611 metric tons of CO_2e (CO_2 equivalents). The inventory itemizes GHG emissions by category and by facility. The report reveals that approximately 71% of the District's total emissions can be attributed to indirect electricity, purchased from PG&E. The District's primary use of electricity is from ground-water pumping. The report is a useful tool for the District to target the most efficient areas for reduction of GHGs throughout its operations.

In terms of adaptation, the Board's climate change resolution also commits the District to addressing climate change in all planning documents in areas such as water conservation and demand management, watershed management, and water supply.

7.3 General projections of global climate change

Temperatures are projected to rise globally, although the projected temperature rise varies, depending on the model. The IPCC (2007) projects an average global warming of about 0.2 degrees C per decade for the next two decades. For the US, temperatures in the lower 48 states are projected to rise about 1/3 more than the global average (American Water Works Association, 2007). The IPCC (2007) projected the following general climate phenomena for the 21^{st} century:

- Warmer and fewer cold days and nights over most land areas.
- Warmer and more frequent hot days and nights over most land areas.

The IPCC (2007) projected, as very likely, the following general climate phenomena for the 21^{st} century:

- Warm spells/heat waves. Frequency increases over most land areas.
- Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas.

The IPCC (2007) projects a global mean sea level rise of up to 3.28 feet by 2100. More recent analyses estimate that sea level rise from warming oceans may be 1.4 meters (approximately 55 inches) over the next 100 years, or higher depending upon the rate at which glaciers and other ice sheets on land melt (San Francisco Bay Conservation and Development Commission, 2008),

7.4 General projections of climate change for California

In a literature review, Kiparsky and Gleick (2003) indicate that climate change will likely increase temperatures in California; increase climate variability, including storm intensity and drought frequency; raise sea level; and alter the effects of extreme events such as the El Niño/Southern Oscillation.

Snyder, Sloan, and Bell (2004) used a regional climate model to explore the potential impacts on the climate of California from increasing atmospheric CO_2 concentrations, from the perspective of the state's 10 hydrologic regions. They found that a doubling of CO_2 atmospheric conditions from pre-industrial values will lead to increased temperatures of up to 4 degrees C on an annual average basis, and of up to 5 degrees C on a monthly basis. Temperature increases were greatest in the central and northern regions. Precipitation results indicate drier winter for all regions, with a large reduction in precipitation from December to April and a smaller decrease from May to November. The result is a wet season that is slightly reduced in length. Their findings suggest that the total amount of water in the state will decrease, water needs will increase, and the timing of water availability will be greatly perturbed. Their results also indicate that the higher elevations tend to warm more rapidly than lower elevations (Snyder, Sloan and Bell, 2004).

According to the District's Water Supply Master Plan (Johnson, 2008; in progress), the following climatic conditions are predicted statewide for California:

- A 3 to 10°F temperature increase by 2100, with a greater proportion of this increase occurring in summer than in winter (Cayan et al., 2006).
- A continuation of mostly winter precipitation, virtually all from North Pacific winter storms. Precipitation may increase in winter while decreasing in spring (Cayan et al., 2006).

• Either relatively little change in overall precipitation statewide (Cayan et al., 2006) or a trend toward moderately decreased precipitation as indicated by a majority of model projections (California Department of Water Resources, 2006).

• A statewide reduction in average annual water availability of 27% and a resulting average annual reduction in water deliveries of 17 %, mainly due to changes in the nature, spatial distribution and timing of precipitation (e.g.; decreased snow pack; Medellin et al., March 2006).

• A relatively small increase in evapotranspiration, due to most of the temperature increase occurring at night (California Department of Water Resources, 2006).

Significant uncertainty remains about the nature and magnitude of potential climatic change in California (California Department of Water Resources, 2006).

7.5 Approaches of assessing climate change at the local scale

There are different approaches to assessing the implications for climate change at the local scale. The first is to downscale global climate models to the regional or local scale. The second is to use a hypothetical approach to assess local vulnerabilities to changes in rainfall and/or temperature (Gleick, 2007).

7.5.1 Downscaling from global climate models

While as many as 21 global climate models are in use, their practical use in downscaling climate projections to local areas is limited. Snyder et al. (2004) have developed a regional model for California that allows greater detail than is possible in global models, and that better describes the physical processes that occur at the local scale. While this model predicts average annual temperature increases everywhere in California, it predicts that the greatest average annual temperature increases will occur inland, with 2-3° F increase along the coast. Bell and Sloan (2006) predict more extreme climate events with a doubling of CO_2 conditions. This includes fewer rain days per year everywhere in the state, but with more intense rainfall in the spring, especially at higher elevations. Along with more concentrated rainfall, the risk of flooding is also predicted to increase (Bell and Sloan, 2006).

Throughout the state, regional models predict that total water availability will likely be reduced, with the timing of water delivery being disrupted, as the snow volume decreases and the rainy season is shortened. This scenario will likely result in increasing challenges to the storage and delivery of water throughout the state. As this happens, groundwater is expected to become increasingly important (Sloan, 2008).

Shortening of the water year is expected to increase fire potential, and to involve significant ecosystem impacts, so that conservation efforts will be more challenging (Sloan, 2008).

Yet, the prediction capability of even regional models is still uncertain, especially for coastal California, where the amount of precipitation depends on storm patterns off the Pacific Ocean. Storms may hit or miss the Santa Cruz Mountains, depending on unpredictable weather patterns.

7.5.2 Using localized hydrologic models

Hydrologic models capable of accepting hypothetical local rainfall and temperature data, to project outcomes in terms of streamflow and soil conditions, are useful for assessing vulnerabilities in different scenarios. However, such hydrologic models for the San Lorenzo River watershed are not currently available (Johnson, 2008; personal communication).

7.6 Adaptation: Climate change and water resource management

A U.S. government assessment (Gleick and Adams, 2000) of the potential consequences of climate change on U.S. water resources found that the country's water resources are seriously threatened by climate change.

To prepare for the impacts of climate change, Gleick (2008) urged water managers "to begin a systematic re-examination of engineering designs, operating rules, contingency plans, and water allocation policies."

According to the American Water Works Association (AWWA, 2007), higher temperatures and rising sea levels are likely to have several impacts on water resource management:

- Increased salinity in coastal aquifers and brackish surface water sources
- Increased risk of coastal flooding of water utility facilities
- Potential increases in coastal storm intensities

Where water utilities depend on snowpack for supply, there are further implications for water resource managers. Snowpack will be smaller and melt earlier, and this change will alter recharge of surface and groundwater sources. Santa Cruz County, like other coastal areas, will not be directly impacted by decreased snowpack .

Generally, far northern areas will likely be wetter, and far southern areas will likely be drier. Generally, winters are projected to be wetter, and summers are projected to be drier. Models also project that the eastern US will be wetter, while the plains and the western US will be drier. Beyond that, precipitation patterns are too complex to predict with any degree of certainty (AWWA, 2007).

A higher demand for water will likely result from more heat waves and dry days, coupled with more intense rainfall and runoff, with less infiltration. In addition, more intense rainfall and runoff could damage water infrastructure, such as intakes, pump stations, and treatment plants.

As precipitation is expected to occur in more intense periods, the increased run-off could potentially result in reduced groundwater recharge. This, in turn, could result in less groundwater storage and lower stream baseflows, both of which would impact the District and the entire watershed.

Changes in temperature and precipitation will change vegetation patterns in watersheds and recharge areas, which could lead to more sedimentation. Increased rainfall and runoff intensity could result in more sewage overflows, and upset the basis of stormwater management plans and TMDLs.

Increased temperature and sedimentation from more intense runoff could lead to eutrophication of source waters.

For more information about the potential impact of climate change on the District's water resources, refer to the District's Draft Water Supply Master Plan (Johnson, 2008; in progress).

7.7 Adaptation: Using climate change models to predict local vulnerabilities

The AWWA (2007) presented several case studies from around the country, showing how climate change models were downscaled to assess local vulnerabilities and prepare appropriate responses. These case studies demonstrate that impacts from climate change may have significant, and far-reaching impacts on water resources that may vary depending on local variables and conditions.

For example, the New York City (NYC) Department of Environmental Protection (DEP) used five global climate models (GCMs) and three IPCC emissions scenarios to downscale projections for the NYC watershed region. The NYC water system uses two large surface water sources, one of which is unfiltered. The DEP is concerned about ways in which climate change could impact water quality regulatory compliance, and how it could increase demand for water.

The DEP has three primary concerns about potential climate change impacts on water quality:

- Increased fecal coliform levels from migrating birds
- Increased number of turbidity events due to more intense rainfall
- Increased algal blooms in reservoirs due to more rainfall and temperature increases

First, if climate change impacts waterfowl migrations, fecal coliform levels from birds could increase. The DEP is tracking bird migrations and using microbiological fingerprinting to identify specific sources of fecal coliform in the watershed. Second, the DEP is concerned about a projected increased number of turbidity events resulting from more intense rainfall. The DEP plans on increasing turbidity monitoring throughout the watershed. Third, climate change could lead to increased algal blooms. Increased rainfall, nutrient loading, and temperature could lead to oxygen depletion, and taste, odor, and color problems. It could also increase fish kills, and disinfection by-products. In response to these concerns, the DEP installed tertiary treatment, and is developing a watershed program to control agricultural nutrient sources. It is also fine-tuning its chlorination process.

The New York City DEP is also concerned that more frequent droughts will cause demand to exceed supply. Anticipated impacts are enforcement of conservation restrictions, balance between water storage and flood control, and difficulty meeting temperature and flow requirements for stream releases. To address these concerns, the DEP is reducing demand through low-flow devices and metering, developing water re-use systems, and evaluating new sources.

7.8 Adaptation: Preparing for historic local extreme climate events

While large cities like New York may have the resources to downscale global climate models to estimate local impacts on their water resources, there are other efficient and less expensive approaches that small districts, such as San Lorenzo Valley Water District, can use. One such approach is to prepare for or adapt to climate change by assessing conditions documented in past extreme climate events and to incorporate practices to address these conditions, should they re-occur. For example, water conservation programs could be implemented earlier in the year to address a higher probability of drought. Likewise, erosion control practices could be implemented in areas of the watershed that are prone to erosion, in anticipation of more intense precipitation events.

According to Johnson (2008, in progress):

> The most significant expected result of climate change in California, reduced snow pack, will not directly impact coastal areas relying solely on local water supplies, such as Santa Cruz County. However, the central coast appears to be located near the boundary between

an increasingly dry south and a possibly wetter north. Furthermore, increased spring and summer temperatures will result in increased water demand.

Johnson (2008, in progress) summarized predictions about the local impacts of climate change:

• During the next 50 to 100 years in Santa Cruz County, temperatures will rise 8° to 9°F and rainfall will decrease by nearly half between February and April, and summers will be hotter with increased water demand, according to researchers from the UCSC Climate Change and Impacts Laboratory (Santa Cruz Sentinel, November 12, 2006).

• Although unlikely, the possibility of sudden climatic change exists as evidenced by extreme droughts apparent in extended records, occurring over large areas and several decades, possibly due to oscillating ocean conditions. Sudden cooling could be brought on by volcanic eruptions or other causes of atmospheric debris (CDWR, July 2006).

• The increased variability of annual rainfall over 10-year periods suggests a potentially greater frequency of extremely wet and/or dry years. Thus, even if little change in mean annual rainfall occurs, it may become more difficult to effectively capture and/or store the increased proportion of average rainfall that occurs during very wet years.

The increased variability also suggests a potentially reduced occurrence of extended droughts. For example, one of the lowest periods of historic variability occurred during the prolonged drought of 1917-1935.

7.9 Forests, climate change, and carbon sequestration

Climate change is altering forests both directly—from changing temperature and moisture—and indirectly— through shifting patterns of fire, insects, and disease.

At the same time, forests help to mitigate climate change. Forests absorb CO_2 from the atmosphere and store it in wood and forest soils. Forests also release CO_2 to the atmosphere whenever land is converted to non-forest uses, or when forests are logged, burned, or suffer from outbreaks of insects and disease.

All living forests both absorb and release CO_2. The relative balance between these two processes determines whether a forest is a source or sink of CO_2.

Climate scientists have identified the next few decades as a crucial period for avoiding potentially catastrophic changes in climate, so immediate changes in traditional forest management policies and practices are called for. Increased time between harvests is especially important, as old-growth forests store much more carbon than younger forests.

Increasing either the frequency or severity of disturbance will generally lower carbon stores. Annual carbon emissions in the U.S. from logging and wood processing exceed those from forest wildfires (Harmon and Krankina, 2008).

Carbon stores in wood products are released over time through decay at an average rate of 2% annually, according to Pacific Forest Trust (2007). The GHG emissions rate of wood products is similar to that of decaying wood in old-growth forests (Harmon and Krankina, 2008). Perhaps more importantly, the declining average age of harvest *rotations* (length of time between harvests) means that less carbon is being stored in forests than in the past, as older forests store more carbon than younger forests (Harmon and Krankina, 2008). While younger forests may, on average, grow at faster rates than older forests, older forests store significantly more carbon per acre than younger ones, and even old-growth forests continue to sequester carbon from the atmosphere (Luyssaert, et al., 2008).

7.9.1 Forests as carbon sinks

Because terrestrial ecological systems retain live biomass, decomposing organic matter and soil, they play an important role in the global carbon cycle. Carbon is exchanged naturally between these systems and the atmosphere through photosynthesis, respiration, decomposition, and combustion. Human activities change carbon stocks in these pools and exchanges between them and the atmosphere through land use, land-use change, and forestry, among other activities. Substantial amounts of carbon have been released from forest clearing at high and middle latitudes over the last several centuries, and in the tropics during the latter part of the 20th century.

Forests are natural sinks of carbon. There is carbon uptake into both vegetation and soils in terrestrial ecosystems, as shown in Table 7-1. Forests absorb carbon dioxide from the atmosphere and store it as carbon in their biomass. When forests are converted to other uses, the carbon stored in the forest biomass, is released into the atmosphere both immediately and over time (IPCC, Special Report on Land Use, 2007). Carbon emissions can also be avoided by conserving and/or protecting forests, as shown by the projects summarized in Table 7-2.

Table 7-1. Global carbon stocks in vegetation and soil carbon pools down to a depth of 1 m.

Biome	Area (10^9 ha)	Global Carbon Stocks (Gt C)		
		Vegetation	*Soil*	*Total*
Tropical forests	1.76	212	216	428
Temperate forests	1.04	59	100	159
Boreal forests	1.37	88	471	559
Tropical savannas	2.25	66	264	330
Temperate grasslands	1.25	9	295	304
Deserts and semideserts	4.55	8	191	199
Tundra	0.95	6	121	127
Wetlands	0.35	15	225	240
Croplands	1.60	3	128	131
Total	15.12	466	2 011	2 477

Note: There is considerable uncertainty in the numbers given, because of ambiguity of definitions of biomes, but the table still provides an overview of the magnitude of carbon stocks in terrestrial systems.

Source: IPCC Special Report on Land Use, Land-Use Change and Forestry, 2007.

Table 7-2. Emissions avoidance through conservation of existing stocks: Forest conservation-protection

Project and host country	Dominant activity	Project information[a]	Area (ha)	Estimated lifetime CO_2 benefits (000 t C)	Estimated CO_2 benefits per hectare (t C ha^{-1})[b]
Amazon Basin, AES/Oxfam, Ecuador, Bolivia, Peru	Protection, land tenure	1992; USA	1,500,000	15,000	10
Paraguay Forest Protection, AES, Paraguay	Protection	1992; USA	58,000	14,600	252
ECOLAND, Costa Rica	Protection	16; 1995; USA	2,500	366	146
Rio Bravo, Belize	Protection, forest management	40; 1994; USA	14,000 protection; 46,406 forest management	2,400	39
Noel Kempff, Bolivia	Protection from logging and deforestation	30; 1996; USA	~696,000	4,000-6,000	7
Protected Area Project, Costa Rica	Preservation via purchase and land title enhancement	25; 1997; USA	530,000	4,600-8,900	17
Virilla Basin Project, Costa Rica	Protection, reforestation	25; 1997; Norway	52,000	231	4
Subtotal Range (or Average)		*27*	*2,852,500*	*41,200-47,500*	*4-252*

[a] Project lifetime (in years); date initiated; investor country.

[b] Estimated CO_2 benefits per hectare and totals for projects are generally reported by project developers, do not use standardized or consistent GHG accounting methods, generally only report CO_2 (not other GHGs), and have not been independently reviewed. The wide range of estimates for conservation/protection projects results from the type of activity (e.g., avoided logging or avoided deforestation) and from a large project area with only a fraction affected by the activity per year

Source: IPCC Special Report on Land Use, Land-Use Change and Forestry: From Table 5-2: Overview of selected LULUCF AIJ pilot program and other projects, in at least early stages of implementation.

The US EPA acknowledges forest practices that affect greenhouse gases, as shown in Table 7-3.

Table 7-3. Forestry practices that sequester or preserve carbon

Key Forestry Practices	Typical definition and some examples	Effect on greenhouse gases
Afforestation	Tree planting on lands previously not in forestry (e.g., conversion of marginal cropland to trees).	Increases carbon storage through sequestration.
Reforestation	Tree planting on lands that in the more recent past were in forestry, excluding the planting of trees immediately after harvest (e.g., restoring trees on severely burned lands that will demonstrably not regenerate without intervention).	Increases carbon storage through sequestration.
Forest preservation or avoided deforestation	Protection of forests that are threatened by logging or clearing.	Avoids CO_2 emissions via conservation of existing carbon stocks.
Forest management	Modification to forestry practices that produce wood products to enhance sequestration over time (e.g., lengthening the harvest-regeneration cycle, adopting low-impact logging).	Increases carbon storage by sequestration and may also avoid CO_2 emissions by altering management. May generate some N_2O emissions due to fertilization practices.

Source: US EPA, 2006

Different approaches have been proposed to address the duration of projects in relation to their ability to increase carbon stocks and decrease greenhouse gas emissions. They should be maintained in perpetuity because their "reversal" at any point in time could invalidate a project; and (ii) they should be maintained until they counteract the effect of an equivalent amount of greenhouse gases emitted to the atmosphere (IPCC Special Report on Land Use, 2007).

Techniques and tools exist to measure carbon stocks in project areas relatively precisely depending on the carbon pool. However, the same level of precision for the climate change mitigation effects of the project may not be achievable because of difficulties in establishing baselines and due to leakage. Currently, there are no guidelines as to the level of precision to which pools should be measured and monitored. Precision and cost of measuring and monitoring are related. Preliminary limited data on measured and monitored relevant aboveground and below-ground carbon pools to precision levels of about 10% of the mean at a cost of about US$ 1–5 per hectare and US$ 0.10–0.50 per ton of carbon have been reported. Qualified independent third-party verification could play an essential role in ensuring unbiased monitoring (IPCC, Special Report on Land Use, 2007).

7.10 The California Climate Action Registry and carbon credits for forestland owners

California Assembly Bill 32 (AB 32), also known as the "California Global Warming Solutions Act of 2006," was the first law to comprehensively limit greenhouse gas (GHG) emissions at the state level. AB 32 was passed by Legislature, signed by the governor, and became law January 1,

2007. It established annual mandatory reporting of GHG emissions for significant sources and sets emission limits to cut the state's GHG emissions to 1990 levels by 2020.

California Senate Bill 527, enacted in 2001, provided for a voluntary, non-profit California Climate Action Registry (CCAR) to assist commercial and governmental entities that operate in the state to establish GHG emissions baselines. Any future GHG emission reduction requirements would apply against these baselines.

The CCAR is a non-profit public/private partnership that serves as a voluntary greenhouse gas (GHG) registry to protect, encourage, and promote early actions to reduce GHG emissions. The Registry provides consistent GHG reporting standards and tools for organizations to measure, report, certify, and reduce their GHG emissions in California and/or the U.S.

AB 32 requires that the California Air Resources Board incorporate the standards and protocols developed by the CCAR when developing the state's mandatory reporting program. CCAR members who have entered their carbon emissions to CCAR standards will have their data recognized and accepted by the state's future reporting program.

The purposes of the CCAR are as follows:

- To enable participating entities to voluntarily measure and record GHG emissions made after 1990 in an accurate manner and consistent format that is independently certified;
- To establish standards that facilitate the accurate, consistent, and transparent measurement and monitoring of GHG emissions;
- To help various entities establish emissions baselines against which any future federal GHG emissions reduction requirements may be applied;
- To encourage voluntary actions to increase energy efficiency and reduce GHG emissions;
- To ensure that participating organizations receive appropriate consideration for certified emissions results under any future state, federal or international regulatory regime relating to GHG emissions;
- To recognize, publicize, and promote participants in the Registry; and
- To recruit broad participation in the process (CCAR, 2007).

7.10.1 The Climate Registry

In 2008, the CCAR announced that it would begin transitioning into a national non-profit known as the Climate Registry, a nonprofit organization that provides meaningful information to reduce greenhouse gas emissions. The Climate Registry adopted many of the same policies and protocols of the CCAR, though it has not yet adopted the CCAR's forestry protocols. It establishes consistent, transparent standards throughout North America for businesses and governments to calculate, verify and publicly report their carbon footprints in a single, unified registry (The Climate Registry, 2009). Members of CCAR have been invited to join The Climate Registry.

7.10.2 CCAR Forest Protocols

The CCAR released draft protocols in December 2008 for landowners of at least 100 acres of forestland in California. At the time of this writing, the California Air Resources Board (CARB) was revising the CCAR protocols for final adoption by the state, but at the time of this writing, the final draft has not been released.

7.10.3 Carbon credits for forest landowners conserving forests

Note: The following discussion addresses CCAR's forest protocols which are being revised at the time of this writing for adoption by the CARB.

The CCAR protocols allow for forest-owning entities to account for and report the biological emissions and carbon stocks of their forests over time. Forest owners who are already members of CCAR, and who have reported their GHG emissions, can register forest projects to quantify and monitor GHG reductions, or net carbon sequestration, resulting from specific activities, such as reforestation, improved forest management practices, and avoided deforestation. The CCAR's Forest Project Protocols follow a set of principles and standards that ensure the rigor and legitimacy of the greenhouse gas emissions reduction credits generated by the project activity:

> **Principle one:** Establish a baseline to compare measurable gains in against which to measure emissions reductions. This requires carbon experts to conduct a comprehensive inventory of carbon stores within the project area.
>
> **Principle two:** Provide proof that the project's emission reductions are additional to what would have happened without the project existing.
>
> For example, by preventing logging of a project area, as scheduled under a filed timber harvest plan, emissions from future logging operations are eliminated, and carbon sequestration is allowed to continue.
>
> **Principle three:** Ensure the permanence of the project's carbon stores.
>
> A permanent conservation easement on the project area legally establishes restrictions on specific carbon-emitting activities in perpetuity.
>
> **Principle four:** Assure against leakage, or the occurrence of emissions elsewhere due to the project activity.
>
> A forest landowner must have all of its land holdings assessed for carbon storage and emissions in order to ensure that the restricted carbon-emitting activity will not simply be displaced to other lands it owned, which would cancel out the benefits of the project.
>
> **Principle five:** Obtain third-party certification of the Forest Project by Registry-approved Forest Certifier.

The Pacific Forest Trust (PFT) was the first land trust in California to purchase conservation easements to address the problem that US forestlands are a declining carbon sink and contribute significantly to the release of carbon dioxide into the atmosphere. PFT's conservation easements generally allow logging to continue, but at less aggressive levels than the State Forest Practice Rules allow.

Sempervirens Fund (2007) was the first land trust to establish a forest carbon project to exclusively embody the management goals of protection and preservation under the standards set forth by the CCAR. Sempervirens Fund entered into an agreement with Pacific Gas & Electric Company to sell 14 years of carbon credits to the utility as part of PG & E's Climate Smart Program (Sempervirens Fund, 2007) .In exchange, Sempervirens agreed to place a conservation easement on the 202-acre Lompico Headwaters project area, which permanently prevents all logging on the property and allows for the continued sequestration of carbon in perpetuity.

A forest carbon market would create the private financial incentive to conserve forests and reduce carbon loss. Such a carbon market would monetize carbon stored in forest biomass, as other carbon dioxide emission sectors would seek to meet their emission reduction goals through the purchase of emission offsets or carbon "credits" from land trusts and other entities that are able to provide these credits.

Private forest landowners could sell their forest carbon stores as credits to buyers and maintaining these forest carbon stores over time. Conservation easements would require forest landowners to keep their forests and grow them older before they are harvested.

To ensure the quality of carbon credits, a standardized carbon accounting system would use generally accepted accounting principles, including annual debits and credits, with adjustments for risk. Standardized rules would ensure that carbon credits developed in the U.S. are accepted in other carbon markets. These standardized rules would reflect the following characteristics, according to PFT (2007):

- Additionality: Carbon sequestration gains are calculated as *additional* to those that would have accrued from "business-as-usual" forest management, under the Forest Practice Rules. This assures net gains in forest carbon stores.

- Permanence: To earn credits in the carbon accounting system, forests must be managed for the *permanent* sequestration of carbon. This ensures that tons stored today are not released again and that forest loss is not simply delayed for a time. Hence, there must be a requirement for permanent deed restrictions or conservation easements.

- Verifiability: The forest carbon accounting system must be accurate and must ensure timely third-party *verification* of forest carbon gains and losses.

- Co-benefits: Forest carbon projects must avoid environmental harm and result in environmental and social co-benefits, such as habitat restoration, biodiversity enhancement, watershed protection and sustainable timber economies.

Conversion of natural forest ecosystems (or non-forest ecosystems like wetlands or grasslands) to forest plantations should not be eligible for credit.

PFT envisions that a forest carbon market would achieve multiple conservation co-benefits:

> As more forest is preserved and grows older, forest biodiversity is enhanced--making forests more resilient. In addition, older preserved forests provide habitat for endangered species and enhance water quality. Forest landowners would be encouraged to provide these additional conservation benefits if they received an economic benefit in return, and a carbon market can provide such dividends (PFT, 2007).

7.10.4 The District's forestland, carbon sequestration, and potential carbon credits

The District owns ≈ 1,800 acres of forest watershed, which is managed toward old-growth to maximize water quality. Carbon sequestration is a substantial co-benefit of these management practices, since large, old redwood trees sequester tons of carbon from the atmosphere. Now that the District has certified its GHG emissions with the CCAR, it may be eligible to use the carbon stores in its forests as carbon credits in future markets. In order to do so, the District would need to inventory the carbon stores in its forest lands, and have that inventory confirmed by a certified third party verifier.

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