Chapter 3 – Affected Environment

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3.1 Introduction

This chapter provides an understanding of both the general environmental setting of the planning area and a more focused description of those resources with the potential to be affected by the implementation of the FMP alternatives. Section 3.2, Project Setting, has been included to provide the background necessary to understanding the geographic, demographic, and geologic environment in which the park is set. The remainder of the chapter is the Affected Environment discussion required by NEPA (CEQ Regulations, § 1502.15); it focuses on the current condition of only those elements of the environment that could be significantly affected by implementation of the FMP alternatives. Through the scoping process, it has been determined that the resources with potential to be significantly affected are watershed processes (soils, hydrology, water quality and aquatic habitat), air quality, vegetation, wetlands, wildlife, special status species, cultural resources, visitor experience and visitor use, human health and safety, park operations, and socioeconomics.

3.2 Project Setting

Overview of the Planning Area

The planning area for the GGNRA FMP is located in central California, in the three westernmost counties that comprise the nine-county San Francisco Bay Area – the fifth largest metropolitan area in the United States. In addition to lands within GGNRA, the planning area for the FMP includes Muir Woods National Monument and Fort Point National Historic Site, both of which are managed by GGNRA.

The planning area consists of approximately 15,000 acres of national park land under the direct management of GGNRA. The parklands include beaches, marshes, coastal cliffs and headlands, marine terraces, coastal uplands, woodlands, old-growth and second-growth forests, several extensive and historically significant former military installations, and approximately 59 miles of shoreline on the Pacific Ocean and on San Francisco Bay.

The GGNRA parklands border on lands with a wide range of ownership type and land use. Adjacent land use is a mix of private residential and agricultural lands, publicly held watershed, and parks and open space. Apart from the approximately 59 miles of shoreline, approximately 40 miles of GGNRA boundary adjoins residential communities in the three counties. In Marin County, adjacent lands include the unincorporated communities of Marin City, Muir Beach, Stinson Beach, Tamalpais Valley, and Homestead Valley, and the incorporated towns of Mill Valley and Sausalito in southern Marin. Parklands in San Francisco adjoin the City and County of San Francisco as well as the Presidio of San Francisco, managed by the Presidio Trust. San Mateo parkland is mostly located in the northern part of the county adjacent to the city of Pacifica; the Phleger Estate is currently the only GGNRA parcel in southern San Mateo County.

GGNRA lands range from landmarks recognized nationwide to areas largely serving adjacent residential communities. National parks more remote from urbanization often see the gradual development of one or more gateway communities at park entrances that provide services and accommodations for both park visitors and staff. By contrast, GGNRA was created in 1970 as an amalgamation of surplus federal lands in the midst of the rapidly developing west bay counties of San Mateo, San Francisco, and Marin. Parcels have been added to GGNRA through the transfer of lands from other federal agencies (such as the U.S. Army) or outright purchase when suitable lands become available. In this urban setting, it has not always been possible to acquire lands that are adjacent to other holdings; some park parcels are close to but not contiguous with other GGNRA lands. This creates a very convoluted boundary for parts of the park, as well as a varied range of adjacent land uses. Some GGNRA lands form more than one boundary of an adjacent residential area, while in other parts of GGNRA residential development nearly surrounds the park parcel. This situation lends itself to many cooperative efforts, including programs to reduce wildland fire risk along the common boundaries.

The section of the Bolinas Ridge south of the Bolinas-Fairfax Road comprises the northernmost portion of the planning area. Bolinas Ridge trends northwest to southeast and parallels the east side of the Olema Valley, Bolinas Lagoon, and the San Andreas Fault Zone. Its southwest-facing slope is primarily grassland and shrub, with east-facing slopes forested with Douglas-fir and coast redwood. The section of the ridge north of the planning area was included in the PRNS FMP as the lands are managed by PRNS under an agreement between the two parks and the NPS Pacific West Regional Office.

Adjacent to parklands in western Marin are properties managed by Audubon Canyon Ranch, California State Parks, the Marin Municipal Water District, and the Green Gulch Farm belonging to the San Francisco Zen Center. Marine boundaries are shared with the Gulf of the Farallones National Marine Sanctuary (NMS), the Monterey Bay NMS, and the Bolinas Lagoon Preserve.

Generally, the more densely developed regions of the Bay Area are around the bay itself, with smaller cities, towns, open spaces and agricultural areas in an outer ring around this urban core. For example, 48 percent (159,044 acres) of the 332,800 acres in Marin County is held as parks, open space, and watershed (Marin County Community Development Agency 2002). Thirty-six percent (119,808 acres) of the county is in agricultural use. Only 11 percent of the land in Marin County is developed, and only 5 percent of the county has future development potential. While the Highway 101 corridor in eastern Marin is heavily developed, western Marin is primarily rural with scattered, small, unincorporated towns providing services for agriculture, local residents, and tourism. Roughly 90 percent of the 250,000 residents of Marin County live in the eastern half of the county along the major transportation corridor, Highway 101.

The City and County of San Francisco, with a population of approximately 800,000 residents, covers 46.7 square miles. The city is built out with the exception of redevelopment areas, small isolated parcels, and undeveloped hilltops. GGNRA manages 1,013 acres within the city limits, including the 29 acres of Fort Point National Historic Site at the northwestern tip of the San Francisco peninsula. GGNRA also manages Area A of the Presidio of San Francisco, comprising 312 coastal acres on the northern and western sides of the former military base. Approximately 1.5 million visitors came to the Civil War-era Fort Point in 2002 and 2003.

Other lands managed by GGNRA in San Francisco include Lands End, Sutro Heights, Ocean Beach, and Fort Funston. Lands End lies in the rugged northwest corner of the San Francisco peninsula between Lincoln Park and the Cliff House. The area is heavily vegetated by a mix of landscape plants and nonnative and native coastal scrub species. At the southern end of Lands End lies the Sutro Baths ruins and the newly reconstructed Cliff House. Overlooking both of these is Sutro Heights, where Adoph Sutro built an estate in the 19th century, now represented by scattered ruins, dense Monterey cypress, and other remnant landscaping. The relatively flat and wide Ocean Beach extends roughly three miles from the Cliff House south to Fort Funston. Fort Funston encompasses approximately 250 acres and is vegetated by iceplant, eucalyptus trees, and native coastal scrub, with scattered remains of military fortifications dating from the Spanish Civil War through World War II.

Lands in San Mateo County managed by GGNRA include Sweeney and Milagra Ridges, Mori Point, Pedro Point, Cattle Hill, and several other smaller parcels in and around the coastal city of Pacifica in northern San Mateo County. GGNRA's Phleger Estate is north of the town of Woodside in southern San Mateo County.

Four areas of residential development in the cities of San Bruno and Pacifica are within the wildland urban interface area of Sweeney Ridge. The subdivisions are either directly adjacent to parkland or separated by relatively small intervening open space parcels. Neighborhoods in the Sweeney Ridge interface include Pacifica's Vallemar, Sharp Park, and Park Pacifica neighborhoods; the Pacific Heights neighborhood of San Bruno; and Skyline Junior College.

Milagra Ridge is almost fully surrounded by medium-density neighborhoods of single-family detached and single-family attached homes. Only the extremely steep slopes in the Milagra Creek drainage north of the park remain undeveloped. Parklands at the southern end of Pacifica at Pedro Point are directly to the south and adjacent to medium-density, single-family detached housing. The interface zone, including part of the residential area, is vegetated by a large, dense eucalyptus woodland. The new park acquisition at Cattle Hill is bordered to the north by the Vallemar neighborhood and to the south by the narrow, streamside, eastern section of the Rockaway Beach neighborhood. There is very limited low-density residential development on the 0.25-mile interface of the Raymunda Road area of northern Woodside with Phleger Estate, and the longer 1.25-mile interface between the western edge of Phleger Estate and the rural residential neighborhood of King's Mountain on Skyline Boulevard.

Special Designation Areas

Golden Gate Biosphere Reserve

GGNRA is part of the Golden Gate Biosphere Reserve, which includes over two million acres of protected lands and waters and extends through the central California coastal region from the Bodega Research Reserve of the University of California at Davis in the north to Stanford University's Jasper Ridge in San Mateo County in the south. Seaward, the Biosphere Reserve extends out from the shore approximately 30 miles to the edge of the Continental Shelf and includes the Farallon Islands. Within San Francisco Bay it includes Angel Island and Alcatraz Island. The Biosphere Reserve also includes lands managed by the NPS, California State Parks, Marin Municipal Water District, and San Francisco Public Utilities Commission, and the Gulf of Farallones and Monterey Bay National Marine Sanctuaries.

Since 1971, the United Nations has designated over 400 "biosphere reserves" in over 95 countries to serve as models of how to protect the extraordinary resources of wildlands and protected areas while ensuring their nondestructive human use and enjoyment. Designation of the Golden Gate Biosphere Reserve as an international biosphere reserve confers international recognition of its importance to the conservation of biodiversity and sustainable development, and to research and education relevant to these areas. It is administered in cooperation with the United Nations Educational, Scientific, and Cultural Organization (UNESCO), as part of its Man and the Biosphere (MAB) program.

Special Ecological Areas (SEAs)

GGNRA's Natural Resources Section of the Resource Management Plan (1999b) designated nine Special Ecological Areas (SEAs) in the park. An SEA is the identified area in each ecological community type that is most biologically intact and diverse and, in the case of grassland and lagoon in the park, represents the only example. SEAs were selected for their biological values. Communities currently represented include perennial grassland, coastal scrub, chaparral, oak woodland, redwood forest, foredune community, coastal strand community, serpentine grassland, riparian forest, estuarine community, fresh water pond community, aquatic stream community, and the intertidal community. The creation of SEAs is not intended to discount the biological value of other natural resources zones within GGNRA and does not exclude management activities in other park areas. One such area in each plant community was designated to ensure the protection and maintenance of ecological diversity and processes.

Preservation of natural resources and processes is the highest priority in these areas. Other uses, therefore, must be documented as having little to no impact on these particular ecosystems prior to use approval. Dogs, bicycles, and offtrail hiking are to be excluded from these areas due to possible conflict with vegetation and wildlife. Equestrian use and park vehicle traffic are limited.

Management programs for concerns such as nonnative species control, erosion, and water quantity and quality have a high priority for implementation in these areas. Emphasis will be made to expand this management into the buffer areas bordering SEAs.

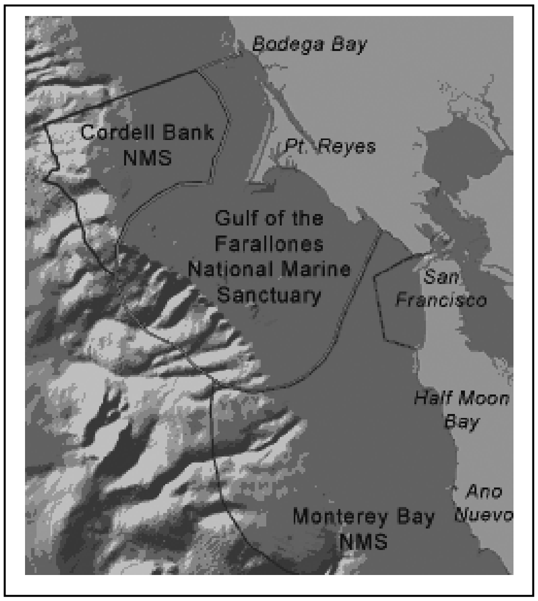
Identified SEAs include:

- The northeast-facing slope of the Muir Woods National Monument redwood forest community.
- The Wolf Ridge area between the Gerbode and Tennessee valleys for the perennial grassland and coastal scrub plant communities.
- The Rodeo Lagoon estuarine community.
- The Bolinas Ridge chaparral community and oak woodland community.
- Presidio serpentine for the rare serpentine grasslands that are the last refuge for many rare and endangered native plant species.
- The Crissy Field dune community.
- The Baker Beach coastal strand community.

- Redwood Creek aquatic, stream, and riparian communities.
- Intertidal communities in Slide Ranch (north end) and Bird Rock (in the Marin Headlands).

National Marine Sanctuaries

Two National Marine Sanctuaries overlap GGNRA jurisdiction along the Pacific coastline. The Gulf of the Farallones National Marine Sanctuary (GFNMS) protects an area of 1,255 square miles off the northern and central California coast. Within the portions of GGNRA addressed in the FMP, the waters up to mean higher high tide line from Stinson Beach to Slide Ranch in Marin County are part of the GFNMS. The Monterey Bay National Marine Sanctuary (MBNMS) extends along GGNRA's shoreline from Slide Ranch south to Point Bonita in Marin County, and then juts seaward outside of GGNRA's boundary south until it meets the shoreline again at Devil's Slide in San Mateo County. MBNMS encompasses 5,322 square miles of ocean and 276 miles of coastline and extends an average of 30 miles offshore. These marine sanctuaries were established for the purpose of resource protection, research, education, and public use. The marine sanctuaries harbor some of the most diverse and productive marine ecosystems in the world, including 33 species of marine mammals, 94 species of seabirds, 345 species of fish, and numerous invertebrates and plants. Sanctuary regulations prohibit discharge or depositing, from beyond the boundary of the sanctuary, any material or other matter that subsequently enters the sanctuary and injures a sanctuary resource or quality (with limited exceptions for some marine activities).



National Marine Sanctuaries in Bay Area

Bolinas Lagoon, Wetland of International Importance

Bolinas Lagoon, a 1,100-acre wetland located along the San Andreas Fault between the towns of Bolinas and Stinson Beach in Marin County, was designated a Wetland of International Importance in 1998 by the Ramsar Convention on Wetlands. The Convention on Wetlands, signed in Ramsar, Iran in 1971, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. Bolinas Lagoon is considered internationally important because it is a representative, rare, or unique example of a natural or near-natural wetland type found within the biogeographic region; it regularly supports more than 20,000 waterbirds; and it is an important source of food for fishes, spawning ground, nursery; and/or migration path on which fish stocks depend.

The majority of the lagoon is held in public ownership by the County of Marin and GGNRA. Bolinas Lagoon is an Open Space Preserve managed by the Marin County Open Space District. The area is a public open space, used predominantly for recreation. Thousands of people visit the area annually.

Activities include bird watching, nature photography, fishing, clamming, shrimping, boating, use of manually powered watercraft (kayaks, canoes, sailboards), bicycling, walking, jogging, and picnicking. A marine laboratory building and dock owned by the College of Marin are located near the mouth of the lagoon. Scientific facilities are also located at the PRBO Conservation Science Center (formerly known as the Point Reyes Bird Observatory) and the Audubon Canyon Ranch (ACR), a private, nonprofit environmental protection, education, and research organization. The lagoon's eastern shore and much of the Bolinas Lagoon watershed lie within GGNRA. The entire lagoon up to mean higher high water is part of the Gulf of the Farallones National Marine Sanctuary.

The lagoon is a tidal embayment with estuarine habitats including subtidal channels, intertidal flats, and emergent salt marsh. These habitats are bordered by sandbars, beaches, freshwater streams, and riparian forest. The lagoon's principal estuarine habitats are all undergoing significant changes in total area and relative amounts. Between 1968 and 1988, the rate of sediment accumulation and loss of tidal prism resulted in conversion of subtidal habitat to intertidal, and intertidal to emergent marsh and upland habitat. The continued increase in sedimentation and loss of tidal prism will result in the narrowing and loss of tidal channels. This will lead to a loss of total estuarine habitat and cause significant changes in the diversity and abundance of lagoon life and ecological functions. Bolinas Lagoon is currently the subject of a study to examine the need, feasibility, and alternative strategies for restoring tidal prism to the system, which has been subject to high levels of sedimentation in recent decades.

Bolinas Lagoon has been subject to numerous research studies, including the behavior and habitats of harbor seals and the ecology of shorebirds. Bird numbers have been monitored since the 1970s. Current research includes a study to determine the relative contribution of sediment to the lagoon from eight perennial creeks. This information will be used to determine erosion control strategies for the Bolinas Lagoon watershed. Monitoring would be conducted following any catastrophic fire event to help direct rehabilitation efforts.

The Bolinas Lagoon Resource Management Plan was developed in 1981 and updated in 1996. Proposed conservation measures include watershed management geared toward reducing sediment inputs, and dredging to remove accumulated sediment and to promote sediment removal from the lagoon via tidal scouring. A public awareness program includes nature tours, information brochures, and public archives.

Geology and Seismicity

GGNRA is located in a seismically active zone. The San Andreas Fault Zone (SAFZ) extends northwest from Mussel Rock in Pacifica through Bolinas Lagoon, the Olema Valley, and Tomales Bay. Southeast of Mussel Rock, the SAFZ crosses the ridgeline above Pacifica and is clearly expressed by Crystal Springs and San Andreas reservoirs in the San Francisco watershed property to the southeast. The SAFZ forms the active tectonic boundary between the Pacific Plate and the continental North American Plate. The Pacific Plate is thought to have displaced as much as 94 miles (150 kilometers) to the northwest in the last 11 million years (Clark and Brabb 1997). Recent investigation within the SAFZ has led researchers to believe that large-scale land movement events may have a recurrence interval of approximately one major event every 250 years (Zhang et al., 2003). Due to different bedrock rock types, the geomorphology, hydrology, soils, and plant communities east of the SAFZ may differ in many ways from conditions to the west. For example, the exposed granite of Montara Mountain on the Pacific Plate differs from the sedimentary deposits lying to the east.

Bedrock parent materials of the Franciscan Formation can be jumbled as a result of the grinding movement along the SAFZ. The Franciscan Formation is believed to have originated as ocean floor deposits 80 to 140 million years ago. The rocks were greatly deformed and partly metamorphosed from the extreme pressure of plate tectonics wherein the ocean floor (the Pacific Plate) is thrust under the western edge of the North American Plate, resulting in a landscape of easily eroded, sheared, and crushed sandstone and shale, with occasional blocks of more resistant rock forming prominent outcrops. The Franciscan Formation is mostly composed of greywacke, sandstone, and shale with different grades of metamorphosis. Some parts of the formation are a mélange, including highly metamorphosed, low-grade mudstone, siltstone, and sandstone with occasional inclusions of limestone, chert, serpentinite, eclogite, and amphibolite conglomerate. Soils are typically thin with high runoff rates and slopes are unstable (Galloway 1977).

The serpentine outcrops within the Franciscan Formation provide the substrate for what is now rare habitat supporting rare endemic plant species. GGNRA serpentine sites are small, and are threatened by a lack of protection and the continued development of privately owned parcels. Serpentine slopes are unstable, very erodible, and subject to further increased instability when degraded by offroad vehicle use or trampling.

Bolinas Ridge is east of the SAFZ and is comprised of the Franciscan Formation that makes up much of California’s Coast Range. The ridge is primarily grassland with the steep, narrow ravines dominated by oak, bay laurel, and Douglas-fir.

The Marin Headlands contain Franciscan Formation rocks that are generally more resistant than the erodible Franciscan Formation north of Pirates Cove. Radiolarian chert composed of fossilized radiolaria underlies about half of the headlands, and because of its resistance to weathering, makes up nearly all the ridgetops and summits.

The parklands in the southwest part of San Francisco, contain younger rocks – soft sedimentary deposits that are less than two million years old. The sea cliffs at Fort Funston were formed from the oldest of these tilted fossil-rich beds of sand and clay (the Merced Formation), and are easily eroded by wave action. In the last few hundred thousand years, sand and clay have accumulated as beaches, dunes, and nearshore deposits, and these are now exposed at Sutro Heights, Baker Beach, and Rodeo Cove.

Climatic and Topographic Factors Influencing Wildland Fire Hazard

Relative Humidity

Humidity is the amount of invisible water vapor in the air. When air contains all the water vapor it can hold, it is saturated. Beyond this point, the vapor condenses and becomes visible as fog or clouds. The most common way to measure water vapor is by relative humidity, which is expressed as the percentage of saturation of the air. If air holds half the moisture it is capable of holding, the relative humidity is 50 percent. If air is saturated, the relative humidity is 100 percent. Warm air is capable of holding more moisture than cold air, so as air cools the relative humidity increases. Because of frequent ocean winds and fogs, the average relative humidity of the coastal section is high, except when the dry northeasterly winds from the interior of the state bring fire weather to the Bay Area, sending the humidity down to 20 percent. The record low is 10 percent at Bear Valley in PRNS.

In general, relative humidity is moderate to high along the coast throughout the year. Inland humidity is high during the winter and low during the summer. Since the ocean is the source of the cool, humid, maritime air of summer, it follows that relative humidity tends to decrease with increasing distance from the ocean. Where mountain barriers prevent the free flow of marine air inland, humidity decreases more rapidly. Where openings in these barriers permit a significant influx of cool, moist air it mixes with the drier inland air, resulting in a more gradual decrease of moisture. This pattern is characteristic of most coastal valleys (Golden Gate Weather Services 2002).

Wind Patterns

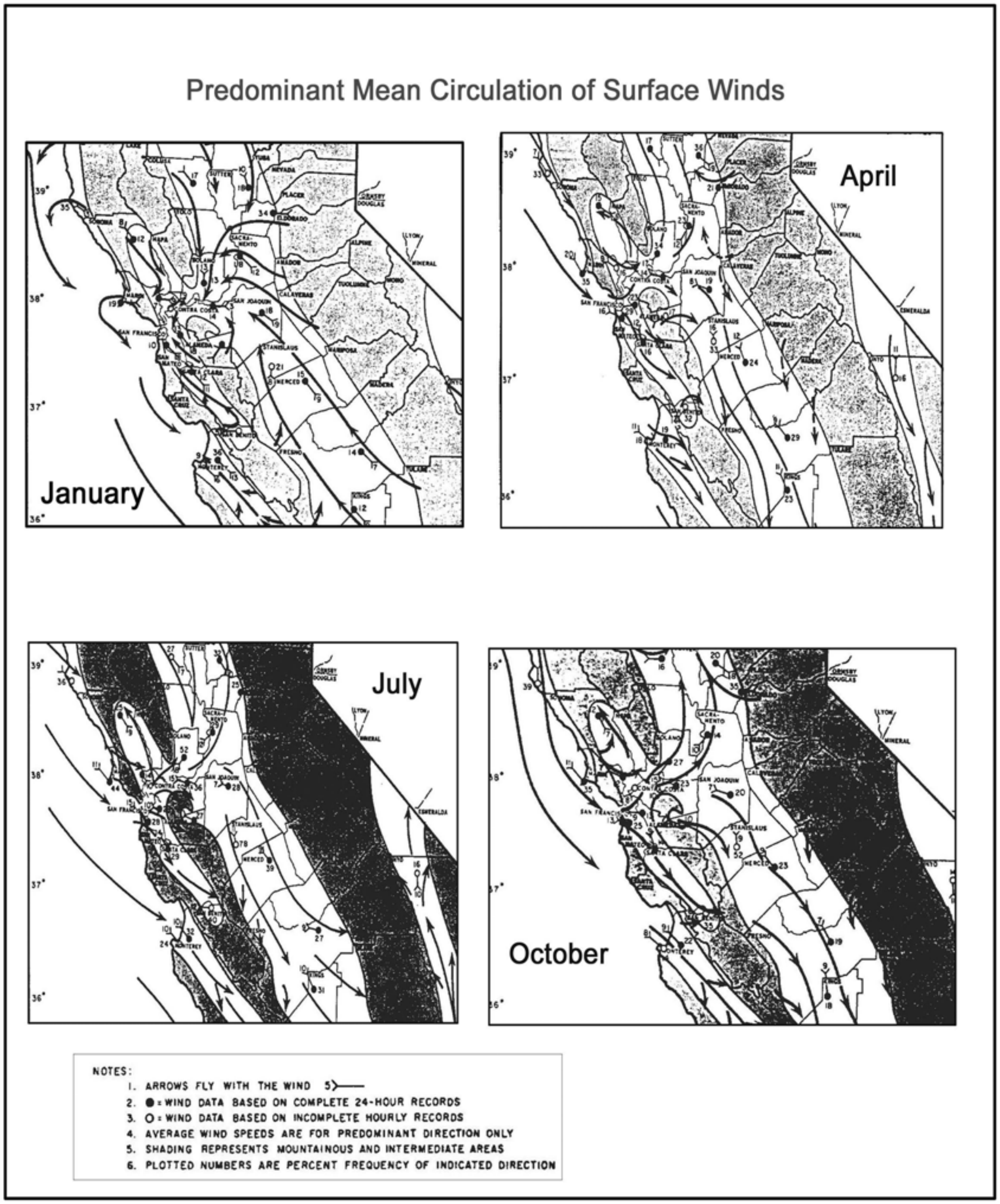
California lies within the zone of prevailing westerlies and on the east side of the semi-permanent high-pressure area of the northeast Pacific Ocean. The basic flow in the free air above GGNRA is therefore from the west or northwest during most of the year. A local characteristic of the northwest wind alongshore is the creation of a jet effect around some of the more prominent headlands. Eddies form near the Golden Gate and just south of Point Reyes. Wind speeds in the immediate vicinity of these major headlands can be two or three times as great as the wind flow at nearby points (Golden Gate Weather Services 2002).

The typical northwest wind of summer is reinforced by the dynamics of the thermal low-pressure area located over the Central Valley and the Southeastern Desert area. In the San Francisco Bay Area, there is a marked diurnal pattern in the strength of the wind even though an onshore circulation tends to continue throughout the 24-hour period. This helps to carry locally produced smoke away from the Bay Area, but creates problems for the regions immediately south and east of the source area.

When wind patterns shift from the prevailing pattern in the summer, winds can flow out of the Great Basin into the Central Valley, the Southeastern Desert Basin, and the South Coast. The result is high pressure over Nevada and lower pressure along the central California coast. The lower coastal pressure causes the hot interior air to be rapidly drawn to the west from the hot, dry interior. The winds are dry, strong, and gusty, sometimes exceeding 100 miles per hour, particularly near the mouths of canyons oriented along the direction of airflow. These interior winds are known as Diablo winds in the Bay Area, “northers” in the Sacramento and San Joaquin valleys, and Santa Ana winds in southern California (Golden Gate Weather Services 2002).

Figure 3-1 illustrates the predominant wind patterns in central California (Bell 1958). In the winter, the regional surface winds blow from the north-northeast. During spring and summer, stronger north-northwest winds dominate. These northwesterly winds are primarily caused and/or strengthened by the combination of high pressure offshore and the warmer air inland. During the fall transition, when warm easterly winds break through to the coast while inland conditions remain hot and dry, the coastal region faces its most significant fire threat.

Figure 3-1: Predominant Wind Patterns in Central California



Source: Bell 1958.

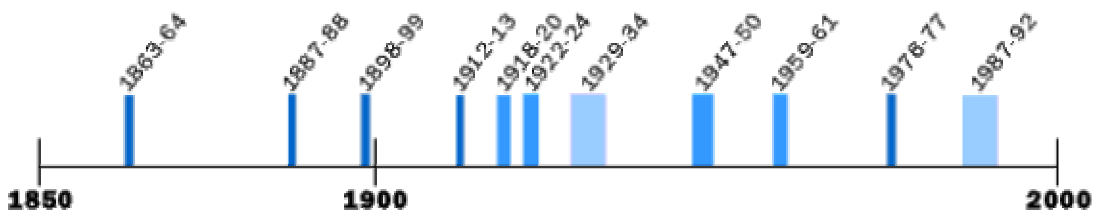
Recurrent Drought

One dry year does not normally constitute a drought in California. Droughts occur slowly, over a multiyear period. There is no universal definition of when a drought begins or ends. Areas most reliant on annual rainfall typically feel impacts of drought first.

Droughts exceeding three years are relatively rare in northern California, the source of much of the state's developed water supply. The 1929-1934 drought years established the criteria commonly used in designing storage capacity and yield of large northern California reservoirs. Figure 3-2 compares the 1929-1934 droughts in the Sacramento and San Joaquin valleys to the 1976-1977 and 1987-1992 droughts. The driest single year of California's measured hydrologic record was 1977. California's most recent multiyear drought was 1987-1992.

Measured hydrologic data for droughts prior to 1900 are minimal. Multiyear dry periods in the second half of the 19th century can be qualitatively identified from the limited records available combined with historical accounts, as illustrated in Figure 3-2, but the severity of the dry periods cannot be directly quantified.

Figure 3-2: California's Multiyear Historical Dry Periods, 1850-Present



Notes:
1. Dry periods prior to 1900 estimated from limited data.
2. Covers dry periods of statewide or major regional extent.

California sustained two epic drought periods, extending over more than three centuries. The first epic drought lasted more than two centuries before the year 1112; the second drought lasted more than 140 years before 1350. Studies of epic droughts evaluated drowned tree stumps rooted in Mono Lake, Tenaya Lake, West Walker River, and Osgood Swamp in the central Sierra Nevada. These investigations indicate that California has been subject to droughts more severe and more prolonged than those evidenced by the brief historical record.

El Niño and La Niña

Under "normal" circumstances over the Pacific Ocean, trade winds rush toward the equator to replace rising sun-heated air and cause an upwelling of air off Peru. These winds are pushed farther west by a high-pressure zone over Tahiti and attracted by a low-pressure zone over northern Australia. During an El Niño episode, the situation is reversed, with a low over Tahiti and a high over Australia. The trade winds die, the upwelling stops, and the ocean surface warms up in the eastern Pacific. The jet stream over the

North Pacific, which normally brings storms to Oregon, Washington, and British Columbia, moves south, picking up warmth from the warm-water bulge below, and deluges California (Gilliam 2002).

During severe El Niño episodes like 1982-1983 and 1997-1998, the Bay Area received more than twice its “normal” rainfall. Houses were destroyed by mudslides, bridges were washed out, and highways were blocked. Although El Niño events occur every four to seven years, they vary greatly in timing and strength. A mild El Niño will scarcely have any important effect, but a strong one can bring disaster. The outlook for El Niño episodes in the 21st century is uncertain. As global warming continues, increasing temperatures of both the air and the water, El Niño events may increase in frequency and intensity (Gilliam 2002).

The opposite of El Niño is the less well-known La Niña. La Niña occurs when trade winds are stronger than usual over the Pacific Ocean, pushing more sun-warmed surface waters westward, causing more upwelling off Peru, and further intensifying the oceanic currents of the northern Pacific Ocean (Gilliam 2002). The wintertime effect of La Niña in the Bay Area is likely to be colder, windier weather and perhaps abnormal rainfall in either direction, too much or too little (and sometimes neither), depending on the erratic location of the jet stream. If La Niña persists into the summer, stronger upwelling off the California coast brings more fog to the area (Gilliam 2002).

Climate Change

Climate has changed over the millennia (e.g., the “Little Ice Age” from 1300-1800 AD), and will continue to change. For example, the amount of fog seems to have increased from 1885 to 1970 (Verran 1982). Unfortunately, after 1970, these data were no longer taken. Climatic change, caused to some degree by human actions, can have an important influence on the human environment, in part by altering the occurrence of wildland fire. It is thought that the influence of human activities upon climate began at least 8,000 years ago with the advent of the agricultural revolution (Ruddiman 2003).

Surface temperature measurements recorded daily at hundreds of locations for more than 100 years indicate that the Earth’s surface has warmed by about 1 degree Fahrenheit in the past century. This warming has been particularly strong during the last 20 years, and has been accompanied by retreating glaciers, thinning arctic ice, rising sea levels, lengthening of growing seasons for some, and earlier arrival of migratory birds (Union of Concerned Scientists 2004).

In California, average surface temperatures have increased 0.7 to 3.0 degrees Fahrenheit in the past century. The 20th century’s ten warmest years all occurred in the last 15 years of the century. Seventeen of the eighteen warmest years in the 20th century occurred since 1980. In 1998, the global temperature set a new record, exceeding that of the previous record year, 1997 (National Assessment Synthesis Team 2000). Air temperature has increased over the past 90 years, more so in large cities than in rural areas. Large urban areas are generally warmer than rural areas, and can have temperatures up to 5 degrees Fahrenheit higher, creating their own weather belt. This can be due to the removal of vegetation and trees, the presence of buildings and streets (which reflect heat stored in pavement), and the production of heat by human activities.

Along the California coast, sea levels will likely continue to rise. Depending on the climate model, they could rise at a rate similar to the historical rate (about 7 inches per century) or almost four times faster (Union of Concerned Scientists). Differences in sea level rise along the coast can occur because of local geological forces, such as land subsidence and plate tectonic activity. The rise in sea level may be associated with increasing global temperatures. Based on results from modeling, warming of the ocean water will cause a greater volume of seawater because of thermal expansion. This is expected to contribute the largest share of sea level rise, followed by melting of mountain glaciers and ice caps (IPCC 2001). The impact of a rise in sea level on coastal areas will be amplified by any increases in the frequency and/or intensity of major storms.

GGNRA winters will quite probably become warmer, windier and wetter during the next century (Fried et al. 2003, Union of Concerned Scientists 2002). Summers may well become warmer, though winter will become proportionally even warmer. El Niños may increase in intensity and/or frequency.

Changes in the timing or amount of precipitation over the next century are likely to have a greater impact than changes in temperature (Union of Concerned Scientists 2002). For example, increases in the amount of winter rains could intensify flooding and landslide hazards. The suitable range will inevitably shift for each mix of plants and animals. Some of these changes are already occurring, providing a first glimpse of the processes and problems ahead. For example, the Edith's Checkerspot (a species of butterfly) is shifting from the southern to the northern limits of its range and from low-elevation to high-elevation sites, a likely consequence of rising temperatures. Other shifts are likely in the future, e.g., expanding grasslands will likely encroach on the foothill shrublands of the coastal ranges. In many cases, however, plant and animal species will not be able to shift northward or upslope because the potential habitat has been claimed by development or nonnative species, or contains unsuitable soils or other physical limitations.

A large proportion of change will occur in the frequency and/or intensity of extreme weather events such as severe storms, winds, droughts, and frosts. Similarly, the frequency and/or magnitude of some ecologically important processes such as wildfires, floods, and disease and pest outbreaks will likely change. Fried et al. (2003) predict that these conditions will produce more intense, faster-spreading fires in most locations. Their model shows that, despite any enhancement of fire suppression efforts, the number of escaped fires (those exceeding initial containment limits) increased 51 percent in the San Francisco Bay Area. Area burned by contained fires could increase by 41 percent. Furthermore, Fried et al. (2003) predicted that fire return intervals in grass and brush vegetation types would be cut in half on average. Their reported estimates represent a minimum expected change, or best-case forecast. In addition to the increased suppression costs and economic damages, changes in fire severity of this magnitude would have widespread impacts on vegetation distribution, ecological condition, and carbon storage, and would greatly increase the risk to property, natural resources, and human life.

Fire Weather

Post-frontal offshore flow can bring high fire danger to the Pacific Coast from British Columbia to southern California. The bulge of the Pacific High moving inland to the rear of a front produces offshore northeasterly winds (Fischer and Hardy 1976). Thunderstorms may occur in California at any time of the year; lightning strikes in the Bay Area are rare but do occur annually. Several lightning ignitions are known to have occurred in the last 18 years (see Table 3-1). Local fire sources (CDF 1980-2002; Sunget and Martin 1984) tell of 14 separate lightning-ignited fires: two in the Douglas-fir forest on Inverness Ridge, two on Mount Tamalpais, one on Bolinas Ridge, and eight additional fires (seven of which occurred during a September 1984 storm). The Bay Area averages about three lightning days a year. Storms with lightning occur, on average, 1.9 times per year on Mount Tamalpais. The storms are usually light and infrequent (Golden Gate Weather Services 2002).

The fire season usually starts in June and lasts into October. Several synoptic weather types produce high fire danger. One is the cold-front passage followed by winds from the northeast quadrant. Another is similar to the east-wind type of the Pacific Northwest coast, except that the high is farther south in the Great Basin. This Great Basin High produces the foehn-type Diablo winds in the central Coast Ranges. Peak occurrence of these winds is in November, and there is a secondary peak in March. A third high fire-danger type occurs when a ridge or closed high aloft persists over the western portion of the United States. At the surface, this pattern produces very high temperatures, low humidity, and air mass instability (Fischer and Hardy 1976).

Table 3-1: Source of Fire Starts/Size of Fire, 1992-2002

Fire Cause (1992–2002)	Marin County (acres)	San Mateo County (acres)
Lightning	3	20
Campfire	12,390 (includes 12,356-acre Vision Fire)	27
Smoking	12	9
Debris Burning	42	14
Arson	25	15
Equipment Use	196	108
Playing With Fire	42	4
Miscellaneous	261	154
Vehicle Fires	0	86
Railroad	0	0
Powerline	87	23
Total Acres	**13,058**	**460**

Source: NPS, Pacific West Regional Office, 2004

The meteorological causes of the October 20, 1991 Oakland Hills fire appear to occur approximately 22 years. Conflagrations have struck the East Bay hills in 1923, 1945, 1970, and 1991. This approximately 20-year cycle coincides with the peaks in the sunspot cycle, which may influence local weather. The magnetic poles of the sun flip every 11 years so that the North Pole returns to the top every 22 years, with calendar dates closely approximating East Bay conflagrations. This pattern suggests that the 1991 conflagration will be repeated in approximately 2013.

As each cycle has occurred, the increased level of urban development in the hills has produced more serious conflagrations. The scenario that emerged for October 1991 was a fire occurring after a very dry, hot, strong wind had desiccated vegetal and structural fuel. This fuel was initially dry from a long drought, an unusual freeze, and a rainless extended summer. The altitude of the fire placed it within a strong inversion layer so that brands shooting out from the fire were channeled downwind into a heavy fuel-loaded urban wildland intermix. Since the interface area sat upslope above the surrounding urban development, brands shooting from the main body of the fire were flung even farther afield, further aiding the fire's spread.

Prescribed Fire Weather

The approximate weather window for prescribed burns in grassland at GGNRA is from June to November. Burning can begin in some areas after annual grasses have cured, which does not normally occur until mid-June to early July. While areas with annual grasses generally have the most flexible burn windows in GGNRA, burns must still be timed to occur between the dissipation of the coastal fog and the onset of afternoon sea breezes.

In shrublands and forested areas, burning can be extremely difficult due to the narrow burning window from late September to early October when fuels dry out. Northeast wind events during this same timeframe can result in Red-Flag Days on which no prescribed or pile burning is allowed. "Burn days," or days when burns would be in prescription, often do not coincide with weather conditions appropriate for burning in GGNRA, as on many of these days smoke dispersal would contribute to air quality problems.

Fire Regime of the Central California Coast

Landscapes consist of a dynamic mosaic of patches, which are created by successive disturbances of various types, including fire (White and Pickett 1985). Disturbances are defined as "any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (White and Pickett 1985). Disturbances affect community structure and dynamics at various spatial scales (Pickett et al. 1989). Factors such as fire, landslides, and precipitation variability usually act at relatively large spatial scales, while disturbances such as grazing, burrowing, and falling tree limbs often affect communities at much smaller spatial scales (Pickett and White 1985). Fire/disturbance regimes help to define the pattern or mosaic of age classes, successional stages, and vegetation types on the landscape.

Five successive fire regimes have been identified for the Pleistocene era in the central California coast. The "management practices" or human influence on the landscape during last the last four eras have dramatically influenced the disturbance regime for this landscape, though to a lesser degree than change in climate. Fire's influence on species composition and productivity can be relatively minor, though fire can influence the rate, direction, and magnitude of more dramatic changes due to climate.

Natural Fire Occurrence (128,000 to About 10,000 Years Before Present)

During the last 20,000 years, the Earth's climate underwent a dramatic transition from glacial to interglacial conditions, a change as large as any change during the past three million years. These climatic variations resulted in large biotic responses, including migrations of individual species and rearrangements of vegetation associations. Table 3-2 shows the changes in Bay Area climate over the last 128,000 years and summarizes the changes in the aforementioned pollen record. For areas in central and northern California, pine is generally an indicator of cooler or glacial conditions, and oak is an indicator of warm conditions. Redwood is an indicator of increased moisture and moderated summer coastal temperature related to coastal fog, also related to coastal upwelling (Heusser 1998).

The Mediterranean climate with hot, dry winters attained prominence in the early Pleistocene (Axelrod 1988) and has been dominant throughout this period. In this climate, high fire danger typically exists during the dry months of May through November. Vegetation characteristics in regions of Mediterranean climate help determine the frequency and intensity of fires (Philpot 1977). Several plant communities, including native chaparral and oak woodland in Marin, San Francisco, and San Mateo counties, display fire-adaptive characteristics, indicating a role for fire in determining the persistence of these species.

Table 3-2: San Francisco Bay Area Climatic Changes

Time Period	Climatic Characteristics	Dominant Plant Communities
128,000 – 28,000 BP	Much cooler than present	Conifers predominate (Abies and Pseudotsuga)
28,000 – 13,000 BP	Cold and dry	NA
13,000 – 7,500 BP	Warm and wet	Oaks begin to increase Abies, Pseudotsuga dominate
7,500 – 2,900 BP	Warm and dry	(Altithermal) oak woodland, prairies and coastal scrub dominate until modern era
2,900 – 900 BP	Cooler	NA
900 – 625 BP	Warm and dry at end	Medieval Warm Period
625 – 500 BP	Current climate	NA
500 – 300 BP	Wetter and cooler	Little Ice Age
300 BP – present	Current climate	Nonnative plants introduced

Source: NPS, Pacific West Regional Office, 2004.
Note:
BP = before present
NA = not applicable

Prior to human settlement of central California, natural ignition sources for wildfire would be lightning or spontaneous combustion. Recent records of lightning strikes in the Bay Area show that fires could occur along the Marin coastline throughout much of the year, regardless of the high probability of dense fog. Without human intervention, it is thought that fire could linger in tree trunks for weeks, and reemerge under drier conditions; thus a fire could burn through the summer and fall until the rainy season began (Stuart 1987). The fog gradient is a principal influence on fire behavior in this scenario.

Native American Period (≈10,000 BP – 1775 AD)

There is increasing evidence that Native American land management practices, including the use of fire, caused cumulative and permanent effects in plant communities and species composition for many Bay Area vegetation types (Stewart 1955, Reynolds 1959, Duncan 1992, Anderson 1993, Lewis 1993, Blackburn and Anderson 1993, Anderson 2001).

Sapsis and Martin (1994) estimated that fire burned from one half million to over 19 million acres of California's total area each year. The exact spatial extent of the influence of burning on the landscape is not known and has been debated. Still, the level of fire use necessary to maintain specific resources in conditions required by the various cultures suggests that extensive and very intensive burning would have been common in important vegetation types (Anderson and Moratto 1996). Over the course of the past 10,000 years, periods of intensive land use and higher population levels were separated by times of diminished populations and reduced land use. The most recent period of intensive land use lasted for roughly 500 years before Euro-Americans came to the San Francisco Bay Area. This interval was long enough for Native American management activities to cause substantial environmental changes.

In California, the oldest definite evidence indicates that humans arrived 9,000 to 10,000 years ago. Although earlier dates have been proposed, they are still not definite (Heizer and Elsasser 1980, Chartkoff and Chartkoff 1984, Fagan 2003). It is thought that California was the most densely populated area of the United States at the time of European arrival, with a population of approximately 150,000 (1.5 persons per square mile). Ohlone and Coast Miwok are native peoples aboriginal to GGNRA parklands. Kroeber (1977) estimates that there were about 7,000 Ohlone in their territory from the Monterey Bay area to the tip of the San Francisco Penninsula, and 3,000 Coast Miwok from present-day Marin County into Sonoma County. Other estimates are much higher (Cook 1976). Archeologists have identified more than 100 Coast Miwok and Ohlone village sites (Kelly 1978, Levy 1978), with the majority being located in valleys and along the bay. The dense population was the product of the relatively peaceful culture of the California tribes and the abundant supply of fish, game, and edible vegetation.

Native American Burning Practices

Although information on their burning practices is scant, both the Coast Miwok and Ohlone peoples are known to have regularly burned extensive areas of coastal prairie, coastal scrub, marshlands, and oak woodland (Collier and Thalman 1996, Duncan 1992, Kelly 1978, Levy 1978). Fire is also thought to have been used as a tool for communication, driving game, security from human enemies and predators, improving the flow of springs, increasing productivity for grazing, increasing yield of food sources (acorns, grasses, forbs, tubers, bulbs, fruits, grains), and removing competing conifers from oak woodland.

Fire management was more common in grassland, oak savannas, and ecotones of grassland and chaparral than in shrublands and forests (the latter two communities burning between 10 and 28 years on average). Palynological (spores and pollen) records from the San Francisco Bay region support the hypothesis that Native American use of fire helped shape the landscape over the past 5,000 years (Russell 1983, Byrne et al. 1991, Duncan 1992, Anderson 2001). For example, prior to suppression, chaparral and coastal scrub are generally believed to have been restricted to the higher slopes and ridges (Lewis 1993). The Bear Valley and Olema fire chronologies (Sunget and Martin 1984, Brown et al. 1999) also suggest that the coastal Coast Miwok burned the land more frequently than lightning-ignited fires occurred.

Fire was an important part of oak management. Fire served to control oak pests and diseases, e.g., the filbert weevil (*Curculio occidentis*) and the filbertworm (*Melissopus latiferreanus*) (McCarthy 1993). Fire also produced larger, more productive trees by removing competition and made it easier to gather acorns (McCarthy 1993). Acorns were then stored for two to four years (Fagan 2003).

Lewis (1993) indicates that California Native Americans generally burned in the fall season, with some summer and spring burns. Fall burns are frequently noted in grasslands, chaparral, and coniferous forests. It is known that inland Miwok burned the land each August after seed gathering from May to August (Kelly 1978). California grasses, along with many chaparral shrubs, produce extraordinary amounts of seeds, and grass and chaparral shrub seeds were an important protein source, especially in treeless zones. Seeds were typically parched, ground into flour, and consumed as dry meal or formed into cakes. Spring burns are noted in chaparral. Summer burns were the time for natural fires (Lewis 1993). Seeds of desirable species were sown after burning.

Spatially, California Native Americans used two types of fire patterns: fire corridors and fire yards (Lewis 1993, Lewis 1999). Fire corridors were created by a consistent pattern of summer burning along higher elevation grassland corridors through coastal coniferous forests or fringes of streams, sloughs, ridges, and trails inland away from redwood forests. Fire yards were open prairie, clearing, meadow, swale, or lakeshore areas created at any elevation within forested areas (Lewis 1993, Lewis 1999). These areas were typically small in acreage in areas where animals congregated or traversed. The clearings increased the abundance of plant and animal resources and made hunting and gathering more predictable.

Ohlone and Coast Miwok fire management is thought to have been similar in strategy and technique. This is because the differences between the tribal groups are largely social (e.g., housing, socio-political organization, technology, ritual) as the two groups had similar seasonal movements, subsistence patterns, and mobility. There is a larger amount of Coast Miwok ethnographic material, so more is known about the Coast Miwok life than the Ohlone. One important difference was that within GGNRA lands, Ohlone populations (with many small villages of less than 100 people) were sparsely populated when compared to the Miwok (with many small villages and three larger villages with populations of 100 to 300 in Olema Valley, Bolinas Lagoon, and Sausalito).

Spanish-Mexican Influences (1769-1848)

Spanish and later Mexican settlement introduced year-long cattle and sheep grazing, burning, and cultivation that led to the extirpation of many native animal species and the further spread of nonnative plants. The rapid, extensive conversion of the landscape to nonnative annual vegetation was so complete that the original extent and species composition of most native perennial grasslands are largely unknown (Burcham 1957, Holland and Keil 1995).

The move toward fire exclusion began early in California. The first law against starting fires was issued under Spanish rule in 1793 (Barrett 1935, Gordon 1977). It was aimed at halting Indian burning of grasslands that reduced the amount of forage available to Spanish horses and livestock. Ranchero owners burned coastal scrub, chaparral, and oak woodland to expand pastures. The rancho period, primarily under Mexican rule, was relatively short-lived (1822-1846), but it exerted such a strong influence on the landscape that the fence lines, roads, and vegetation pattern are still visible today. Within GGNRA, there were three ranchos in San Mateo County (Buri Buri, Corral de Tierra, and San Pedro), two in San Francisco (Laguna de la Merced and Cañada de Guadalupe, although the majority of the latter was in San Mateo County, and three in Marin County (Saucelito, Tomales y Baulines, and Las Baulines).

American Influences (1848-1945)

Following the Mexican American War in 1848, California became first a territory of the United States and then a state. The discovery of gold in the Sierra foothills in 1848 led to an immense influx of Americans and other gold seekers to the area virtually overnight.

In this period the large ranchos, such as Rancho Saucelito, were subdivided into smaller ranches and a 1900-acre parcel in the Marin Headlands was sold to the Army. Other ranchos within GGNRA lands were similarly subdivided and sold to farmers, dairymen, and timber outfits. This change in ownership and management changed the pattern and types of disturbance across the landscape as fences went up, fertile marine terraces were tilled, and forests were logged on a large scale (Stanger 1967, Hynding 1982, Fairley 1987).

Dairy farming began in Marin in 1857 and, by 1880, a census counted 32,449 cattle (mostly dairy cows). More and more lands were burned to increase grazing. Grazing and farming in the San Mateo lands of GGNRA were less intense and started later in the 1930s. As the Central Valley became the primary cattle producer, the coastal cattle industry began to fade (Burcham 1957, Toogood 1980) but many of the burning and grazing practices lasted until the 1960s.

Logging, focused primarily on redwoods, began in earnest in 1849. In the Bolinas area alone, 13 to 15 million board feet were removed in a 10-year period. (A board foot equals a piece of wood 12 inches by 12 inches and 1 inch thick). On the Phleger property, the Whipple Mill operated from 1852 to 1855 until the entire property was logged. After redwood was removed, loggers focused on cordwood (oak, bishop pine, madrone, etc.). In some areas after the trees were cut, workers skimmed the soil for clay to make bricks (Fairley 1987). Logging operations began to fade on GGNRA lands in the 1850s as operations moved north to the larger forests. Among the legacies of this period are dense second-growth forests and high levels of siltation, such as at Bolinas Lagoon (Fairley 1987).

The spread of fire-adapted nonnative species further changed the landscape and further altered the fire regime. Eucalyptus was first planted in San Francisco Bay Area in 1856 (McClatchie 1902). Extolled for its qualities as a fast-growing timber species, eucalyptus became a widely planted for ornamental use, timber, and windbreaks. These stands filled in quickly and expanded, making eucalyptus one of the dominant trees around the Golden Gate. French broom (*Genista monspessulana*), Portuguese broom (*Cytisus striatus*), Scotch broom (*Cytisus scoparius*), and Spanish broom (*Spartium junceum*) all were introduced into California in the mid-1800s for landscaping and to control roadside erosion control. The ability of these plants to fix nitrogen, to produce copious amounts of long-lived seed, and to tolerate almost any soil condition allowed these species to grow rapidly and form dense stands, making regeneration of most native species difficult or impossible. The thick brush also created a dangerous fire hazard.

Wildland fires were frequent and large in the late 1800s and early 1900s (Perry 1984). In many cases, the fires prevented grasslands from being invaded by brush. The Forest Reserve Act of 1891 introduced programs to control fire and grazing. In the late 1800s, foresters were urging the public to support fire exclusion in forests to increase future wood production (California State Board of Forestry 1888). By 1900, fire exclusion became a general policy among government agencies, although it was not yet fully accepted by the public (Office of the State Forester 1912). Despite initial public reluctance, the beginnings of successful reduction of fires occurred by 1910 (Office of the State Forester 1912). Active suppression changed the old pattern of smaller fires. Fire control would contain wildfire for several decades. In the 1900s, prescribed fire was part of early efforts at fire prevention in Marin County (Spitz 1997). The 18,000-acre Carson Canyon fire in 1945 was the last large fire to date in Golden Gate lands in Marin, and in 1946 a northern San Francisco Watershed fire was the last large fire-intense event in GGNRA lands in San Mateo County.

Modern Influences (1945-present)

Grazing by domesticated livestock and clearing of pastureland continued to be practiced until the 1960s (Burcham 1957). These practices had resulted in lighter fuel loading, especially near residential areas, markedly lowering the fire danger for the area. By 1990, explosive growth had filled in the central flats of the San Francisco Bay Area and agriculture had moved beyond the suburbs.

In general, disturbances by fire have gone from long intervals in the pre-human period to shorter intervals in the late Native American and Spanish-Mexican periods, moderate intervals in the early Anglo era, back to long intervals in the modern era. The altered fire regime has led to an increase in crown and surface fuels, increased tree density bringing high-intensity fires and higher fire frequency in some areas (which continued until 1940s), conversion of oak woodland to grassland, and the invasion of understory woody vegetation.

If current management strategies are continued indefinitely, it is difficult to predict where this change in fire regimes will ultimately lead, especially with the potential of future warmer and drier climate patterns. However, if warm, dry years become more common, as some suggest is likely (Fried et al. 2003, Union of Concerned Scientists 2002), the recent paradigm of large, severe fires would be expected to continue.

Fire Regime Research in the Central California Coast

Fire history can be reconstructed from a variety of data sources: tree-ring analysis (dendrochronology), cultural and historical accounts, written records, and the analysis of charcoal in sediment cores. Each of these data sources has limitations with regard to spatial and temporal detail and accuracy. Several fire history studies have been completed within the San Francisco Bay Area

Sunget and Martin (1984) studied the occurrence of lightning in the Marin coastal area and the potential for a fire start. Storms with lightning occurred 1.9 times per year at Mount Tamalpais in the years 1901 and 1908-1926. The weather station at this site indicates that 18 percent of these storms occurred in September. At this time of year fuels are dry, relative humidity is low, temperatures are high, and winds are frequently of high velocity.

Prior to the 20th century, fires burned through redwood and Douglas-fir/hardwood forests in the San Francisco Bay Area at intervals of 5 to 175 years (Langenheim et al. 1983, Jacobs et al. 1985, Finney 1990, Greenlee and Langenheim 1990, Finney and Martin 1992). In northern redwood forests, Veirs (1980) found that coastal stands experienced fire intervals of 250 to 300 years, inland stands 33 to 50 years, and stands intermediate to the two locations 150 to 200 years. Stuart (1987) found average fire sizes for inland coastal redwood of 1,942 acres for pre-settlement, 2,711 for settlement (1875-1897), and 2,268 acres for post-settlement. Oswald (1968) found recent average timber losses from windthrow (uprooted by the wind) exceeded the combined losses from fire, insects, and disease in coastal Humboldt County.

Locally, a fire chronology based on fire scar examination was done for two redwood *(Sequoia sempervirens)* forest sites in Marin County (McBride and Jacobs 1978). Fire frequencies averaged 21.7 and 27.3 years. The difference between the two sites was attributed to the increased influence of fog (Jacobs et al. 1985). The distribution of fire intervals was skewed and displayed a larger number of shorter interval fires. This suggests that fires were separated by first a short and then a longer time interval. In general, it is thought that fires occurring at shorter intervals would have been less intense. High-severity fires were rare.

The aforementioned findings are fairly similar to those found by Finney and Martin (1989) at Salt Point State Park and those at the Bear Valley area of Point Reyes National Seashore (Sunget and Martin 1984). The intervals at Bear Valley were shorter than expected and are probably related to the fact that Bear Valley was a center for much Native American activity and associated burning practices. While Brown et al. (1999) found similar numbers for frequency, they also reported that fires generally occurred late in the growing season or after growth had ceased for the year. In addition, fires were highly variable in size, from local stands to extensive landscape-scale events (Brown et al. 1999).

The paleoecological record and historical data show that changes in wildfire frequency are closely linked to changes in climate. Several recent studies tracking trends over the past century have found that fire frequency (Clark 1990, Brown and Swetnam 1994) and fire size (Flannigan and Van Wagner 1991) correlate with air temperature. The long-term importance of fire in San Francisco Bay Area ecosystems is suggested by the common occurrence of charcoal in the paleoecological record of the last 6,000 years (Russell 1983, Duncan 1992, Anderson 2001). This record suggests that climate and vegetation have varied considerably over this period (Adam and West 1983, Rypins et al. 1989, Reidy 1994). Given that fire can act as a catalyst for vegetation change during periods of rapid climate change (Whitlock 1992, Wigand et al. 1995), it is important to note the large charcoal peaks (indicating heightened fire activity) during the last 3,000 years were followed by vegetation proportions considerably different from those found before this period (Russell 1983, Duncan 1992, Anderson 2001). However, the available data for the San Francisco Bay Area are insufficient to allow a more precise description of the role fire played in reorganizing vegetation at various times in the past. Still, the evidence from interpretation of long-term trends in sediment cores has shown that fire was a component of the San Francisco Bay Area environment even before the current vegetation communities became established (Russell 1983, Duncan 1992, Anderson 2001).

Marin County

Sediment cores in Marin County (Russell 1983, Rypins 1989, Duncan 1992, Anderson 2001) found that high-intensity storm activity existed between 12,000 and 7,000 years ago (Rypins et al. 1989). Abies (coniferous trees referred to commonly as true firs) declined beginning10,000 years ago, suggesting cooler conditions until that time (Rypins et al. 1989). True firs and Douglas-firs disappear from the records at the beginning of the period from 10,000 to 7,500 years ago; during the remainder of the period there were marked increases in grassland, coastal scrub, and oak woodland (Rypins et al. 1989). Anderson (2001) found that fire activity increased dramatically after the period from 6,000 to 2,300 years ago during which fire was relatively infrequent. This increase in frequency cannot be attributed to climate change (Rypins et al. 1989), and may be due to the increased use of fire by Native Americans beginning around 3,000 years ago (Duncan 1992, Meyer 2001, Fagan 2003). In the last 1,000 years, the proportion of grassland and coastal scrub seems to have been stabilized even before European settlement (Russell 1983, Duncan 1992). Effects of colonization (e.g., grazing) are correlated with some changes in pollen (e.g., increase in grass-shrub pollen ratio). The sudden drop in Sequoia pollen and subsequent recovery are interpreted as reflecting the heavy logging of this species in the early 20th century (Russell 1983).

San Francisco

Interpretation of sediment cores from Mountain Lake in the Presidio (Reidy 1994), a lake that formed approximately 2000 years ago, suggests that redwood and pine pollen percentages remained stable across the Pre-European-Early Spanish period boundary. In addition, *Artemisia* pollen dropped dramatically early in the Spanish period, which probably reflects the clearing of sagebrush to encourage grasses for grazing. During the Spanish period, nonnative pollen types first appeared at Mountain Lake. The first nonnative plant to appear was *Erodium cicutarium* in approximately 1800; it was probably introduced by cattle grazing. The second nonnative weed pollen to appear was *Rumex* acetosella around 1840 during the Mexican period in San Francisco. Plants from the mustard family also become locally important in the later Mexican period according to the sediment record.

San Mateo County

A sediment core was taken from Pearson’s Pond, near the community of La Honda in central San Mateo County near the Pacific coast (Adam 1975). The core indicated that coast redwood was much more abundant in approximately 850 AD than it is today. Logging probably was responsible for the increase in Douglas-fir pollen as redwood pollen decreased (Adam 1975). Adam et al. (1981) recognized three zones over the past 30,000 years from Laguna de Las Trancas, northern coastal Santa Cruz County. The deepest (earliest) zone was dominated by pine species and tentatively aged at 30,000 to 24,000 years ago; the pine-fir zone, 24,000 to 12,000 years ago; and the redwood zone, approximately 12,000 to 5,000 years ago. In the redwood zone, pine was virtually absent, and redwood was apparently dominant in the mesic sites (those with a balanced source of moisture), with the drier sites supporting open grassland.

Recent Fire History in Marin and San Mateo Counties

Nineteenth and early 20th century newspapers from Marin and San Mateo counties and records from local fire departments document many fires that occurred in coastal Marin and San Mateo counties (Perry 1984, U.S. Forest Service 1939-41). These fires were often the result of known human activities, but the locations and impacts of the fires are often vague. Table 3-3 lists fires by date for the two counties, and Figures 3-3 and 3-4 show fire locations. Months are given when known.

Table 3-3: Fire History of Coastal Marin and San Mateo Counties

Date	Description
1859 September	Wildland fire, Mount Tamalpais, burned for three months.
1865	Woods of Marin along the shore of Bolinas Bay burned for two weeks.
1877	Area west of San Andreas Lake burned over large territory for more than three weeks.
1878	1,200-1,500 acres of chaparral, grass, and timber burned near Nicasio.
1880	Campers caused fires, burned 5-mile by 10-mile area in San Mateo County.
1881 September	65,000-acre wildland fire burned for seven days, one fatality. Started near Blithedale Canyon, Mill Valley, by a man who set fire to a pile of brush.
1887	Fire spread from below San Andreas Lake to San Mateo Creek, burning 2,500 acres of second growth bay, oak, and madrone.
1889	On the ridge between San Andreas Lake and Crystal Springs Lake and two ridges west of San Andreas Lake. “For miles the hills are black and bare, the fire burned for at least 4 days spreading at least 1 ½ square miles a day.”
1890 October	More than 8,000 acres burned between San Rafael and Bolinas.
1891 June	12,000 acres of Mount Tamalpais burned; fire started in Bill Williams Gulch near Ross.
1892 August	Fire started on Bolinas Road by two men cooking breakfast, spread over several hundred acres.
1893 August	Fire thought to have been started by campers burned over 3,000 acres of Mount Tamalpais and Mill Valley.
1894 September	Mill Valley fire originated from a campfire left by hunters started in redwood forest and “burned over a large stretch of country.”
1904 September	15,000-20,000 acres of grass and timber burned on the west side of Bolinas Ridge.

Date	Description
1913 July	On Mount Tamalpais, between 1,600 and 2,000 acres burned, from Rock Springs to Larkspur, including summit of mountain, Blithedale and Cascade Canyons, most of Fern Canyon, and spot fires beyond Muir Woods National Monument on the Dipsea Trail. Started west of West Point Inn at 10 A.M. probably by railroad sparks.
1919 September	Fire started near Pipeline Reservoir, burned 40 houses on the ridge and stopped within 100 yards of Muir Woods.
1919	Fire swept from the hills above Sausalito, burned a hall, 5 stores, and 12 homes.
1923	Fire burned from Bolinas Ridge to within four miles of Fairfax, with a total size of 30-50 square miles.
1928	200 acres of brush burned around Fort Barry.
1929 July	"Great Mt. Tamalpais Fire," involving 2,500 acres of brush, forest, and grassland. Fire burned into Mill Valley from Fern and Cascade Canyons; 117 homes burned.
1929	A week-long fire around the town of Montara; completely burned down the town.
1931 December	Illegal campfire in large group of charred redwoods in Cathedral Grove, Muir Woods.
1932 November	Thanksgiving Eve Fire. Started at 10:25 P.M. in heavy grass 50 feet west of Panoramic Highway near Alpine Club. North winds spread it toward Muir Woods and Tourist Club. Sixty acres burned, including two acres of chaparral inside Muir Woods' boundaries.
1933 December	Fires prohibited in Muir Woods; all fireplaces eliminated.
1945 September	18,000-acre fire that began at the entrance to Carson Canyon (Kent Lake).
1946	Large intense fires in northern San Francisco watershed.
1959 July	2:53 A.M. fire report in Kent Canyon near logging operations on Brazil Ranch. No wind; burned 50 acres before being controlled by 75 men.
1965 October	150 acre fire ¼ mile from Muir Woods, near southeast boundary.
1995 October	12,354 acres at Mount Vision, Point Reyes National Seashore. Forty-eight structures destroyed; 1,200 firefighters participated, took 9 days to control fire.

Source: NPS, Pacific West Region, 2004.

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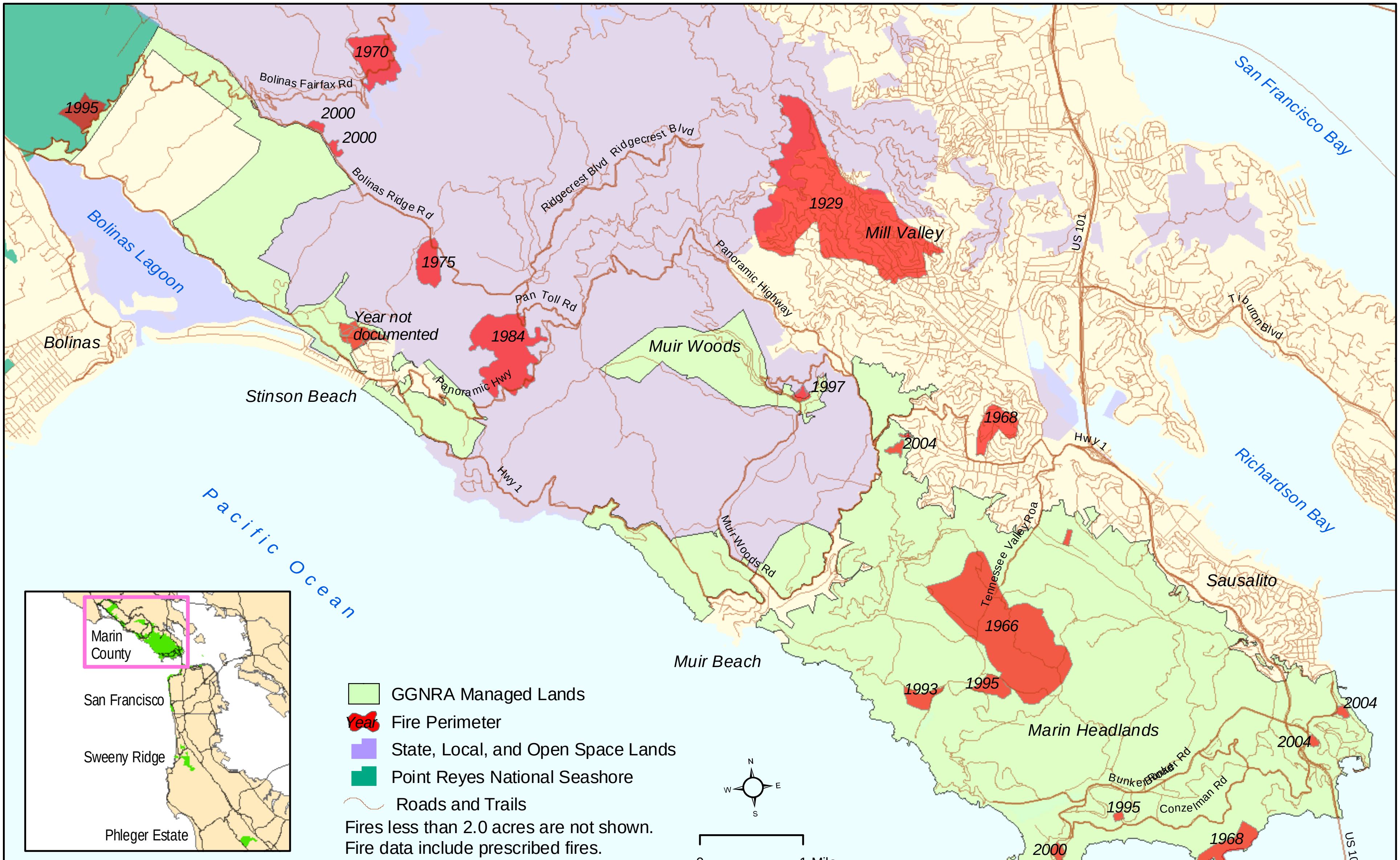
Fire History 1929-2004

Marin County

National Park Service
U.S. Department of the Interior
Golden Gate National Recreation Area



Fire Management Plan EIS August 2005

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Figure 3-3

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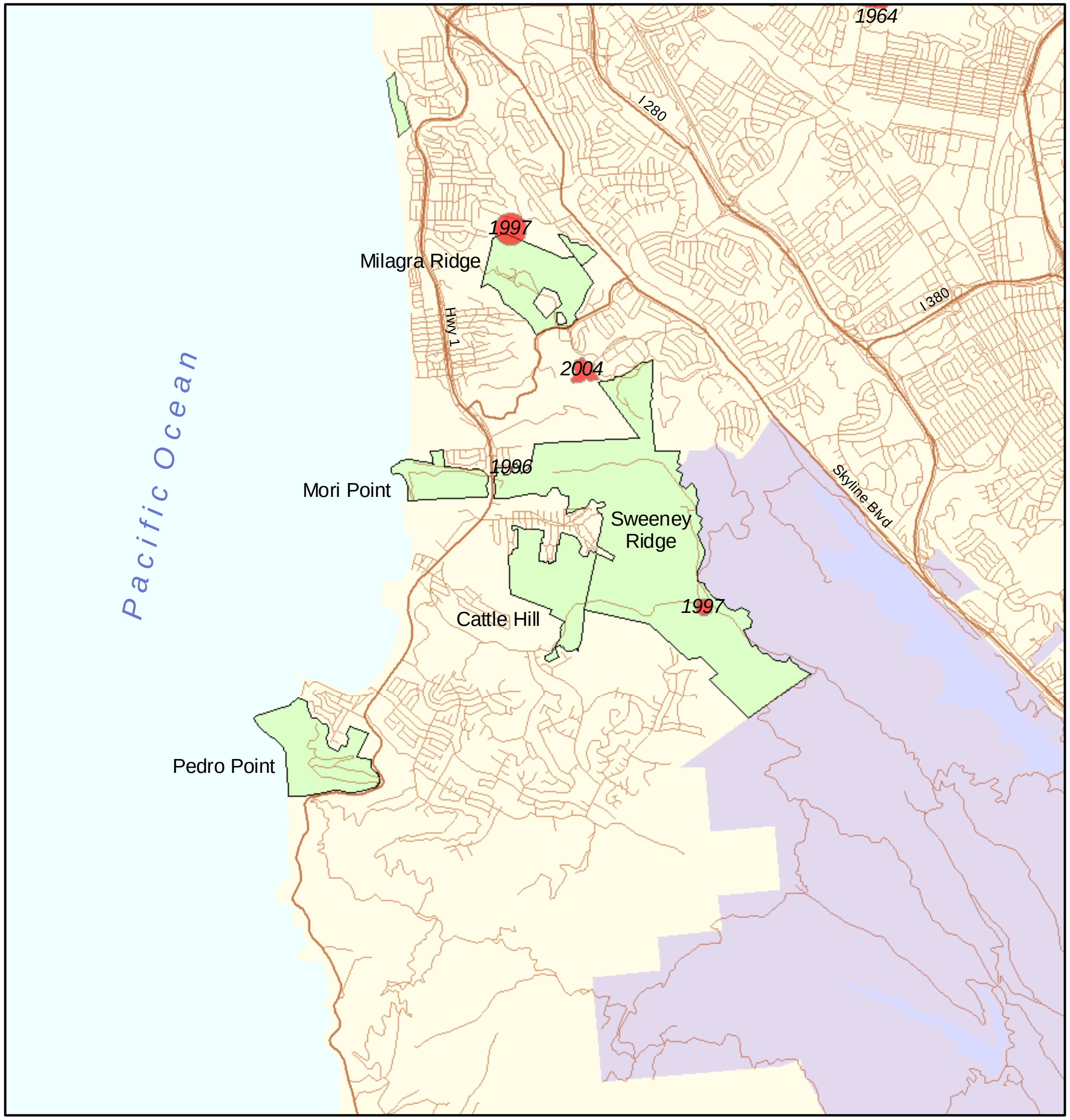
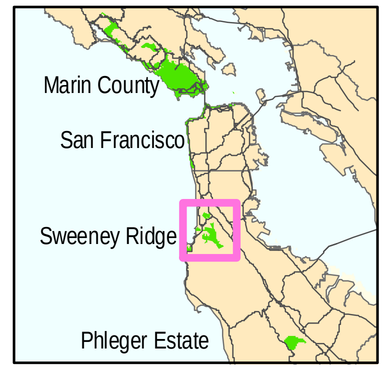
Fire History 1929 - 2004

San Mateo County

National Park Service
U.S. Department of the Interior
Golden Gate National Recreation Area



GGNRA Managed Lands
Year Fire Perimeter
State and Open Space Lands
Roads and Trails



Note:
Fires less than 2.0 acres are not shown.
There is no record of fires greater than 2.0 acres in San Francisco and no record of any fires in Mori Point, Pedro Point, or Phleger Estate.

Historical records indicate a 25 acre fire occurred near Sweeney Ridge in 1988, however the exact location and geographical extent is not known.

N W E S

0 1 Mile

Figure 3-4

Fire Management Plan EIS August 2005

3-04 fire_hist_south.mxd 8/22/2004

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3.3 Physical Environment

Watershed Processes: Soils, Hydrology, Water Quality, and Aquatic Habitat

Water resources, water quality, and soils are interrelated in their impacts within a watershed. Therefore, these resources are discussed together in the affected environment. Each of the watersheds described in this section has unique resources and characteristics, but the types of soils within the park do not vary significantly enough to warrant discussion of any particular area.

Soils

From an aerial view of the GGNRA landscape, the threats posed to the park from erosion are clear. Coastal waves rhythmically crash against the shoreline; deep, long gullies originate at old roads; heavily used areas are devoid of vegetation; undesignated social trails crisscross through the natural areas; and landslides or slumps exist in most of the small valleys.

Past and current land use practices such as logging, grazing, and development, as described above in the Fire Regime descriptions, have altered vegetative composition, aggravated and increased soil erosion, and precipitated landslide activity and recurrent gully formation. These practices have contributed to increasing sediment loads to streams, bays, and shorelines. They have also accelerated the loss of large quantities of top soil and have resulted in prominent visual scars and recurrent maintenance costs.

Slopes in the Coast Range are inherently unstable. Intense shearing associated with faulting along the plate margin has reduced the strength of the rock. Ongoing uplift of the mountains causes continued erosion as the landscape strives to become stable. Surface disturbances, such as cuts for trails and roads, vegetation clearing, and alteration of surface water drainages, can trigger or lead to slope failures.

Most of the soils within GGNRA belong to the following complexes: Blucher-Cole, Centissima-Barnabe, Cronkhite-Barnabe, Dipsea-Barnabe, Felton Variant-SoulaJule, Gilroy-Gilroy Variant-Bonnydoon Variant, Henneke stony clay loam, Kehoe, Rodeo Clay Loam, and Tamalpais-Barnabe Variant (USDA, Soil Surveys for Marin, San Francisco, and San Mateo Counties). All of these soils are susceptible to sheet and rill erosion when disturbed or exposed. The susceptibility to wind erosion is generally low.

Hydrology and Watersheds

Water resources in GGNRA include springs, streams, ponds, lakes, wetlands, lagoons, the San Francisco Bay, and the Pacific Ocean. Many significant watersheds are located wholly or partially within the park. From north to south, the watersheds are Bolinas Lagoon, Redwood Creek, Tennessee Valley (Elk Creek), Rodeo Lagoon (including Gerbode Valley subwatershed), Nyhan Creek, Lobos Creek, Milagra and Sweeney Ridges, San Pedro Creek, West Union Creek, and the San Francisco watershed lands in San Mateo County (see Figures 3-5 and 3-6). Many smaller watersheds drain the steep coastal bluffs directly into the San Francisco Bay or Pacific Ocean.

Eleven rare wildlife species are associated with GGNRA waters, including nine federally listed species: the California freshwater shrimp (*Syncaris pacifica*), tidewater goby (*Eucyclogobius newberryi*), red-legged frog (*Rana aurora draytonii*), Sacramento River winter-run chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Oncorhynchus mykiss*), coho salmon (*Oncorhynchus kisutch*), San Francisco garter snake (*Thamnophis sirtalis tetrataenia*), Steller sea lion (*Eumetopias jubatus*), and California brown pelican (*Pelecanus occidentalis*).

The NPS has been monitoring water quality to varying degrees within these aquatic systems (discussed more in the next section). Most water quality sampling to date has focused on specific sites with known or suspected water quality impacts, including beach water quality monitoring. The NPS is presently designing a more comprehensive monitoring program that should identify any existing impacts and serve as baseline data to determine future impacts such as catastrophic fire events. For the lands in the southern part of the park (San Francisco and San Mateo counties), this work will also include an inventory of the largely unknown water resources. The monitoring will be coordinated through the San Francisco Bay Area network of regional national park sites.

Watershed Characteristics

The watersheds in GGNRA vary in the ratio of forest cover to scrub vegetation. Watersheds in southern Marin, such as Rodeo Lagoon and Tennessee Valley, are dominated by scrub and grassland vegetation with the majority of the trees in the riparian zone. These watersheds also have extensive stream and wetland complexes throughout their valley floors. Other watersheds, such as the Redwood Creek watershed, Bolinas Lagoon watershed, and the San Pedro Creek watershed, have denser forests beyond the riparian zone. These watersheds have steeper slopes and narrower valleys, and thus restrict the extent of wetlands.

Marin County Watersheds

Most Marin County watersheds drain to the Pacific Ocean. Watersheds relevant to GGNRA lands are as follows:

Bolinas Lagoon

The NPS manages several small subwatersheds that drain to the southern end of Bolinas Lagoon. The Bolinas Lagoon watershed extends from the Bolinas Ridges west to Inverness Ridge, encompassing 16.7 square miles. Sixty-six percent of the watershed is in public ownership and is managed by GGNRA, Point Reyes National Seashore (PRNS), Mount Tamalpais State Park, the Marin Municipal Water District (MMWD), and the Marin County Open Space District (MCOSD). Private lands in the watershed include Audubon Canyon Ranch and the communities of Bolinas, Seadrift, and Stinson Beach. Streams within the NPS-managed areas of Bolinas Lagoon Watershed in GGNRA include Morses Gulch, McKinnon Gulch, Stinson Gulch, Easkoot Creek, and several unnamed tributaries. Easkoot Creek provides domestic water supply to the town of Stinson Beach (via the Stinson Beach Water District) and GGNRA facilities at Stinson Beach.

Watersheds

Marin County

National Park Service
U.S. Department of the Interior
Golden Gate National Recreation Area

Fire Management Plan EIS 2005

3-05 Watersheds_FMP_north.mxd 8/22/2005

Figure 3-5

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Watersheds

San Francisco and San Mateo County

National Park Service
U.S. Department of the Interior
Golden Gate National Recreation Area

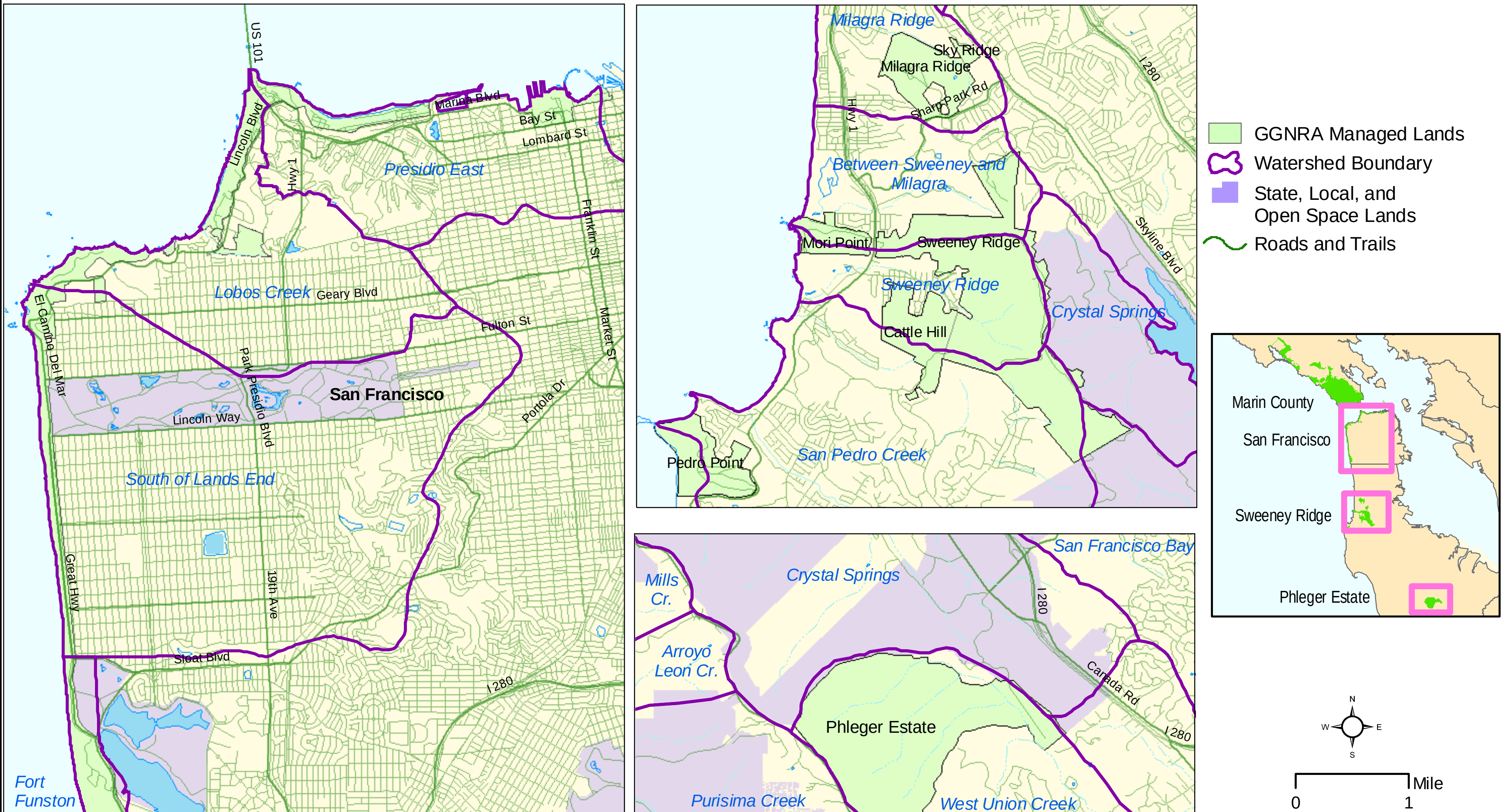

Figure 3-6

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3-06 Watersheds_FMP_South.mxd
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These tributaries are steep and flow through highly erodible Franciscan Complex. Any activity that creates soil disturbance in these watersheds, including fire management actions, could potentially increase erosion and sediment delivery rates to Bolinas Lagoon through loss of vegetation cover and subsequent soil exposure to rainwater erosion. MCOSD is currently evaluating the need to restore Bolinas Lagoon, as well as potential strategies to increase tidal prism, that may include dredging of accumulated sediment from the lagoon.

South of Bolinas

Between Bolinas Lagoon and Muir Beach, the "Game Refuge" watershed drains 3.6 square miles of Mount Tamalpais State Park and GGNRA lands directly to the Pacific Ocean. Several streams, including Steep Ravine Canyon, Lone Tree Creek, and Cold Stream, drain steep landscapes that are dominated by Franciscan Formation. Landslides are common in this area, and the steep terrain combined with unstable geology results in high erosion rates and sensitivity to disturbance in these watersheds.

Redwood Creek

The Redwood Creek watershed encompasses 8.9 square miles extending from the peaks of Mount Tamalpais, through Muir Woods National Monument, to the Pacific Ocean at Muir Beach. Ninety-five percent of the watershed is owned and managed by three public agencies: Marin Municipal Water District, California Department of Parks and Recreation (Mount Tamalpais State Park), and the NPS (Muir Woods National Monument and GGNRA). Three residential communities also are located in the watershed: Muir Beach, Muir Woods Park, and Green Gulch Farm (a part of the San Francisco Zen Center). Several threatened animal species also occur in the watershed, including coho salmon, steelhead, California red-legged frog, and the northern spotted owl (*Strix occidentalis caurina*). Public agencies in the watershed, including the NPS, have recently published the Redwood Creek Watershed Vision for the Future (July 2003). FMP actions in this watershed should be consistent with the Guiding Principles and Desired Future Conditions stated in this vision document.

Marin Headlands

The 2.4-square-mile Tennessee Valley watershed extends from Coyote Ridge to Wolf Ridge. GGNRA encompasses several facilities in this watershed, including Miwok Horse Stable, a parking lot, extensive trails, and a walk-in camping area. The watershed contains several small impoundments, all of which are remnant stock ponds from prior ranching. Recent dam removal activities at one of the stock ponds have led to a short-term increase in sediment to the streams; sediment levels are expected to stabilize as the new stream configuration becomes vegetated. Two small watersheds, Pirates Cove Bluffs and Tennessee Bluffs, drain into the Pacific near the mouth of the Tennessee Valley watershed.

The Rodeo Lagoon watershed, including the Gerbode Valley subwatershed, drains 4.4 square miles of GGNRA. Rodeo Lagoon is a significant wetland/estuarine resource that provides important habitat for marine birds and other species. The NPS is currently working with the University of California at Berkeley (U.C. Berkeley) to assess resources conditions in this watershed and develop a restoration plan for the creek and its associated wetlands. West of Rodeo Valley, the Point Bonita Bluffs watershed drains the steep cliffs into the Pacific.

San Francisco Bay Drainages (Marin)

The upper reaches of the Homestead Valley, Nyhan Creek, and Morning Sun watersheds are in GGNRA lands, while the lower reaches include the communities of Sausalito, Marin City, Tam Junction, and Mill Valley. The streams in these watersheds drain to Richardson Bay.

Golden Gate Channel and San Francisco Bay

Several small, steep watersheds drain 1.9 square miles of GGNRA lands in the southern Marin Headlands directly to the Golden Gate Channel and San Francisco Bay in the vicinity of the Golden Gate Bridge. These include the Bonita Cove, Kirby Cove, East Fort Baker, and Sausalito watersheds.

San Francisco City and County Watersheds

The majority of the watersheds in San Francisco are highly urbanized, and their boundaries have been modified by storm drainage projects and other urban infrastructure. The NPS manages lands in San Francisco draining to San Francisco Bay, the Golden Gate Channel, and the Pacific Ocean. Tennessee Hollow and Lobos Creek, both of which are within the GGNRA and the Presidio, remain in a relatively unurbanized state and are significant water resources in the park. The Tennessee Hollow stream, in the Presidio East watershed, is the main fresh water source for the Crissy Field marsh, a recently completed wetland restoration project. Lobos Creek, in the Presidio West watershed, is the main water supply for the Presidio.

San Mateo County Watersheds

The watersheds in San Mateo County have not been comprehensively studied due to piecemeal land management by various agencies and private holdings. The watersheds that wholly or partly contain GGNRA land include Milagra, between Sweeney and Milagra, Sweeney, San Pedro Creek, Crystal Springs (part of the larger San Francisco watershed), and West Union/San Francisquito Creek.

The 23-square-mile San Francisco watershed is owned by the San Francisco Public Utilities Commission and is part of the water supply storage for the City and County of San Francisco. This watershed includes San Andreas Lake, Crystal Springs, Pilarcitos Lake, and a portion of the Pilarcitos Creek watershed.

The San Pedro Creek watershed drains portions of the San Francisco watershed lands, Picardo Ranch, and portions of Devils Slide. The West Union Creek watershed contains a tributary to the Searsville Lake that drains the Phleger Estate at the south end of GGNRA.

Water Quality

The size and nature of the park (including high visitor use, the urban interface, and multitude of land uses) create several water quality-related issues. Accelerated erosion due to roads, trails, and other uses and developments threatens the sediment balance and ecological health of several watersheds. Grazing is no longer allowed on NPS-managed lands in GGNRA (NPS 1999b) but some of the impacts remain. Bacteria and nutrient inputs from equestrian operations, pet waste, agricultural operations, and potentially sewer and septic systems can affect wildlife and public health as well as the overall ecological balance of water resources. Alteration of channels (including dams and culverts) affects the ecological health of park watersheds. These primary issues occur to varying extents within multiple park watersheds.

Many park water quality issues are related to facilities and structures. A roads and trails inventory exists and many structures are documented in the Maintenance Division's facilities database. However, a comprehensive inventory of park facilities and structures (including dams, culverts, and outfalls) has not been conducted.

Work is in progress to document facilities/roads and trails and other water quality threats more thoroughly. For example, for the Redwood Creek watershed, a sediment budget study and a report of all sediment sources in the watershed were conducted. Trail maps are being updated for the park and erosion surveys continue throughout the Marin Headlands. Culvert mapping has occurred in Rodeo Valley.

A summary of existing data for GGNRA water resources and a description of future monitoring needs is included in a report entitled San Francisco Area Network Preliminary Water Quality Status Report (Cooprider, 2004), which is a review of the nine regional park units. The following information summarizes the park watersheds that are described in the report.

Marin Headlands/Redwood Creek/Stinson Beach/Bolinas Lagoon Areas

Water quality monitoring has been conducted in Redwood Creek and tributaries (including Kent Creek, Camino del Canyon, Banducci Tributary, Green Gulch, and Golden Gate Dairy Tributary) at numerous locations throughout the years. Several data sets exist for discrete (i.e., short-term, focused) monitoring projects. For example, monitoring by the NPS in the Redwood Creek watershed was conducted in 1986-1988, 1990-1991, and 1993-1996. Much of the water quality monitoring within the park has focused on lower Redwood Creek due to concerns related to nutrient and bacteria inputs in this locale, including recent data related to the Golden Gate Dairy and Big Lagoon.

Short-term data sets also exist for Rodeo Creek and Tennessee Valley (1994-1996). Rodeo Creek and Tennessee Valley were monitored along with Green Gulch between 1998 and 2001 as part of intensive sampling related to stable operations and other potential sources of bacteria and nutrients. Parameters typically monitored included flow (though flow data has been sporadic), pH, temperature, dissolved oxygen, conductivity, BOD (Biological Oxygen Demand), salinity, TSS (Total Suspended Solids), fecal and total coliforms, nitrates, ammonia, phosphates, Total P, metals (emphasis on copper), MBAS (Methyl Blue Activated Substances), and chloride. Not all parameters were monitored at all sites.

Consultants, the United States Geological Survey (USGS), and other entities have also conducted monitoring. For example, the Stinson Beach County Water Agency currently monitors Easkoot Creek for fecal coliforms and nutrients. Limited monitoring has also been conducted in Oakwood Valley and Nyhan Creek as part of an overall stormwater monitoring project including Redwood Creek, Tennessee Valley, and Rodeo Creek.

Flow monitoring by various entities, including the NPS, USGS, local universities, and consultants, has also been conducted. Flow monitoring sites have typically corresponded with water quality monitoring sites and include the Redwood Creek watershed (including Camino del Canyon, Kent Creek, Banducci Tributary, and Green Gulch Creek) as well as Easkoot Creek, Rodeo Creek, and Tennessee Valley. The USGS also monitored sediment and streamflow in Audubon Canyon and Morses Creek (near Bolinas) between 1967 and 1969. UC Berkeley (Lehre 1974) monitored Lone Tree Creek (south of Stinson Beach) between 1972 and 1974. Stream gauges were installed by the NPS at Redwood Creek (Highway 1 bridge) and Easkoot Creek.

Because of high/toxic nutrient loads, algal blooms have occurred in Rodeo Lagoon. In addition to nutrient issues, Rodeo Lagoon sediments may contain elevated amounts of copper from copper sulfate (algaecide) treatment.

San Francisco and San Mateo County

Water quality monitoring has been conducted periodically at the Presidio for several years. Until very recently, however, no monitoring of surface water had been conducted by the NPS in the southern GGNRA lands.

At Lobos Creek in the Presidio, the Urban Watershed Project (UWP), a nonprofit group has conducted fecal coliform monitoring through a contract with the Presidio Trust. The City and County of San Francisco has also recently conducted monitoring in Lobos Creek. Limited sampling of Lobos Creek was also conducted through the Environmental Remediation Program. Likewise, basic water quality parameters have been collected in Tennessee Hollow by UWP, and by the NPS at the Crissy Field marsh.

Some limited water quality monitoring has been conducted within the West Union/San Franciscquito Creek watershed (West Union Creek is located within this watershed), but no monitoring has been conducted on NPS lands. The San Francisquito Creek Watershed Council is actively involved in management and monitoring of this watershed. Through the Watershed Council, consultants have monitored the Bear Creek watershed (including West Union Creek). However, no sites have been located within Phleger Estate or the adjacent county park.

The Environmental Protection Agency (EPA) and the City of San Francisco Waste Water Treatment Plant conducted water quality monitoring (including several indicator bacteria) in San Pedro Creek. A local high school student has also tested the creek for temperature, pH, conductivity, transparency, and oxygen. The San Pedro Creek Watershed Coalition has submitted a proposal to conduct DNA testing and optical brightener testing to determine the source of high indicator bacteria levels in the creek (San Pedro Creek Watershed Council 2002).

San Francisquito Creek is listed on the Section 303d list as being impaired by sediment and diazinon. Concerns in West Union Creek, a San Francisquito Creek tributary within Phleger Estate, include erosion and runoff from trails. Landslides and significant bank erosion have been observed.

Issues in Milagra, Sanchez, and Calera Creeks are mostly unknown due to the lack of water quality data. However, suspected issues in these urban creeks include fertilizer or pesticide runoff from lawns in residential areas and a golf course. In addition, pet waste, oil and chemical runoff from roads, and bacteria and nutrient inputs from leaky sewer pipes are also suspected concerns.

Air Quality

The primary objective of the Clean Air Act (CAA) is to establish federal standards for various pollutants from both stationary and mobile sources and area sources and to provide for the regulation of polluting emissions via state implementation plans. Substantial amendments to the CAA were enacted in 1977[1] (P.L. 95-95; 91 Stat. 685) and in 1990 (P.L. 101-549, 104 Stat. 2399). A principal objective of the 1977 amendments is to prevent significant deterioration in areas where air quality meets or is better than the national ambient air quality standards (NAAQS), and to provide for improved air quality in areas that do not meet NAAQS ("nonattainment" areas).

The 1977 amendments to the CAA established Class I, II, and III areas, where emissions of particulate matter, sulfur dioxide, and nitrogen dioxide are to be restricted to control impacts on visibility from haze and smog. The restrictions are most protective in Class I areas, such as Yosemite National Park and PRNS. Mandatory Class I areas are defined by the CAA as international parks, national wilderness, and national memorial parks greater than 5,000 acres and national parks greater than 6,000 acres that were in existence when the 1977 amendments were enacted. Such areas may not be redesignated to either Class II or Class III. GGNRA is a "Class II area", defined as areas that are national monuments, national primitive areas, national preserves, national recreation areas, national wild and scenic rivers, national wildlife refuges, and national lakeshores or seashores that were in existence (or authorized) on August 7, 1977 and exceed 10,000 acres, and national parks and wilderness areas established after August 7, 1977. A Class III designation, where new air pollution would be allowed, was envisioned by Congress, but no areas have been given that designation (Sandburg et al. 2002). Only states or Native American governing bodies have authority to redesignate areas to Class III.

In accordance with the CAA, the NPS, as the Federal Land Manager (FLM) of GGNRA, is responsible for the protection of the park's air quality-related values (AQRVs) such as visibility, odors, plants, animals, soils, water quality, and cultural and historic structures that may be affected by air pollution. Historically, the EPA has regarded smoke from wildland fires as temporary and therefore not subject to issuance of a PSD permit that would allow an action to increase pollution levels (Sandburg et al. 2002)

Actions of the GGNRA FMP must also protect air quality at Point Reyes National Seashore (PRNS), a Clean Air Act Class I park to the northwest of GGNRA. There are currently no significant air pollution

[1] The 1977 amendments to the Clean Air Act established a national visibility goal of "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas..."

emission issues at PRNS, which was rated by a recent NPS report as having low exposure to ozone, sulfur, and nitrogen emissions and low potential for acidification of surface waters (Sullivan et al. 2001).

GGNRA is located in the San Francisco Bay Area Air Basin and is under the jurisdiction of the Bay Area Air Quality Management District (BAAQMD). BAAQMD regulates air quality under agreements with the California Air Resources Board (CARB) and the U.S. Environmental Protection Agency (EPA), Region 9. BAAQMD has direct responsibility for the protection of air quality and implementation of local rules and the State Implementation Plan (SIP) measures for achieving and maintaining the national and state standards within the Bay Area Air Basin. To achieve these objectives, BAAQMD is charged with monitoring air pollution emissions under the Clean Air Act and permitting stationary sources, such as power plants, that contribute emissions to the ambient air quality of the Bay Area Air Basin.

Both CARB and the EPA have general oversight responsibilities to ensure that local, state, and federal rules and regulations, including the issuance of air pollution permits, are implemented consistent with PSD requirements and attainment and maintenance of the California standards and NAAQS. In most circumstances, mobile sources, such as vehicle traffic, are regulated by CARB.

A required by the Clean Air Act, the EPA identifies and sets standards to protect human health and welfare for six pollutants: ozone, carbon monoxide, particulate matter (PM_{10} and $PM_{2.5}$), sulfur dioxide, lead, and nitrogen oxide. The term “criteria pollutants” derives from the requirement that the EPA describe the characteristics and potential health and welfare effects of these pollutants. EPA periodically reviews new scientific data and may propose revisions to the standards as a result. The standards for the criteria pollutants – NAAQS – have been established and are shown in Table 3-4. Both primary (or

Table 3-4: Ambient Air Quality Standards and Bay Area Attainment Status

Pollutant	Averaging Time	California Standards[1]		National Standards[2]	
		Concentration	Attainment Status	Concentration[3]	Attainment Status
Ozone	8-Hour	0.070 ppm (137 µg/m^3)	See Note 9	0.08 ppm	N[4]
	1-Hour	0.09 ppm (180 µg/m^3)	N		See Note 5
Carbon Monoxide	8-Hour	9.0 ppm (10 mg/m^3)	A	9 ppm (10 mg/m^3)	A[6]
	1-Hour	20 ppm (23 mg/m^3)	A	35 ppm (40 mg/m^3)	A
Nitrogen Dioxide	Annual Average			0.053 ppm (100 µg/m^3)	A
	1-Hour	0.25 ppm (470 µg/m^3)	A		
Sulfur Dioxide	Annual Average			80 µg/m3 (0.03 ppm)	A
	24-Hour	0.04 ppm (105 µg/m^3)	A	0.14 ppm (365 µg/m3)	A
	1-Hour	0.25 ppm (655 µg/m^3)	A		

Pollutant	Averaging Time	California Standards[1] Concentration	California Standards[1] Attainment Status	National Standards[2] Concentration[3]	National Standards[2] Attainment Status
Particulate Matter (PM_{10})	Annual Arithmetic Mean	20 µg/m^3	N[7]	50 µg/m3	A
	24-Hour	50 µg/m^3	N	150 µg/m3	U
Particulate Matter – Fine ($PM_{2.5}$)	Annual Arithmetic Mean	12 µg/m^3	N[7]	15 µg/m3	A
	24-Hour			65 µg/m3	A
Sulfates	24-Hour	25 µg/m^3	A		
Lead	Calendar Quarter			1.5 µg/m3	A
	30-Day Average	1.5 µg/m^3	A		
Hydrogen Sulfide	1-Hour	0.03 ppm (42 µg/m^3)	U		
Vinyl Chloride (chloroethene)	24-Hour	0.010 ppm (26 µg/m^3)	No information available		
Visibility-Reducing Particles	8-Hour (1000 to 1800 Pacific Standard Time)	See Note 8	A		

Source: BAAQMD July 2005.
Notes:
A = Attainment N = Nonattainment U = Unclassified
ppm = parts per million
mg/m3 = milligrams per cubic meter
µg/m3 = micrograms per cubic meter

1. California standards for ozone, carbon monoxide (except Lake Tahoe), sulfur dioxide (1-hour and 24-hour), nitrogen dioxide, suspended particulate matter – PM_{10}, and visibility-reducing particles are values that are not to be exceeded. The standards for sulfates, Lake Tahoe carbon monoxide, lead, hydrogen sulfide, and vinyl chloride are not to be equaled or exceeded. If the standard is for a 1-hour, 8-hour, or 24-hour average (i.e., all standards except for lead and the PM_{10} annual standard), then some measurements may be excluded. In particular, measurements are excluded that CARB determines would occur less than once per year on the average. The Lake Tahoe carbon monoxide standard is 6.0 ppm, a level one-half the national standard and two-thirds the state standard.
2. National standards other than for ozone, particulates, and those based on annual averages are not to be exceeded more than once a year. The 1-hour ozone standard is attained if, during the most recent three-year period, the average number of days per year with maximum hourly concentrations above the standard is equal to or less than one. The 8-hour ozone standard is attained when the 3-year average of the fourth highest daily concentrations is 0.08 ppm or less. The 24-hour PM_{10} standard is attained when the 3-year average of the 99th percentile of monitored concentrations is less than 150 µg/m3. The 24-hour $PM_{2.5}$ standard is attained when the 3-year average of 98th percentiles is less than 65 µg/m3.
   Except for the national particulate standards, annual standards are met if the annual average falls below the standard at every site. The national annual particulate standard for PM_{10} is met if the 3-year average falls below the standard at every site. The annual $PM_{2.5}$ standard is met if the 3-year average of annual averages spatially-averaged across officially designed clusters of sites falls below the standard.
3. National air quality standards are set at levels determined to be protective of public health with an adequate margin of safety. Each state must attain these standards no later than three years after that state's implementation plan is approved by the Environmental Protection Agency.
4. In June 2004, the Bay Area was designated as a marginal nonattainment area for the national 8-hour standard.
5. The national 1-hour ozone standard was revoked on June 15, 2005.
6. In April 1998, the Bay Area was redesignated to attainment for the national 8-hour carbon monoxide standard.
7. In June 2002, CARB established new annual standards for $PM_{2.5}$ and PM_{10}.
8. Statewide Visibility-Reducing Particles Standard (except Lake Tahoe Air Basin): Particles in sufficient amount to produce an extinction coefficient of 0.23 per kilometer when the relative humidity is less than 70 percent. This standard is intended to limit the frequency and severity of visibility impairment due to regional haze and is equivalent to a 10-mile nominal visual range.
9. This standard was approved by the California Air Resources Board on April 28, 2005 and is expected to become effective in early 2006.

health-based) and secondary (or welfare-based) standards are provided for under the NAAQS. As already noted, a geographic area that meets or does better than the NAAQS is called an “attainment” area; areas that do not meet the NAAQS are called “nonattainment” areas.

Under state statutes, California regulations can be stricter than federal regulations. For example, in California there are ambient standards for vinyl chloride and hydrogen sulfide, and a visibility protection standard that regulates visibility-reducing particles. Criteria for determining violations of a state standard vary, depending on the pollutant, from any exceedance of the standard to a statistically-based test requiring multiple years of monitoring data. Also, the standards themselves vary from short-term average levels such as 83-hour or 24-hour concentrations, to annual average concentrations of a particular pollutant.

Five of the six criteria pollutants are potential by-products of FMP actions such as prescribed burning, wildland fire suppression, and mechanical fuel reduction treatments. The health and ecological effects of these five criteria pollutants are shown in Table 3-5. The sixth criteria pollutant – lead – is not a by-product of FMP actions, and current Bay Area Air Basin levels of lead would not be affected by implementation of the FMP alternatives.

Smoke from wild and prescribed fires is inventoried and managed differently from air pollution emissions. Wildfires are natural events and their emissions are addressed by the Environmental Protection Agency (EPA) Natural Events Policy. Emissions from prescribed fire are addressed by EPA’s Interim Air Quality Policy on Wildland and Prescribed Fire. The states use these policy documents and other information in the development of the SIP. In accordance with the California Smoke Management Guidelines, BAAQMD manages smoke emissions from prescribed burning through a Smoke Management Program by regulating allowable burn days, reviewing burn plans, and coordinating the number of allowable burns per day. The goal of BAAQMD’s smoke management program is to continue prescribed burning as a resource management tool while minimizing smoke impacts on public health in populated areas.

The San Francisco Bay Area Air Basin is a nonattainment area for the state standard for PM_{10} and $PM_{2.5}$ (particulate matter less than 10 microns and 2.5 microns in diameter, respectively), the state one-hour ozone standard, and in marginal non-attainment for the federal eight-hour ozone standard (see Table 3-4). Under the 1990 CAA amendments, the EPA was mandated to adopt conformity regulations for implementing Section 176 of the CAA. Under this provision and the implementing requirements of 1993, federal actions proposed in areas that exceed NAAQS must conform to the SIP. Since the area is in nonattainment for ozone and PM, federal actions, such as the GGNRA FMP, must conform to the federally approved SIP. Exceedance of federal standards cannot occur more than once per year for an area to stay in attainment. California ambient air quality standards (AAQS) are generally not to be exceeded at all.

Table 3-5: Health and Ecological Effects of the Federal Criteria Pollutants[1]

Federal Criteria Pollutant	Important By-Product of FMP Actions?	Principal Health and Ecological Effects
OZONE (O_3) Oxygen we breathe is 2 oxygen atoms (O_2) while ozone is 3 atoms (O_3). Ozone occurs in nature; it produces the sharp smell noticed near a lightning strike. High concentrations are found in the stratosphere, where ozone shields the Earth against harmful sunrays. Ground-level ozone is a component of smog produced by burning, especially coal, gasoline, and other fuels, and chemical emissions from products such as solvents and paints.	**No,** not a significant by-product.	• High levels can cause lung irritation and inflammation, wheezing, coughing, and breathing difficulties during exercise or outdoor activities. People with respiratory problems are most vulnerable, but healthy adults and children that exercise outdoors can be affected. • Repeated exposure to ozone pollution over several months may cause permanent lung damage. • Even at very low levels, ozone can aggravate asthma, reduce lung capacity, and increase susceptibility to respiratory illnesses like pneumonia and bronchitis. • Ozone interferes with the ability of plants to produce and store food, which can make them more susceptible to disease, insects, other pollutants, and harsh weather. • Ozone damages the leaves of trees and other plants, reducing crop and forest yields, and degrading the appearance of cities, national parks, and recreation areas.
CARBON MONOXIDE (CO) A colorless, odorless, poisonous gas, produced by incomplete burning of synthetic and carbon-based fuels, including gasoline, oil and wood.	**Yes,** CO is one by-product of the incomplete burning or smoldering of fuels during wildland fire, pile burning, and prescribed burning.	• Low levels of CO can be a serious threat for sufferers of heart disease, clogged arteries, or congestive heart failure. • Healthy people who breathe high levels of CO can develop vision problems, reduced ability to work or learn, reduced manual dexterity, and difficulty performing complex tasks. • At extremely high levels, CO is poisonous and can cause death. • CO contributes to the formation of smog (ground-level ozone), which can trigger serious respiratory problems.
PARTICULATE MATTER (PM) Includes dust, soot and other tiny bits of solid materials released into the air. PM_{10} particles are between 2.5 and 10 micrometers in size (25 to 100 times thinner than a human hair). Particles less than 2.5 micrometers are a California criteria pollutant and are referred to as $PM_{2.5}$.	**Yes,** PM is the main pollutant of concern associated with smoke.	• Breathing PM is linked to significant health problems, including eye, nose, and throat irritation; aggravated asthma; coughing and difficult or painful breathing; chronic bronchitis; decreased lung function; and premature death. • PM is a major source of visibility impairment in national parks. • PM can be carried long distances by wind before settling on ground or water. The effects can include making lakes and streams

Federal Criteria Pollutant	Important By-Product of FMP Actions?	Principal Health and Ecological Effects
		acidic, changing the nutrient balance in coastal waters and large river basins, depleting the nutrients in soil, damaging sensitive forests and farm crops, and affecting the diversity of ecosystems. • PM causes damage to cultural resources by eroding and staining (soot) structures such as monuments and statues.
NITROGEN OXIDES (NO_X) Highly reactive gases emitted primarily by fuel combustion and present in all urban atmospheres. NO_X is an important precursor to both ozone and acid rain. The reaction between NO_X and VOCs (volatile organic compounds) forms ozone or smog.	**Yes**, formed mainly by fuels burning at high temperatures.	• Smog can cause lung tissue damage and reduction in lung function in people working or exercising outside and people with lung diseases (e.g., asthma). • NO_X, sulfur dioxide, and other substances form acidic precipitation or dry particles in the air. Acid rain causes deterioration of vehicles, buildings, and historical monuments, and can degrade aquatic habitat as water becomes more acidic. • NO_X reacts with ammonia, moisture, and other compounds to form nitric acid that can affect breathing and cause permanent damage to lung tissue. • Small acidic particles can penetrate deeply into the lungs and can cause or worsen respiratory diseases such as emphysema and bronchitis, and aggravate heart disease. • Increased nitrogen loading in water bodies, particularly coastal estuaries, upsets the chemical balance of nutrients used by aquatic plants and animals and accelerates oxygen depletion. • NO_X accumulating in the atmosphere with other gasses is causing a gradual rise in the Earth's temperature with risks for human health, sea level rise, and habitat change. • NO_X reacts readily with common organic chemicals and ozone to form a wide variety of toxic products, some of which may cause biological mutations (nitroarenes and nitrosamines). • Nitrate particles and nitrogen dioxide can block the transmission of light, reducing visibility in urban areas and on a regional scale in national parks.

Federal Criteria Pollutant	Important By-Product of FMP Actions?	Principal Health and Ecological Effects
SULFUR DIOXIDE (SO_2) A gas consisting of one sulfur and two oxygen atoms. SO_2 converts to an aerosol that is a very efficient light scatterer. It can convert into acid droplets consisting primarily of sulfuric acid. Principally produced by coal- and oil-burning power plants.	**No,** not a significant by-product.	• High levels of SO_2 can cause temporary breathing difficulty for people with asthma who are active outdoors. Long-term exposure to SO_2 gas and particles can cause respiratory illness and aggravate existing heart disease. • Sulfate particles are the major cause of haze, which reduces visibility in many national parks. • SO_2 and nitrogen oxides react to form acids, which fall to earth as acidic rain or dry particles. Acid rain damages forests and crops, changes the makeup of soil, and makes lakes and streams acidic and unsuitable for fish. Continued exposure can change the natural variety of plants and animals in an ecosystem. • SO_2 accelerates the decay of building materials including irreplaceable monuments, statues, and sculptures.

Source: BAAQMD, 2004.
Note:
1. Five of six federal criteria pollutants could be emitted to the air by FMP actions. The sixth criteria pollutant, lead, would not be a by-product of the actions included in the FMP.

Section 176 of the Clear Air Act states that federal actions, such as implementation of the FMP alternatives, must not:

- Cause or contribute to new violations of any standard;
- Increase the frequency or severity of any existing violation;
- Interfere with timely attainment or maintenance of any standard;
- Delay emission reduction milestones; or
- Contradict SIP requirements.

GGNRA has historically ensured the conformity of fire management actions by ensuring that all prescribed burning is planned and implemented in accordance with the BAAQMD Smoke Management Program.

The overall attainment status of the Bay Area Air Basin with regard to the NAAQS and state AAQS is shown in Table 3-4.

Air Quality Monitoring Sources of Emissions within GGNRA

In order to assess and minimize the impacts of NPS activities such as fire management actions on air quality and other resources and values in GGNRA, the other current sources of air pollution within the parks need to be identified. An air emissions inventory was conducted in 1999 to determine the origins, compositions, and rates of emission of pollutants affecting park lands and resources (NPS 2000d). In addition to GGNRA activities, the inventory included air emissions associated with park partners and concessionaire operations and visitor activities to the extent that data were available. Standardized emission factors and air quality models from the California Air Resources Board (CARB) and the U.S. Environmental Protection Agency (EPA) were used to develop emission levels for the range of activities and facilities that can emit pollutants in GGNRA.

Sources of air emission within GGNRA include all three types identified by the Clean Air Act – stationary sources, area sources, and mobile sources. Stationary sources can include fossil fuel-fired space and water heating equipment, backup generators, fuel storage tanks, paint and chemical usage, and woodworking equipment. Area sources may include prescribed burning, campfires, and bonfires. Mobile sources may include vehicles and other equipment operated within the park by visitors, tour operators, GGNRA employees, and concessionaire employees.

The emissions inventory included all lands and uses within the FMP planning area with the exception of the Presidio, which is primarily under the management of the Presidio Trust, a separate federal agency. Included in the inventory were all structures, vehicles, boats, and equipment used by the park, park partners, or concessionaires, such as the Blue and Gold Fleet that operates the ferry service to Alcatraz Island.

As shown in Tables 3-6 and 3-7, carbon monoxide (CO) and particulate matter (PM) emissions from prescribed burning, although not major by CAA definitions, were the largest air emission sources generated at GGNRA for the year 1998,when the emissions inventory was calculated. Three prescribed burns were conducted that year totaling 123 acres. Table 3-6 shows how lighter fuels, such as the grasses burned at the Pablo and Whitegate prescribed burns, emit much lower levels of emissions per acre than shrublands or forested areas. Table 3-7 compares the annual emissions estimated for all stationary, mobile, and area sources at GGNRA as part of the 1998 emissions inventory.

Table 3-6: GGNRA 1998 Prescribed Burning Emissions

Fire Name	Acres	Fuel Type	PM_{10} (lbs/yr)	SO_2 (lbs/yr)	NO_X (lbs/yr)	CO (lbs/yr)	VOC (lbs/yr)
Pablo	35	Grass	1,400	190	2,530	10,530	0
Whitegate	50	Grass	2,000	275	3,600	15,040	0
Ben Johnson	38	Timber	16,250	210	2,740	151,700	8,700
Total	123		19,650	675	8,870	177,270	8.700

Source: NPS 2000d, GGNRA Emission Inventory 1998.

PM_{10} = particulate matter NO_X = nitrogen dioxide   VOC = volatile organic compounds
SO_2 = sulfur dioxide   CO = carbon monoxide   lbs/yr = pounds per year

Table 3-7: Summary of Annual Emissions from Stationary and Area Sources

Activity	Particulates		Sulfur Dioxide		Nitrogen Oxides		Carbon Monoxide		VOCs (ozone precursor)	
	lbs/yr	tons/yr	lbs/yr	tons/yr	lbs/yr	tons/yr	lbs/yr	tons/yr	lbs/yr	tons/yr
Stationary Combustion Sources										
Space and Water Heating Units	958	0.48	50	0.03	29,220	14.61	4,650	2.33	714	0.36
Generators	33	0.02	31	0.02	470	0.24	101	0.05	38	0.02
Fireplaces	484	0.24	6	0.00	36	0.02	3,536	1.77	3,206	1.60
Combustion Emission Subtotal	1,475	0.74	87	0.05	29,726	14.87	8,287	4.15	3,958	1.98
Area Sources										
Campfires	129	0.06	–	–	30	0.02	1,060	0.53	144	0.07
Beach Fires	39	0.02	–	–	9	0.00	322	0.16	44	0.02
Prescribed Burns	19,650	9.83	190	0.10	8,870	4.44	177,270	88.64	8,700	4.35
Area Source Emission Subtotal	19,818	9.91	190	0.10	8,909	4.46	178,652	89.33	8,888	4.44
Vehicles										
Visitor Vehicles	870	0.44	–	–	394	0.20	2,804	1.40	214	0.11
GGNRA Vehicle	Not Available									
Park Partner/Concession	Not Available									
Vehicle Emission Subtotal	870	0.44	–	–	394	0.20	2,804	1.40	214	0.11
Ferry Vessels										
Blue and Gold Fleet Vessels	15,780	7.89	13,930	6.97	331,000	165.50	106,600	53.30	26,900	13.45
Totals										
Totals	Particulates		Sulfur Dioxide		Nitrogen Oxides		Carbon Monoxide		VOCs	
	lbs/yr	tons/yr	lbs/yr	tons/yr	lbs/yr	tons/yr	lbs/yr	tons/yr	lbs/yr	tons/yr
	37,943	18.98	14,207	7.12	370,029	185.03	293,343	148.18	39,960	19.98

Source: NPS 2000d, GGNRA Emission Inventory 1998.

VOCs = volatile organic compounds lbs/yr = pounds per year tons/yr = tons per year

There are no air quality monitoring stations in operation for the coastal areas of the Bay Area Air Basin that are certain to represent air quality conditions within GGNRA. A monitoring station at Fort Cronkhite in the Marin Headlands records levels of toxins present in the air as a by-product of manufacturing, such as acetone and benzene, and does not monitor for criteria pollutants. The closest monitoring stations to GGNRA lands that record levels of criteria pollutants are in the eastern halves of the three GGNRA counties in the cities of San Rafael, Redwood City, and eastern San Francisco. The levels recorded at these stations, which are based in the midst of urbanized development, would be more representative of the cumulative levels of air pollutants in urbanized areas that contain heavily trafficked roadways, urban and residential sources, and existing stationary sources throughout the air basin. Data collected at these stations can serve as very conservative estimates of ambient air quality affecting the parklands, which are largely coastal and generally upwind (based on prevailing wind direction) of local sources of Bay Area air emissions, but are still subject to pollutant problems such as ozone that have a more regional effect on air quality. However, the actual ambient pollutant concentrations within the parklands are anticipated to have lower background levels of these pollutants because the project area and surroundings are more remote and generally upwind of roadways and other emission sources.

As shown in Table 3-4, the nine-county San Francisco Bay Area Air Basin (consisting of seven entire counties and parts of two counties) is in nonattainment for the state PM_{10} and $PM_{2.5}$ standards and federal and state ozone standards. Attainment status is based on air basin-wide air quality, e.g., if one monitoring station in the air basin records qualifying exceedances to the standards, the entire air basin is judged nonattainment. On July 10, 1998, EPA published a final rule (63 FR 37258) designating the San Francisco Bay Area as nonattainment with the federal 1-hour ozone NAAQS, but did not assign the Bay Area a classification. Then on July 22, 1999, EPA published a final rule (64 FR 39416) assigning the area a nonattainment classification of moderate for purposes of funding appropriation under the Transportation Equity Act for the 21st Century (TEA 21), Congestion Mitigation and Air Quality improvement Program (CMAQ) only. In the April 15, 2004 *Federal Register*, the EPA also designated the Bay Area nonattainment for the 8-hour ozone NAAQS and classified the region as marginal, which indicates an attainment date of June 2007. The 1-hour ozone nonattainment status for the area will only be in effect until the area demonstrates attainment of that standard or until the State of California develops an approvable 8-hour SIP, whichever occurs first.

Table 3-8 shows how attainment status would vary from county to county and presents the attainment status for the three-county area with respect to the state and federal ambient air quality standards for criteria pollutants. . All three counties have a higher overall conformance with federal and state standards than the full air basin. For example, Table 3-9 details the ambient ozone monitoring status for the three monitoring stations in the GGNRA counties. The three stations in the GGNRA counties have similar trends: each station complies with the federal standards for both 1-hour and 8-hour NAAQS and, with the exception of one day of exceedance occurrence recorded at the Redwood City station, all three conform to the stricter state 1-hour ambient standard (see Tables 3-8 and 3-9). Generally, the monitoring stations in the three GGNRA counties recorded air quality that meets federal and state standards.

However, on a broader scale, the San Francisco Bay Area as a whole is designated by the EPA as nonattainment for both the 1-hour and the new 8-hour ozone NAAQS. These nonattainment designations are based on ambient monitoring conducted in the nine-county Bay Area air basin. As mentioned above, although the county monitoring stations indicate attainment of the ozone 8-hour NAAQS, in the summer of 2004, the EPA designated the entire Bay Area Air Basin as nonattainment for ozone. The three stations representing the GGNRA counties meet the federal and state standards for carbon monoxide, nitrogen dioxide, and sulfur dioxide, and the federal standard for particulate matter less than 10 microns in diameter. All three sites have one or more exceedances recorded for 24-hour maximum standard for PM_{10} of 50 micrograms per cubic meters but have been in conformance with the less stringent federal annual average standard of 150 micrograms per cubic meter or less (BAAQMD 2004).

Table 3-8: County Variation in Attainment Status*[1]
Demonstrated by Monitoring Station Data, 2001–2003

Pollutant	Redwood City San Mateo County		San Francisco San Francisco County		San Rafael Marin County	
	State Standard	Federal Standard	State Standard	Federal Standard	State Standard	Federal Standard
Ozone (1-hour)*	N	NA	A	NA	A	NA
Ozone (8-hour)	NA	NA	NA	NA	NA	NA
Carbon monoxide	A	A	A	A	A	A
Nitrogen dioxide	A	A	A	A	A	A
Sulfur dioxide	ND	ND	A	A	ND	ND
Particulate matter (PM_{10}) (Max. 24-hour)	NA	A	N	A	NA	A

Source: BAAQMD Annual Bay Area Air Quality Summary 2003
Notes:

A = Attainment N = Nonattainment U = Unclassified NA = Not Applicable ND = No Data

[1] The EPA does not designate areas for the lead standard in the same manner as for other pollutants. There are no areas in California that exceed the federal standard for lead.

* Attainment status is assigned only on an air-basin level. Though specific county monitors indicate attainment with NAAQS, all counties are included in the San Francisco Bay Area Air Basin, which is designated as a nonattainment area for 1-hour and 8-hour ozone national standards and for state standards for PM_{10}.

The annual ambient air quality standard for particulate matter in California became more stringent in 2004. Federal and state standards for particulate matter of 2.5 microns in diameter or less are now enforced as sufficient baseline monitoring data has been collected. EPA and the State of California are designating all areas of the state as attainment, unclassified, or nonattainment based on availability of ambient monitoring data. The federal 24-hour standard will be attained when 98 percent of the daily concentrations, averaged over three years, are equal to or less than the standard. Averaging of $PM_{2.5}$ emissions over several years would prevent spikes from overly influencing data collection for purposes of determining average ambient levels. Events that could lead to spikes could include a large wildfire that would otherwise have impressive yet short-term effects.

Project activities are expected to be minimally affected by implementation of the new national standards for ozone and $PM_{2.5}$, since all prescribed burning would continue to occur under the auspices of the BAAQMD Smoke Management Program, which would be planned and managed to ensure compliance with all applicable rules and regulations. Moreover, the NPS is required under Section 118 of the CAA to comply with all applicable local, state, and federal rules and regulations to help ensure that all ambient air quality standards are attained and maintained.

Table 3-9: Ozone Levels at Monitoring Stations in the Three Counties with GGNRA Lands, 2001-2003

	1-Hour Standard (0.09 pphm State/0.12 pphm Federal)				8-Hour Standard (0.08 pphm Federal)		
Monitoring Station (County)	**Maximum Level (1-hour)[1]**	**Number of Days Exceeding Federal Standard[2]**	**Number of Days Exceeding State Standard[3]**	**3-Year Average (days)[4]**	**Maximum Level (1-hour)[1]**	**Number of Days Exceeding Federal Standard[2]**	**3-Year Average (pphm)[5]**
San Rafael (Marin County)	0.09 ppm	0	0	0.0	0.07 ppm	0	0.04.9 ppm
San Francisco (SF County)	0.09 ppm	0	0	0.0	0.06 ppm	0	0.04.8 ppm
Redwood City (San Mateo County)	0.11 ppm	0	1 day	0.0	0.08 ppm	0	0.05.8 ppm

Source: Bay Area Pollution Summary 2003.

Notes:

pphm = parts per hundred million ppm = parts per million

[1] The highest average contaminant concentration over a 1-hour or 8-hour period in parts per million.

[2] The number of days during the year for which the monitoring station recorded contaminant concentrations in excess of the federal standard.

[3] The number of days during the year for which the monitoring station recorded contaminant concentrations in excess of the state standard.

[4] For the 1-hour ozone standard only, 3-year average is the average number of days per year during which ozone levels were in excess of the federal 1-hour standard, based on the most recent 3-year period. An average higher than 1.0 means the region will be considered nonattainment by the EPA.

[5] For the 8-hour ozone standard only, the 3-year average is the fourth highest 8-hour average ozone concentration for each monitoring station. A 3-year average greater than 8.4 at any monitoring station means that the region will be considered nonattainment by the EPA.

Also, with the disclosure of projected worst case emissions envisioned in this EIS for GGNRA, it is the intent of the NPS to ensure that state and local air management authorities include these emissions in the area's emissions budget used for 8-hour ozone (and $PM_{2.5}$, if necessary) SIP development activities. Incorporation of emissions generated from NPS activities and facilities at GGNRA during SIP planning would make it unnecessary for the NPS to conduct SIP conformity determinations or demonstrations under Section 176(c) of the CAA on a project-by-project basis. This accountability by air management authorities would ensure that GGNRA emissions conform to the SIP, by definition.

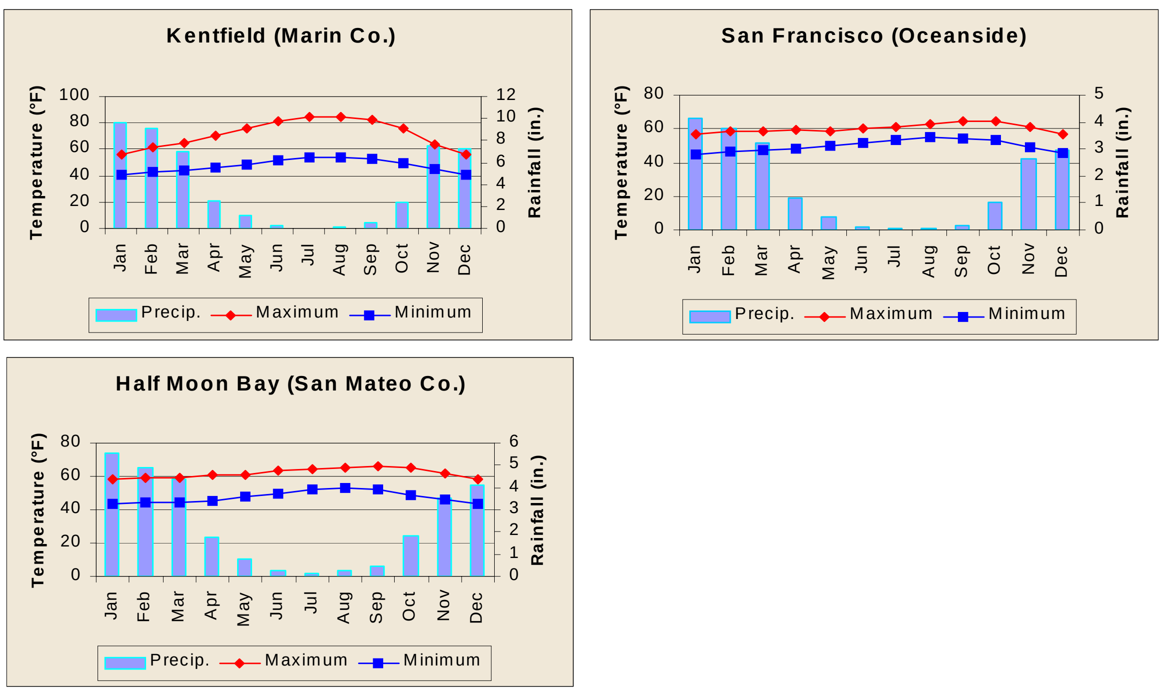
Influence of Climate and Topography on Smoke Dispersion and Air Quality

The weather pattern of the project area, along with much of the West Coast, is controlled by a semi-permanent high-pressure system centered over the northeastern Pacific Ocean a thousand miles or so offshore. This mass of air is referred to as the Pacific High (Gilliam 2002, BAAQMD 1998). Precipitation from late fall through spring provides significant moisture. In the summer, the relatively northern location of this strong high-pressure system results in clear skies and dry weather away from the coast, such as at the Phleger Estate, while coastal parklands such as Pedro Point or the Marin Headlands can be in dense fog. Because of the fog, humidity, and cool temperatures, vegetation dries out more slowly on the coast, reducing the summer fire hazard. Beginning in the fall, high pressure forming over the warmer inland areas breaks the summer pattern, introducing warm, dry winds from the northeast and east. These conditions reduce vegetation moisture levels throughout GGNRA and significantly increase fire threat. Through the winter, the high-pressure system weakens and moves south, allowing storm systems to move through the area, replenishing the vegetation moisture levels and restarting the annual cycle.

Generally cool and mild temperatures characteristic of the coastal part of central California prevail throughout the year in GGNRA. The seasonal range of temperatures is small; this is in keeping with the predominant flow of marine air that moves over the area. Average winter temperature ranges from 48 to 53 degrees Fahrenheit (F) with minimums from 45-50 degrees F. Summer average temperatures range from 55 to 65 degrees F with maximums of 64 to 70 degrees F (SWA Group 1975). Temperatures below freezing are expected on clear nights in winter and early spring, when extensive cold-air drifts occur in the gullies and canyons (see Figure 3-7).

Spring weather is highly variable in GGNRA. Cold gusting winds typical in winter months often continue into early spring. This is caused by northwest winds intensifying with the Pacific High. The Pacific High causes upwelling of offshore ocean water. The upwelling waters cool the air, causing condensation of moisture and subsequent formation of a thick fog bank. (The strongest upwelling tends to occur in August.) The fog bank intermittently hangs along the coast throughout the late spring and summer, though warm, calm days in the spring season may occur.

Figure 3-7: GGNRA Regional Climate – 1971-2000 Monthly Normals



Source: National Weather Service, 2004.

During the summer, the Pacific High typically moves farther north, causing stronger cooler winds to move inland from the ocean. These moisture-laden offshore winds cross cold coastal upwelling zones to form the fogs, which pour through gaps in the Coast Ranges (Azevado and Morgan 1974). Within GGNRA are several gaps that channel air through the hills and allow fog blocked by the main ridges of GGNRA to reach the bay. The Golden Gate is the largest gap and as such it has the most significant influence on Bay Area climate, but other gaps function as “little Golden Gates” (Gilliam 2002). Immediately north of the Golden Gate there are three gaps: a narrow one at Tennessee Valley, a higher one above Muir Woods National Monument, and one at Nicasio Gap in West Marin near the valley created by the Tomales Bay and the San Andreas Fault. On the San Francisco peninsula, there are two important gaps at San Bruno and at Crystal Springs. The San Bruno Gap extends from the west at Fort Funston to the San Francisco International Airport on the bay. The gap is oriented in the same direction as prevailing winds and the low elevation (less than 200 feet) allows marine air to flow easily toward the bay (BAAQMD 1998). The gap is second only to the Golden Gate in its influence on Bay Area climate (Gilliam 2002). The San Andreas Fault has created another gap in the coastal range called the Crystal Springs Gap, which lies along the Highway 92 corridor between Half Moon Bay and San Carlos. The low point is 900 feet with elevations of 1,500 feet north and south of the gap. This gap facilitates a cooling effect commonly seen from San Mateo to Redwood City (BAAQMD 1998).

As the cool, moisture-laden fog moves in through the gaps, it slides beneath the warm air layer and continues to push up as more and more cool air flows in. This phenomenon creates an inversion layer with temperatures actually increasing at higher elevations. The height of the inversion, which marks the boundary between the two contrasting layers, is variable but averages from 1,500 to 2,000 feet. Characteristically, this layer of clouds extends inland farther during the night and then recedes to the vicinity of the coast during the day. By comparison, spring inversion layers typically reach about 200 feet (61 meters) in elevation. Some of the coldest weather in GGNRA occurs during the summer when fog created by cooled surface air meets warm air.

In the summer, rainstorms are usually blocked by the Pacific High. Rainfall from May through September is relatively rare, with an aggregate of less than an inch, or only about five percent of the yearly average. During the spring and summer months, coastal fog normally keeps fuels moist from the ridges to the coast. The amount of additional moisture deposited by fog drip is a function of the presence and the type of vegetation as well as local topography. For example, Oberlander (1956) found a range of 1.8 to 58.8 inches of additional precipitation from fog drip, with trees with direct seaward exposure receiving more moisture, followed by a gradual decline in precipitation to the east and downslope. The taller the trees, the greater the amount of fog drip deposited.

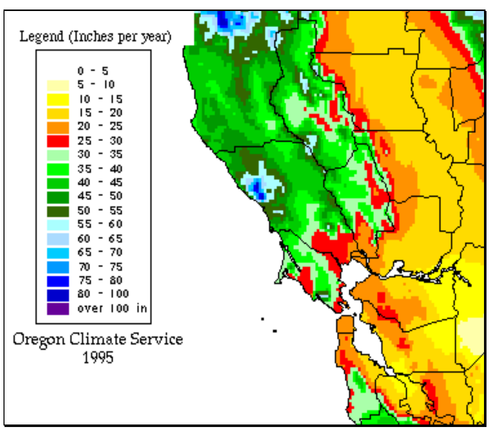
While the coastal areas of GGNRA are often foggy during the summer, the surface of the eastern portion of GGNRA is warmer. The warm air evaporates any fog approaching from the west; thus fog rarely reaches areas to the east like Fort Baker.

September and October are usually the two warmest months of the year (Western Regional Climate Center 2004). In autumn, the Pacific High begins to move south, winds decrease, and an inversion layer forms, usually at 1,500 feet above sea level. Inversions during the fall can act as a nearly impenetrable lid to the vertical mixing of pollutants level and are particularly conducive to concentrating pollutants, such as CO from auto exhaust, emitted close to the ground.

In winter, when the Pacific High weakens and shifts southward, upwelling ceases, and winter storms become frequent. During the winter rainy periods, inversions are weak or nonexistent, winds are often moderate, and air pollution potential is very low. With a strong high-pressure area over the Great Basin and an intense low-pressure area approaching the coast from the west, strong and sometimes damaging winds occur, usually from an easterly or southeasterly direction. As the storms move inland, the winds veer to southerly and southwesterly directions, and high wind speeds may occur anywhere in GGNRA with the greatest velocities at high elevations. Occasionally, the Pacific High becomes dominant, and surface-based inversions become strong and pollution potential is high. These periods are characterized by winds that flow out of the Central Valley into the Bay Area and often include tule fog (BAAQMD 1998).

Over 80 percent of GGNRA's seasonal rain falls between November and March, with a mean number of 66 days with measurable rain. The yearly average ranges from 20 to 25 inches in San Francisco, and from 20 to 60 inches in Marin and San Mateo counties. Winter thunderstorms occur on the average only twice per season in cold unstable post-frontal air masses (Golden Gate Weather Services 2002). GGNRA generally has a high diversity of microclimates, particularly in its rainfall patterns. Within a distance of only a few miles in GGNRA there can be more than a 50-percent difference in average annual rainfall (e.g., from 25 to 52 inches) (see Figure 3-8) (Oregon Climate Service 1995).

Figure 3-8: Annual Average Precipitation in Inches



Source: Oregon Climate Service, 1995.

Localized Effects of Climate and Topography Influence on Smoke Dispersion

Marin County

In the winter, proximity to the ocean keeps the coastal regions relatively warm. Temperatures do not vary much over the year at these coastal areas, and are typically in the high 50s in the winter and low 60s in the summer. The warmest months are September and October, with temperatures into the mid- to upper 60s (BAAQMD 1998).

The eastern side of Marin County has warmer weather and less fog. This is due less to the blocking effect of the hilly terrain to the west, but more to the area's distance from the ocean. Although there are a few mountains above 1,500 feet, most of the terrain is only 800 to 1,000 feet high. Much of time, this is not high enough to block the marine layer, which averages 1,700 feet in depth. Because of the wedge shape of the county, areas to the north are farther from the ocean. This extra distance from the ocean allows the marine air mass to be heated before it arrives at eastern Marin County cities. In southern Marin County, the travel distance is short and the elevations lower, so there is a higher incidence of cool, unmodified, maritime air (BAAQMD 1998).

Cities next to the bay have their temperatures somewhat moderated. For example, San Rafael, being near the bay, experiences average maximum winter temperatures in the high 50s to low 60s, and average maximum summer temperatures in the high 70s to low 80s. Inland areas, such as Kentfield, experience average maximum temperatures two degrees cooler in the winter and two degrees warmer in the summer. Average minimum temperatures in San Rafael are in the low 40s in winter and low 50s in summer. Minimum temperatures farther inland in Kentfield are two degrees cooler all year (BAAQMD 1998).

Wind speeds are highest along the western coast of Marin, about 8 to 10 miles per hour. Although most of the terrain throughout central Marin County is not high enough to act as a barrier to the marine airflow, the complex terrain creates sufficient friction to slow the airflow. Downwind, at the former Hamilton Air Force Base in eastern Marin County, the annual average wind speeds are only 5 miles per hour. The prevailing wind directions throughout Marin County show less variation, and are generally from the northwest (BAAQMD 1998).

The mountainous terrain in Marin County has higher rainfall amounts than most parts of the Bay Area with the exception of the southern Santa Cruz Mountains. Areas near Mount Tamalpais have rainfall amounts twice as high as the rest of the Bay Area, with San Rafael reporting an average of 37.5 inches per year and Kentfield reporting 49 inches per year (BAAQMD 1998).

Smoke problems are likeliest on the eastern side of Marin County. This is where the semi-sheltered valleys and largest population centers are located. Most urban development is located along the bay, particularly in southern Marin. In the south, where distances to the ocean are short, the influence of the marine air will keep smoke levels low. Farther north where the valleys are more sheltered from the sea breeze, the potential for greater smoke accumulation is higher (BAAQMD 1998).

San Mateo County

The peninsula region of GGNRA extends from the Golden Gate south to the Phleger Estate in Woodside. The Santa Cruz Mountains extend up the center of the peninsula, with elevations exceeding 2,000 feet at the south end, and gradually decreasing to 500 feet near South San Francisco. Coastal towns such as Half Moon Bay and Pacifica experience a high incidence of cool, foggy weather in the summer. The larger cities on the eastern side of the peninsula experience warmer temperatures and few foggy days, because of the blocking effect of the 2,000-foot ridge to the west. At the north end of the peninsula lies San Francisco, where most elevations are less than 200 feet and the marine layer is able to flow across nearly all of the city, making its climate cool and windy (BAAQMD 1998).

The blocking effect of the Santa Cruz Mountains can be seen in the summertime maximum temperatures. For example, at Half Moon Bay and San Francisco, the maximum daily temperatures in June through August are 62 to 64 degrees Fahrenheit, F, while on the eastern side at Redwood City, the maximum temperatures are in the low 80s for the same period. Daily maximum temperatures throughout the peninsula during the winter months are in the high 50s. Large temperature gradients are not seen in the minimum temperatures, which range from the 40s to 50s (BAAQMD 1998).

Annual average wind speeds range from 5 to 10 miles per hour throughout the peninsula. The tendency is for the higher wind speeds to be found along the western coast. However, winds on the eastern side of the peninsula can also be high in certain areas because low-lying areas in the mountain range, i.e., San Bruno Gap and Crystal Springs Gap, commonly allow the marine layer to pass across the peninsula (BAAQMD 1998). While prevailing winds are westerly along the peninsula's western coast, individual sites can show significant differences. For example, Fort Funston has a southwest wind pattern, while Pillar Point in San Mateo County has a northwest wind pattern. A rise in elevation of ridgelines by a few hundred feet will induce wind flow around that feature instead of over it during stable atmospheric conditions. This can change the wind pattern by as much as 90 degrees over short distances. On mornings without a strong pressure gradient, areas on the eastern side of the peninsula often experience eastern flow in the surface layer, induced by upslope flow on the east-facing slopes and by the bay breeze. The bay breeze is rarely seen after noon because the stronger sea breeze dominates the flow pattern (BAAQMD 1998).

Rainfall amounts on the eastern side of the peninsula are somewhat lower than on the western side. San Francisco and Redwood City report an average rainfall of 19.5 inches per year, while Half Moon Bay reports 25 inches per year. Areas to the south in the Santa Cruz Mountains have significantly higher rainfall, especially west of the ridgeline, due to elevation-induced condensation, close proximity to a moisture source, and fog drip.

Smoke accumulation potential is highest along the southeastern portion of the peninsula because this area is most protected from the high winds and fog of the marine layer, the emission density is relatively high, and smoke transport from upwind sites is possible. In San Francisco, wind speeds are generally fast enough to carry any smoke away before it can accumulate (BAAQMD 1998).

3.4 Biological Environment

Plant Communities

The vegetation of GGNRA is a result of the juxtaposition of physical landforms and water masses, associated geology, climate, and history. The moist maritime climate along the coastline is a dominant influence, while the park’s east-facing sites are subject to drier inland conditions. Distinct changes in soils from the rich conditions of the Franciscan mélange to the unique chemistry of serpentinitic outcrops have created a diverse mosaic of vegetation communities. Natural processes that affect these patterns add another layer of complexity to the system, with landslides, rainfall patterns, and fires. GGNRA is known to support 572 native and 336 nonnative terrestrial plant species, including 25 federally listed threatened and endangered plant and wildlife species.

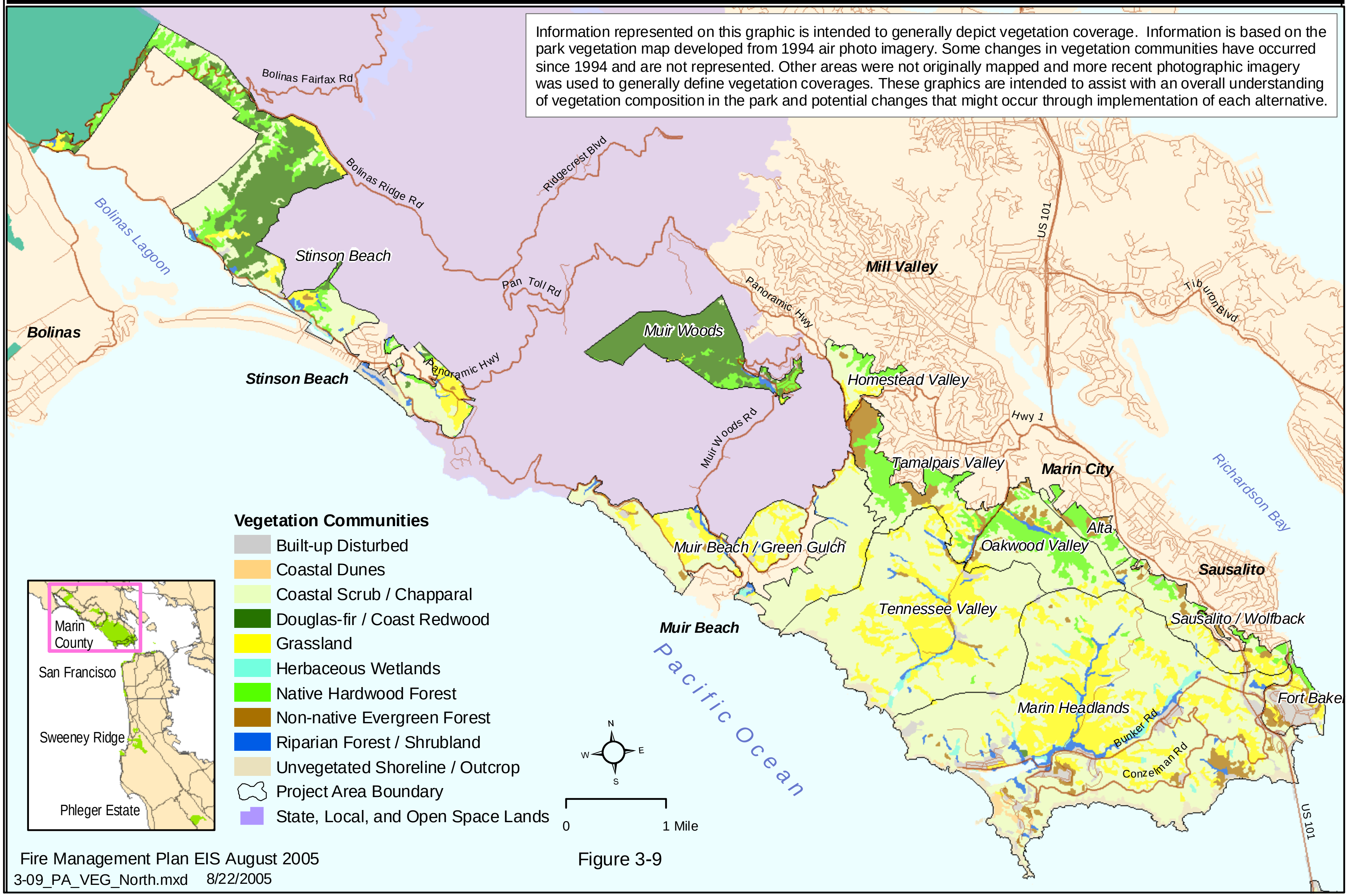
Fires can play a significant role in Mediterranean ecosystems such as those found in GGNRA. Many plants are adapted to fire, and tree growth rings in some portions of the park document significant fire histories. Mediterranean plant communities change in the absence of fire, and fuels can build up to hazardous proportions. These hazardous fuel buildups create highly flammable conditions, particularly in native chaparral and introduced forests. The FMP will not distinguish between the roles of Native American and lightning fires. It will recognize that Native American burning occurred more often than lightning fires. The intention is not to duplicate Native American burning but to recognize that it influenced fire frequency and the vegetative mosaic. In general, disturbances by fire have gone from long intervals in the pre-human era to shorter intervals in the Native American, Spanish-Mexican, and early Anglo eras, back to long intervals in the modern era (see “Fire Regimes” section above). The vegetation patterns exhibited today have been largely influenced by these changes.

The vegetation of GGNRA was mapped and incorporated into the park’s Geographic Information System (GIS) using aerial photography and interpolation in 1994. This mapping effort used the National Vegetation Classification System, with groupings based on structure and environmental factors such as elevation and hydrologic regime, resulting in over 80 vegetation alliances. For the FMP, these alliances have been grouped into 10 different vegetation communities for the purposes of analysis: Coastal Dunes, Unvegetated Shoreline and Rock Outcrops, Builtup/Developed/Disturbed, Coastal Scrub and Chaparral, Grasslands, Herbaceous Wetlands, Riparian Forest and Scrub, Native Hardwood Forest, Douglas-Fir and Coast Redwood, and Nonnative Evergreen Forest (see Figures 3-9 and 3-10). Each “community” has been defined by overall species composition, structure, geographic location, and fire dependency/adaptation. Acreages and overall distributions are based on the 1994 GGNRA vegetation map, and are rounded to the nearest acre (see Table 3-10). These FMP communities correspond most closely to the “community level” of the vegetation map classification hierarchy; however, some communities have been grouped where fire and fire effects have little to no influence on overall distribution and structure. Three of these “communities” either have no fire management objectives or are unlikely to support fire, and are not described further in the document: Coastal Dunes, Unvegetated Shoreline and Rock Outcrops, and Builtup/Developed/Disturbed areas.

Fire Management Project Areas and Vegetation Types

Marin County

National Park Service
U.S. Department of the Interior
Golden Gate National Recreation Area



Fire Management Plan EIS August 2005

Figure 3-9

3-09_PA_VEG_North.mxd 8/22/2005

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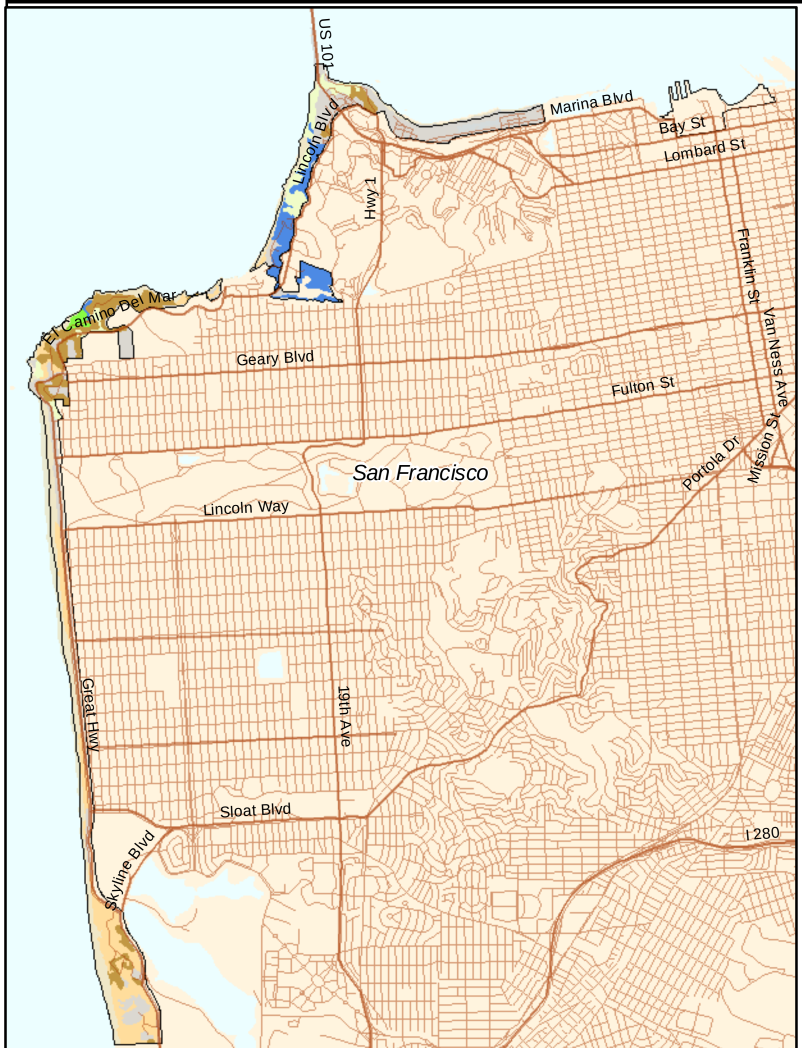
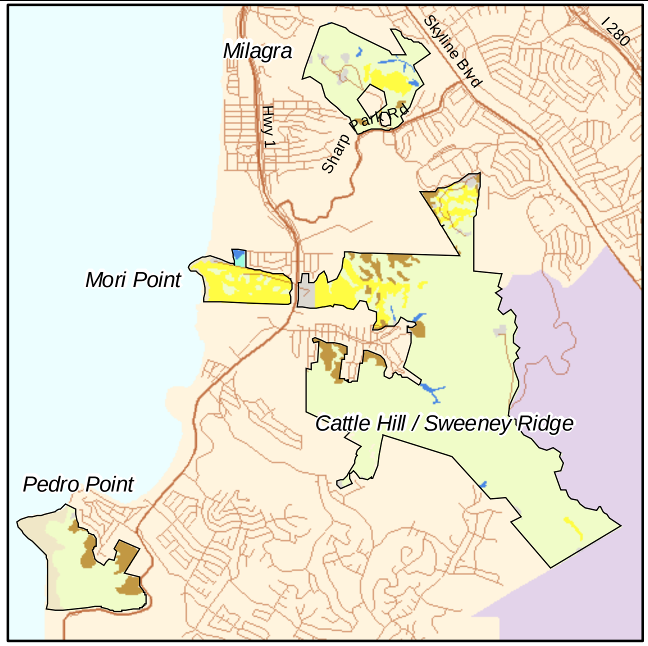
Fire Management Project Areas and Vegetation Types

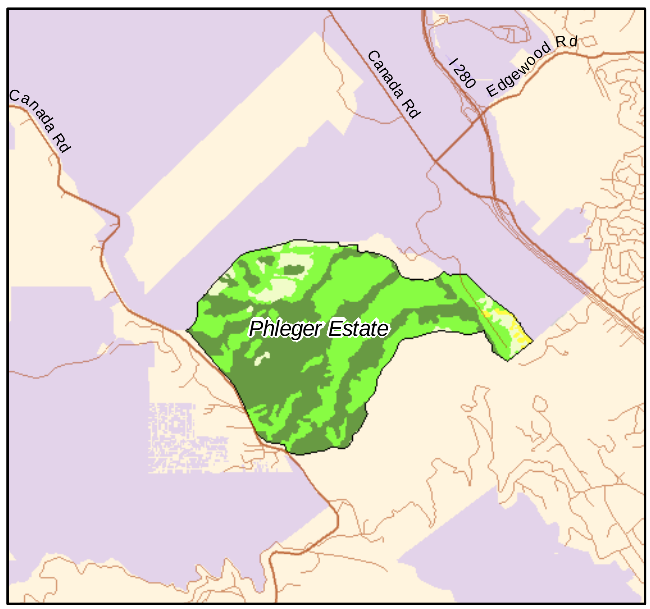
San Francisco and San Mateo County

National Park Service
U.S. Department of the Interior
Golden Gate National Recreation Area



Information represented on this graphic is intended to generally depict vegetation coverage. Information is based on the park vegetation map developed from 1994 air photo imagery. Some changes in vegetation communities have occurred since 1994 and are not represented. Other areas were not originally mapped and more recent photographic imagery was used to generally define vegetation coverages. These graphics are intended to assist with an overall understanding of vegetation composition in the park and potential changes that might occur through implementation of each alternative.





Vegetation Communities
- Built-up Disturbed
- Coastal Dunes
- Coastal Scrub / Chapparal
- Douglas-fir / Coast Redwood
- Grassland
- Herbaceous Wetlands
- Native Hardwood Forest
- Non-native Evergreen Forest
- Riparian Forest / Shrubland
- Unvegetated Shoreline / Outcrop
- Project Area Boundary
- State, Local, and Open Space Lands

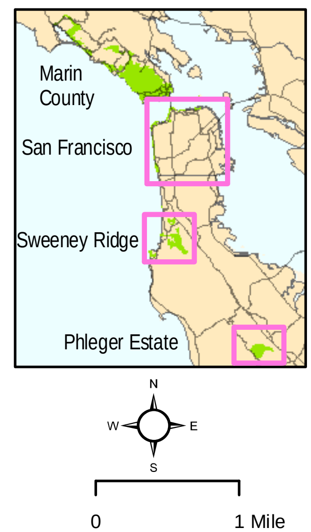


Figure 3-10

Fire Management Plan EIS August 2005

3-10_PA_VEG_South.mxd 8/22/2005

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Table 3-10: Acres Within Each General Vegetation Class By Project Area

Project Area	FMU	County	Acres	Developed	Coastal Dunes	Coastal Scrub/ Chaparral	Douglas-Fir/ Coast Redwood	Grassland	Herbaceous Wetlands	Native Hardwood Forest	Nonnative Evergreen Forest	Riparian Forest/ Shrubland	Unvegetated Shoreline/ Outcrop
Alta	WUI	Marin	**153**			55				60	38		
Fort Baker	WUI	Marin	**178**	75		34		26		12	31		
Homestead Valley	WUI	Marin	**166**			94		23		44	5		
Marin Headlands	Park Interior	Marin	**3,667**	202	30	2,230	3	785	53	11	92	116	145
Milagra Ridge	WUI	San Mateo	**245**	10		204		23			3	5	
Mori Point	WUI	San Mateo	**110**	3		15		79	3			2	8
Muir Beach/ Green Gulch	WUI/Park Interior	Marin	**1,202**	15		905		208	4	3	11	25	31
Muir Woods National Monument	Muir Woods	Marin	**558**	6		2	472	2		59	2	15	
Oakwood Valley	WUI/Park Interior	Marin	**567**	2		310		27		171	45	12	
Phleger Estate	WUI	San Mateo	**1,205**			82	556	9		558			
San Francisco	WUI	San Francisco	**923**	347	150	69				8	122	75	152
San Pedro Point	WUI	San Mateo	**229**	1		142					33		53
Stinson Beach	WUI/Park Interior	Marin	**1,683**	38		555	561	172	13	265	10	34	35
Sweeney Ridge/ Cattle Hill	WUI	San Mateo	**1,432**	29		1,231		95			64	13	
Tam. Valley	WUI	Marin	**495**	3		147	1	42		188	109	5	
Tennessee Valley	Park Interior	Marin	**1,928**	16		1,348		453	19	2	18	30	42
Wolfback/ Sausalito	WUI	Marin	**398**	14		231		60		49	41	3	
Total			**15,139**	**761**	**180**	**7,654**	**1,593**	**2,004**	**92**	**1,430**	**624**	**335**	**466**

Source: NPS, GGNRA Fire Management Office, 2004.

FMU = Fire Management Unit WUI = Wildland Urban Interface