66 917

Gutierrez, Jeffrey

From: HeidiWestNPS@aol.com
Sent: Friday, October 13, 2006 8:25 AM
To: Lusby, Karen
Cc: Van Dyke, Nancy; Gutman, Lori
Subject: Re: GOGA Fire Managment Plan
Attachments: 07_chapter_3_part_1.pdf; 08_chapter_3_part_2.pdf; 09_chapter_4_part_1.pdf

In a message dated 10/12/2006 1:29:18 PM Mountain Standard Time, klusby@louisberger.com writes:

> Heidi – Do you have a copy of the GOGA Fire Management Plan/EIS? Per the message below, Sarah wants us to take a look at the GOGA thresholds in the Fire Mg't Plan, and how the document was written. I'll look at these thresholds in comparison to what we did at CAHA before our discussion on November 2nd.
>
> We are going to have to begin the task of getting some of the documents that you have over to our office and copied if needed before we begin working on impact analyses. I am assuming many of the EAs/EISs and other sources of data will need to be entered into the admin record database by our new intern/junior planner.
>
> I know…there's enough going on right now…..

Karen Z. Lusby

Senior Environmental Planner

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From: Gutman, Lori
Sent: Thursday, October 12, 2006 9:32 AM
To: Lusby, Karen; Van Dyke, Nancy
Cc: Niosi, Dan
Subject: GOGA Thresholdsd

Hey guys,

While talking budget with Sarah and the EQD folks on GOGA today, one thing that came up is that we need to get a handle on the thresholds that were drafted. Some were drafted and submitted to the park, at the same time the park expressed a preference for the ones used in their Fire Management Plan (Karen, I think Sarah talked about this to you). So there are two things here:

1. Sarah would like to meet on November 2 from 10 -2 (may end earlier) at Berger to discuss thresholds. She knows Nancy will not be there and I will be in DC, but would like Dan and Karen there. I have emailed Liz to see if she can reserve the medium conference room for that day. Please let me know if either of you will have a problem making it.
2. Sarah also expressed that she would like Nancy and Karen to take a look at the thresholds that were developed as well as the Fire Management Plan ones to see if you had any ideas or suggestions. She was impressed with past threshold efforts such as CAHA and feels you two would have a lot to add to this discussion. I let her know that you two would pow wow on this and Karen would bring the results of your discussion to the meeting.

Please let me know if any of this raises a conflict with prior commitments. Sarah feels this is a very critical step and does not want any work proceeding on finishing up impacts of no action until these thresholds are set.

Hope all is going well ~~back in Denver – Ohio~~ is in the middle of a cold snap so I ~~am looking forward to~~ coming back!

Lori

Lori Gutman, AICP

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Chapter 3 – Affected Environment (part 1)

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 38 miles of GGNRA boundary adjoin 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

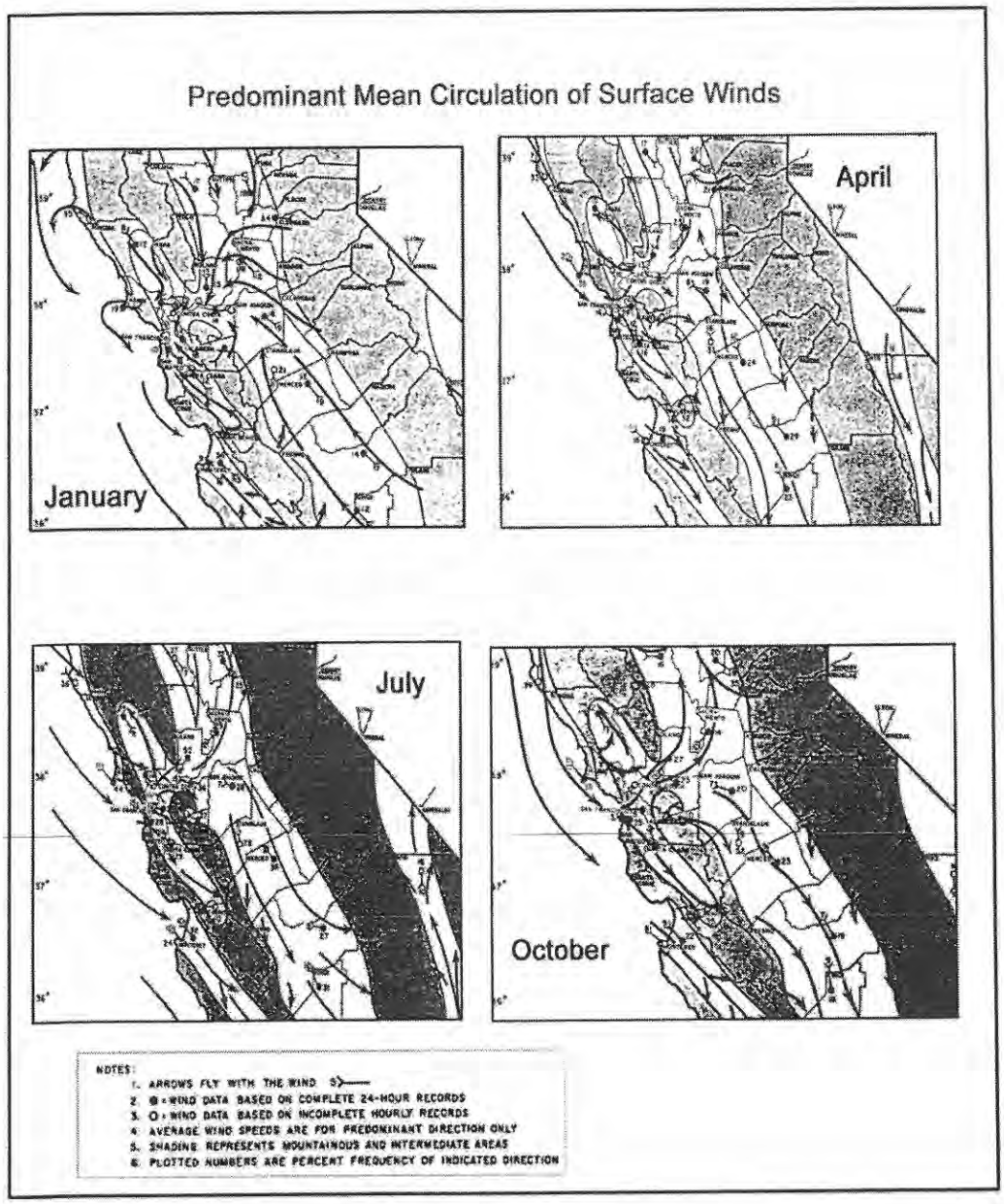
California lies within the zone of prevailing westerlies and on the east side of the semi-permanent high-pressure area of the northeast Pacific Ocean. The basic flow in the free air above GGNRA is therefore from the west or northwest during most of the year. A local characteristic of the northwest wind 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.

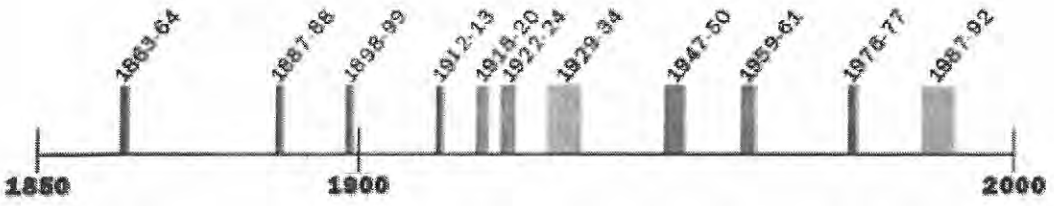
Recurrent Drought

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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Figure 3-3 Fire History 1929-2004 – North Lands

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Figure 3-4 Fire History 1929-2004 – South Lands

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.

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Figure 3-5 Watersheds – North Lands

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Figure 3-6 Watersheds – South Lands

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. A dam inventory will be included in upcoming Water Quality Data Inventory and Analysis Report. Culvert mapping has occurred in Rodeo Valley.

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 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

[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..."

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 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.

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			0.08 ppm	N[4]
	1-Hour	0.09 ppm (180 µg/m^3)	N	0.12 ppm (235µg/m^3)	N[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		
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

Pollutant	Averaging Time	California Standards[1]		National Standards[2]	
		Concentration	Attainment Status	Concentration[3]	Attainment Status
Particulate Matter – Fine ($PM_{2.5}$)	Annual Arithmetic Mean	12 µg/m^3	N[7]	15 µg/m3	U
	24-Hour			65 µg/m3	U
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 2004.

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. In April 2004, U. S. EPA determined that the Bay Area had an attainment record for the national 1-hour ozone standard. EPA must approve a redesignation request, currently under development, in order for the Bay Area to be redesignated to attainment status.
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.

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), federal and state one-hour ozone standards, and 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 2000, 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 2000, 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 due to monitoring within the greater Bay Area, which includes most of a nine-county area (seven entire counties and parts of two counties). The three stations 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 is about to become more stringent, upon approval by the State Office of Administrative Law. The effect this may have on future compliance status of the region remains to be seen. Further, the federal and state standards for particulate matter of 2.5 microns in diameter or less would be enforced pending sufficient baseline monitoring data collection, as determined by the US EPA. Currently, the $PM_{2.5}$ standard is not enforced. EPA and the State of California are currently engaged in a process that will designate all areas of the state as attainment, unclassified, or nonattainment based on availability of ambient monitoring data. These designations should occur by the end of 2004. When fully implemented, 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

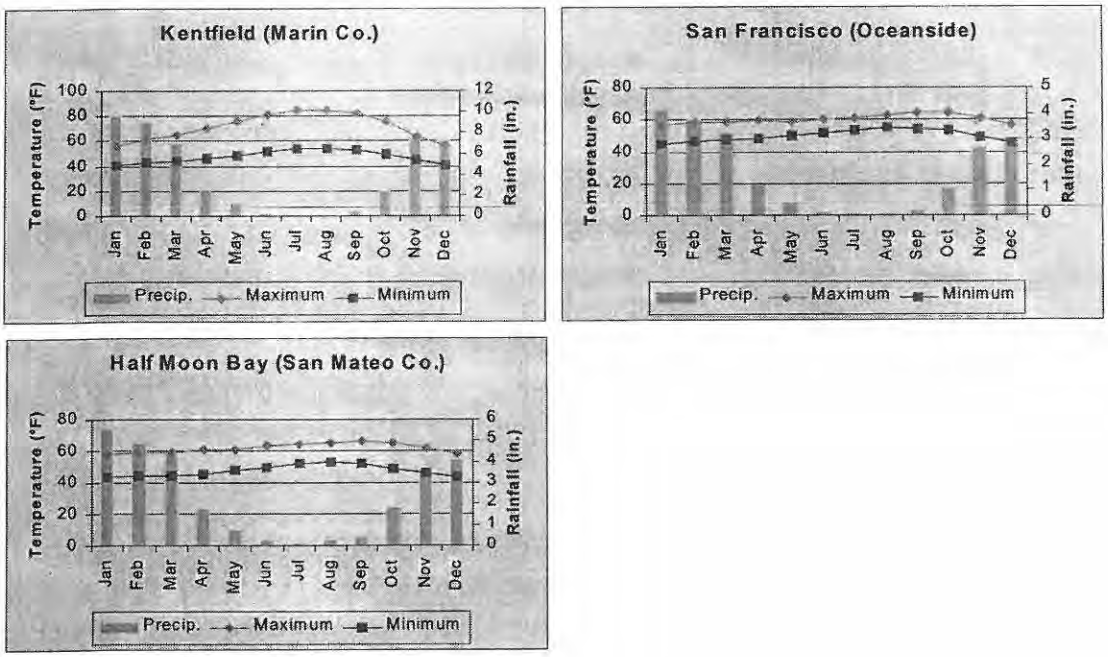
The weather pattern of the project area, along with much of the West Coast, is controlled by a semi-permanent high-pressure system centered over the northeastern Pacific Ocean a thousand miles or so offshore. This mass of air is referred to as the Pacific High (Gilliam 2002, BAAQMD 1998). Precipitation 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.

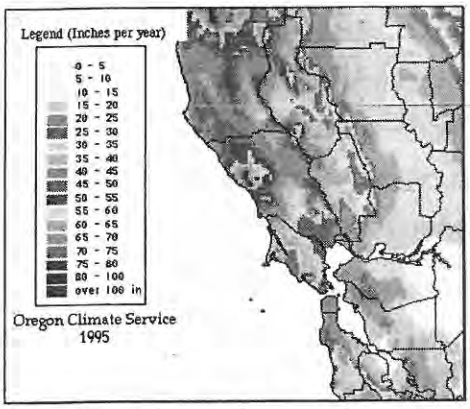
September and October are usually the two warmest months of the year (Western Regional Climate Center 2004). In autumn, the Pacific High begins to move south, winds decrease, and an inversion layer forms, usually at 1,500 feet above sea level. Inversions during the fall can act as a nearly impenetrable 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).

Chapter 3 – Affected Environment (part 2)

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.

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Figure 3-9 Fire Management Project Areas and Vegetation Types –North Lands

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Figure 3-10 Fire Management Project Areas and Vegetation Types – South Lands

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

The vegetation communities of concern from a fire management standpoint are described below in detail in terms of overall vegetation composition, fire ecology, and management objectives. The communities consist of:

Coastal Scrub and Chaparral
Grasslands
Herbaceous Wetlands
Riparian Forest and Scrub
Native Hardwood Forest
Douglas-Fir and Coast Redwood
Nonnative Evergreen Forest

Coastal Scrub and Chaparral

General Characteristics

The coastal scrub community is dominated by coyote brush (*Baccharis pilularis*), California sagebrush (*Artemisia californica*), bush lupine (*Lupinus arboreus*), and poison oak (*Toxicodendron diversilobum*), with variations in dominant species based on moisture levels, soil types and slopes, and past land use history (Howell 1970). This community intergrades and creates a mosaic with the grassland community, and is found throughout the park from near sea level to 2,500 feet. The coastal scrub community also contains large numbers of nonnative species, and at times is dominated by nonnative shrubs such as French broom (*Genista monspessulana*) and thoroughwart (*Ageratina adenophora*). Chaparral stands, although not abundant at GGNRA, contain a high number of locally to regionally rare species of concern for the park, and are contiguous with coastal scrub stands. Small communities of chaparral exist in Muir Woods and the Marin Headlands, as well as larger areas on Bolinas Ridge. There are several types of chaparral in GGNRA, including chamise chaparral, ceanothus chaparral, and manzanita chaparral.

Fire Ecology

Most species in the coastal scrub and chaparral communities are adapted to fire, sprouting being the most common adaptation. Species that do not sprout often have fire-resistant seeds that retain viability for years. Almost all of the germination cues identified for these species are related to fire: heat, chemicals leached from charred wood, release from toxic compounds, increased light, and stratification (Parker and Kelly 1989).

Fire is often used to convert brushland, such as coastal scrub and chaparral, to grassland. This can be accomplished through a series of successive burns in close proximity to each other, and may kill new brush seedlings before they produce seed (Emrick and Adams 1977). Vogl (1977) observed that coastal scrub communities can result from premature burning or increased fire frequency within chaparral.

Timing of prescribed burns and the resulting intensity can drastically influence post-fire revegetation (Parker 1987, Florence 1987). Species diversity in coastal scrub and chaparral is best accomplished by late summer or fall burns of medium intensities (Rundel 1982). This fuel type produces a high fire intensity with fast spreading fires involving the foliage and live and dead fine woody material in the

crowns of a nearly continuous secondary overstory. The fire behavior can be expected to be erratic and extreme when live fuel moisture drops below 90 percent.

Decadent stands located on steep slopes, like the one that exists on Bolinas Ridge, present an extreme fire behavior potential.

Young growth chaparral stands, like the one that exists in the Gerbode Valley, show evidence of recent fire and do not present a current potential for extreme fire behavior. Spring burns create higher root and burl mortality, probably due to the phenological state of the dominant plants and their depleted carbohydrate reserves. Carbohydrates are tied up in growing plant parts, and deficiencies in root and lignotuber carbohydrates result in a lack of sprouting activity during this period. Fire can serve to break down litter, which is resistant to decomposition; remove inhibitors of decomposition; and alter the wettability of the soil.

High fire intensities are correlated with high shrub mortality. High-intensity fires in mature chaparral often have flame lengths exceeding 50 feet (Lotan et al. 1981) and temperatures as high as 1,200 degrees F (Sampson 1944b, Bentley and Fenner 1958), with fuel consumption of all but the largest branches.

Indications are that organic and inorganic nutrient levels are increased as a result of fire (Christensen 1973, Christensen and Muller 1975). Soil levels of organic nitrogen are reduced, but the level of available nitrogen increases (Rundel 1981). Post-fire bacteria and fungi are more abundant in burned than unburned soils (Christensen 1973, Christensen and Muller 1975). Mineral levels as well as available nutrients added by ash increase dramatically (Hanes 1977). These characteristics of moderate intensity fires decrease the likelihood of development of hydrophobic soils, lessening associated problems of soil erosion and sedimentation, loss of topsoil, and invasion by nonnative plant species in these uninhabited sites.

The historic role of fire in coastal scrub was most related to manipulation of the vegetation to support other activities, such as farming and ranching. Coastal scrub, while adapted to fire, is not dependent upon it for regeneration, although fire can clear out woody materials and create openings for sub-shrubs and forbs, whereas older stands are more characterized by similarly-statured shrubs with little to no herbaceous or forb component. Fire increases overall species diversity in this community, and can exclude coyote brush to the point that the scrub gives way to grasslands (described below). Fire can also be used to manage and suppress nonnative shrubs such as French broom that have become established in these shrublands. Fires may periodically serve to suppress fungal pathogens and other soil-borne diseases affecting plant species. The host plant for mission blue butterfly, silver-leaf lupine (*Lupinus albifrons*), occurs within coastal scrub (and grassland). Lupines in general are known as disturbance-dependent or -tolerant species, and this lupine may benefit from periodic fires that create openings and soil conditions favorable for establishment within the usually dense stands of coastal scrub in the Marin Headlands.

The fire return interval for chaparral varies between 20 and 45 years, depending on the dominant species. The continued statewide suppression of fires within this community has endangered many plant species that grow in association with it, including 14 threatened and 11 endangered species of manzanita and five threatened and 4 endangered species of ceanothus. Of these, GGNRA has one endangered species of manzanita, two rare manzanita, and one rare ceanothus. The mason's ceanothus *(Ceanothus masonii)* is

state-listed rare, and the only known population of this species occurs at Bolinas Ridge in Marin County. Lack of fire in the habitat has contributed to its decline. Prescribed fire of moderate intensity may be necessary to stimulate germination of this species and other species with hard seed coats.

The coastal scrub fuel type remains in a semi-fire-resistant state until the fall of the year when the live fuel moistures drop and the fuels can produce fire with flame lengths of 12 to 20 feet. The fuel normally does not present a fire behavior problem unless it is in the fall of the year, when live fuel moisture drops below 90 percent, or it is burning in a slope and preheating the fuels above it.

Chaparral produces a high fire intensity with fast-spreading fires involving the foliage and live and dead fine woody material in the crowns of a nearly continuous secondary overstory. The fire behavior can be expected to be erratic and extreme when live fuel moisture drops below 90 percent. Decadent stands located on steep slopes, like the one that exists on Bolinas Ridge, present an extreme fire behavior potential. Young growth chaparral stands, like the one that exists in the Gerbode Valley, show evidence of recent fire and do not present a current potential for extreme fire behavior.

Grasslands

General Characteristics

The grassland community at GGNRA extends from sea level to nearly 2,600 feet. It forms a mosaic with the coastal scrub community and mixed evergreen forests (Savage 1974). It is generally accepted that fires are part of the evolutionary forces affecting grassland (Heady 1972). Native American burning has occurred for at least the last 8,000 years in the San Francisco Bay Area according to early narrative reports (Sampson 1944b). The coastal prairie areas appear to have evolved under light seasonal grazing pressure with occasional fire (Heady et al. 1977).

Pristine grassland was thought to have been composed of evenly spaced bunchgrasses with annual forbs occupying areas between tussocks. It has been shown that purple needlegrass (*Nasella pulchra)* – the California state grass – was a major dominant of that grassland type (Bartolome et al. 1986), along with other perennial grasses. The lack of continuous fuels and compactness of the bunches themselves would have resulted in fires of moderate intensity with low to moderate rates of spread. These grasslands have had the greatest disturbance of any natural habitat in this area (Savage 1974). Four main factors have contributed to this disturbance: (1) an increase in grazing pressures, (2) the introduction of highly competitive nonnative plants, (3) cultivation, and (4) the elimination of fire.

Today, the grasslands are dominated by nonnative annual grasses and forbs adapted to Mediterranean conditions. These dense stands of annual grasses burn with greater intensity and more rapid rates of spread. Additionally, annual species cure rapidly with the onset of summer drought, resulting in a longer fire season (Langenheim et al. 1983).

Tilling and controlled grazing or clipping experiments have been employed in an attempt to enhance native perennial grasses in rangelands. Dennis (1989) found that the timing of grazing is critical, and concluded that annual vegetation affects the growth of perennials more through its influence on the physical environment than through resource competition.

Exclusion of grazing, extirpation of large native mammals, and suppression of wildfires have caused a marked increase in acreage covered by coyote bush (*B. pilularis*) and the resulting coastal scrub community in the Bay Area (McBride and Heady 1968, Clark 1952). It should be noted that grassland and coastal scrub communities are a dynamic mosaic with changes in dominance over time (Russell 1983), and in some areas these two communities are in equilibrium with no invasion occurring (Davidson and Barbour 1977). The boundary between grassland and coastal scrub is probably maintained by one or more of the following factors: allelopathy, herbivory, limited seed dispersal, and differential use of soil moisture (Davis and Mooney 1985). Invasions of coyote brush are sporadic with the shrub canopy developing quickly, effectively shading out most grassland species and providing shelter for herbivores that further reduce grassland species (Hobbs and Mooney 1986).

Fire Ecology

The native perennial grasses in GGNRA, including purple needlegrass (*N. pulchra*), appear to have evolved under periodic fire (Bartolome 1981). These species thrive when annual grassland is burned in the fall season. Disturbance during other seasons is detrimental, suggesting that the plants have adapted to fall fires, rather than the grazing that is common in any season. Purple needlegrass can be favored by burning in the fall to decrease competition and provide a suitable seedbed, enhancing establishment conditions for residual seeds in the soil seed bank (Bartolome 1981).

Prescribed burning research at Henry Coe State Park supports the hypothesis that the presence of heavy annual mulch residue is an inhibitor to perennial grass (Parker 1989). Fall burning was found to reduce the abundance of annual grasses while increasing the diversity of native species. This research also concluded that reduction in annual grass mulch will potentially increase perennial grass establishment.

Fire can also be used to slow the invasion of coyote brush *(Baccharis pilularis)* into annual grassland (McBride and Heady 1968, McBride 1974). The reintroduction of fire to duplicate natural processes will kill susceptible seedlings and top kill some adult plants. Ford (1991) has found that the rate of cover regrowth is inversely related to fire severity.

Prescribed fires within this community have been conducted for the purposes of maintaining native species diversity, maintaining grasslands (that are being converted to scrubland through the invasion of coyote brush), and controlling nonnative species. When the objective is to reduce nonnative plant densities while encouraging native perennials, it is advantageous to burn in fall or early winter (Bartolome 1984). Germination of annual grasses and forbs often occurs one to three weeks after the first rain (Bartolome 1979). Burning during this period can destroy the annual seed crop, thereby reducing competition of annuals. The perennial rootstock is wet after the first rain and less susceptible to fire intensities (Biswell 1984), supporting the strategy of carefully timed fires to favor reestablishment of native species.

Herbaceous Wetlands

General Characteristics

Herbaceous wetlands are known as emergent wetlands in the Cowardin wetlands classification. They consist of a mix of low-growing species of sedges (*Carex* spp.), rushes (*Juncus* spp.), and other wetland-

dependent species (*Scirpus microcarpus*, *Typha* spp. *Cyperus eragrostis*, *Equisetum* spp.), as well as some nonnative species of grasses (especially velvet grass [*Holcus lanatus*] and harding grass [*phalaris aquatica*]) and forbs including Cape-ivy (*Delaria odorata*) and Vinca (*Vinca major* and *V. minor*). Areas covered with various reeds along the shores of lagoons and ponds, herbaceous strips of vegetation along perennial and ephemeral stream courses, and isolated wetland patches where seeps spring from the hill slopes throughout the park are included. Some special status plant species – locally to regionally rare – occur within this community.

Fire Ecology

While this community is not fire-dependent or -adapted, it is found intermixed with other communities that could be manipulated for fire management purposes, and can be affected by those actions.

Riparian Forest and Scrub

General Characteristics

These streamside forests and shrub lands are dominated by broad-leaved deciduous trees or shrubs, most commonly willows (*Salix lasiolepis* or *S. lucida* ssp. *lasiandra*) and occasionally red alder (*Alnus rubra*). The understory is typically dense, with a variety of shrubs including berries – native salmonberry (*Rubus spectabilis*), thimbleberry (*R. parviflorus*), and California blackberry (*R. ursinus*), as well as nonnative Himalayan blackberry and Cape-ivy. Numerous herbaceous species including ferns, rushes, and sedges dominate the shrub understory. Nonnative trees including eucalypts (*Eucalyptus* spp.) and Monterey cypress (*Cupressus macrocarpa*) have become successfully established within the riparian forest strands in the park.

Fire Ecology

While this community is not fire-dependent or -adapted, it is found intermixed with other communities that could be manipulated for fire management purposes, and can be affected by those actions, including actions specific to removal of nonnative species.

Native Hardwood Forest

General Characteristics

This variable community extends from 200 to 2,500 feet in elevation, and is dominated by oak *(Quercus* spp.), California bay laurel *(Umbellularia californica)* and/or tanbark oak *(Lithocarpus densiflorus).* Along the mesic boundary of this mixed evergreen forest is the redwood/Douglas-fir community and along the xeric boundary is the coastal scrub and grasslands (Sawyer et al. 1977).

Coast live oak (*Quercus agrifolia*) dominates this community at elevations below 1,000 feet. It is often the only species present on hills frequented by a cool, foggy, coastal climate. Interior live oak (*Q. wislizenii*) sometimes replaces coastal live oak in canyon bottoms and north-facing slopes. As the community approaches 1,000 feet in elevation, California bay (*Umbellularia californica*), tanbark oak (*Lithocarpus densiflorus*), and other hardwoods become common.

Fire Ecology

The old-growth oak and bay laurel woodlands are stately California communities where the past occurrence of fire is evident in the multiple-trunked character of most trees, indicating early bole damage and subsequent sprouting (Plumb 1980). As for mature trees, bark thickness is the most important factor contributing to their degree of fire tolerance. Coastal live oak has thick bark and is therefore the most resistant to fire. It sprouts from the main trunk and upper branches following complete charring, as does California bay laurel. Prescribed burns in Cuyumaca State Park have shown that both coast live oak and canyon live oak respond well to low-intensity, backing fires, and new sprouts that appear after fire are palatable and attractive to deer.

The native hardwood forests support little ground fuel (probably less than five tons per acre) (Plumb 1980) and as a result associated fire intensities are minimal. The exception is where eucalyptus are invading these woodlands. Here, the community has become more susceptible to fire than it was historically.

Fall burns following rainfall will create erratic fire behavior and effectively reduce small ground fuels. Surface fine fuels typically dry approximately one week after rain, whereas larger fuels take most of the summer to dry out. Thus, the reduction of these larger fuels can be accomplished under low fire intensities when duff layers are moist. Isolated pockets of heavy fuel accumulation can be expected to create erratic but localized fire behavior.

The native hardwood forest has many fire-resistant properties and many species sprout. The gradual incursion of Sudden Oak Death (SOD) into these forests (Figure 3-11) poses a serious threat to their continued existence, and the use of fire may help manage both the forest structure and potentially stall or inhibit the effects of SOD. Recent studies suggest fire can be used to manage the spread of SOD, and may kill off fungal spores.

Douglas-Fir and Coast Redwood

General Characteristics

The majestic old-growth redwood forest at Muir Woods, with Redwood Creek peacefully flowing through groves of tall trees, attracts much visitor attention. This tranquil scene is a rare sight close to a large metropolitan area. Preservation of the pristine character of these woods is a management priority. Many species contribute to this ecosystem. Major overstory and understory trees include coast redwood *(Sequoia sempervirens),* Douglas-fir *(Pseudotsuga menziesii),* California bay laurel *(Umbellularia californica),* tanbark oak *(Lithocarpus densiflorus),* California hazel *(Corylus californica),* and madrone *(Arbutus menziesii).*

Douglas-fir communities are found on Bolinas Ridge and within Muir Woods. The communities on Bolinas Ridge have been logged. Douglas-fir in Muir Woods sites have a brush understory and a significant component of dead fuel. When mature, Douglas-fir has thick bark that acts as fire insulation to vital cambium tissues. Young Douglas-fir are susceptible to fire and are often killed. Mortality increases with scorch height, percent crown scorch, and bole damage, but decreases with trunk diameter. In addition, mortality following fall fires is slightly higher than following spring fires (Ryan et al. 1988).

Douglas-fir seeds ripen in burned cones and require relatively open conditions for reproduction (Franklin and Dyrness 1973); the species is considered shade-intolerant. It takes a severe fire to destroy the seed bank of Douglas-fir. Following a light to moderate burn an adequate seed bank remains (Sawyer et al. 1977). An open environment is brought about by burning and Douglas-fir germination is enhanced.

Fire Ecology

The many fire-scarred trees in Muir Woods provide evidence of historical fire occurrence. The last recorded fires occurred in 1800 on the valley floor (Sudborough 1966) and 1850 on the slope (Cornelius 1969). The most complete fire history in Marin County redwood communities (McBride and Jacobs 1978) was done using fire scar data from redwood stumps at two study sites: Old Mill Creek and Alpine Dam. Average fire return intervals of 21.7 and 27.3 years occurred respectively, the difference between these intervals being attributed to climatic moisture differences (Jacobs et al. 1985). It should be noted, however, that fire scar data provide conservative estimates of fire frequency, since low-intensity fires would not always scar the trees.

These aforementioned fire intervals are post-human settlement. Available evidence indicates that the "natural" mean fire interval in southern redwood forests is 50 to 300 years, and the presence of humans has caused the decrease in the mean fire interval to today's levels (Langenheim et al. 1983). Recent changes in fire suppression abilities have somewhat increased fire intervals in the redwoods themselves, but Veirs (1980) found that redwood forests in northern California have not significantly changed as a result of fire suppression, since most species have the ability to sprout. Other studies indicate that the exclusion of fire may reduce the opportunity for redwood establishment but not the establishment of many competitors, and long-term fire exclusion could result in redwood replacement by other species.

The effect of fire intensity is important to the role of fire. Low-intensity fires favor redwood rather than Douglas-fir, while high-intensity fires do the opposite (Veirs 1980). However, most large redwoods (greater than 20 centimeters [cm] at breast height [dbh]) survive prescription levels higher than those that have been used in Muir Woods (Finney 1991). Fungal pathogens can enter redwoods through fire scars, creating rot in the heartwood. Although it is not fatal to the redwood, it places stress on the trees and increases the chance of wind breakage and damage by fire (Fritz 1932).

Fire plays a primary role in coast redwood reproduction. Seedling establishment and sprouting are stimulated by burning. Redwood seedling establishment requires bare mineral soil with adequate soil moisture, which protects seedlings from attack by damping-off and root-rotting fungus (Davidson 1971). These conditions exist after fires – which remove ground litter and sterilize the soil – and after floods when soils are exposed and silt deposition occurs on stream banks. Another form of reproduction is vegetative sprouting, which is triggered by mechanical injury, changes in light intensity, and fire (Simmons 1973).

Douglas-fir will generally dominate the post-fire generation in this community. Other tolerant tree species such as redwood develop almost simultaneously (Lotan et al. 1981). The majority of herbs and shrubs associated with this community sprout following crown destruction by fire (Lyon and Stickney 1974). Seeds of some species (e.g., *Ceanothus* spp.) require heat treatment before germination. Redwood needles are more flammable than Douglas-fir and will burn with a higher relative humidity. The redwood bark

Placeholder page

Figure 3-11 Areas of Sudden Oak Death Infestation from Best Available Field Information

chars even with low-intensity fire. Charring can be reduced significantly by limited raking of litter 1 to 2 feet away from trees (Boyd 1984).

The vegetation of the coast redwood and Douglas-fir communities is adapted to the varying effects of fire and can benefit from carefully implemented management actions. Fuel loads within the Douglas-fir-dominated areas present a hazard, and elimination of fire from this environment will only perpetuate and increase this hazard.

These forests have developed a large fuel buildup due to years of fire suppression. The fuel accumulations around the base of redwood trees provide fuels that will produce fire intensity causing fire to climb up the trunks of individual trees. The Douglas-fir trees have very significant ladder fuels that will contribute to fire being carried high into the trees. A fall season fire in this forest can be expected to produce a crown fire. This type of fire is difficult to control, requiring a backing off or containing strategy. Past prescribed fire experience in this fuel type produced fire climbing the bark of trees and burning for hours in the tops of the trees. This fuel type normally produces slow-burning ground fires with low flame heights. The fire may encounter occasional "jackpot" or heavy fuel concentrations that can flare up. Under hot fall weather conditions extreme fire behavior can exist.

The fire hazard at Muir Woods was analyzed by McBride and Jacobs (1978). Five major categories of fire hazard were identified: surface-fuel condition, ladder-fuel condition, downed woody fuel, slope-wind correlations, and ignition risks. The greatest threat of wildfire exists in the alluvial flat and on the northeast and south boundaries of Muir Woods. It should be emphasized that the hazard in this portion of Muir Woods is greater now than when the fire hazard was analyzed and will continue to increase without treatment.

In 1985 a prescribed burn was conducted in Muir Woods National Monument. This was the first step in reducing fuel loads and reintroducing fire into that environment. Subsequent prescribed burns have been implemented with positive results for both fuel load reductions and control of nonnative species moving into the forest understory from adjacent coastal scrub and grassland communities.

Nonnative Evergreen Forest

General Characteristics

Many nonnative tree species have become established in GGNRA through both intentional and unintentional introductions, including ornamental plantings, wind breaks or shade for pastures, and escapes from cultivated and developed areas. Many of these trees – including a number of eucalypts (*Eucalyptus* spp.), acacia (*Acacia* spp.), Monterey pine (*Pinus radiata*), and Monterey cypress (*Cupressus macrocarpa*) – have invaded native communities. Most are very flammable, or significantly change the fire potential in areas that otherwise would support low-intensity or minimal fires, such as the coastal scrub and grassland areas of the park. Some stands of trees are located in close proximity to urban areas, or are within areas that would otherwise support rare communities or species (such as the mission blue butterfly). Both situations pose a threat to park neighbors and to these sensitive species due to the highly flammable nature of the nonnative trees and the changes they cause in environmental conditions including shade, duff and litter loads, moisture levels, and chemical additions to the soil.

Fire Ecology

Blue gum (*Eucalyptus globulus*), other eucalypt species, and acacia are inhabitants of the dry schlerophyll forests of Australia, where they have evolved under a frequent fire regime. Adaptations to moderate and intense fire are many, including rapid growth to great heights, which minimizes lower limb exposure to fire; thick fire-resistant bark; fire-resistant seed capsules that take advantage of the open post-fire seedbed and germinate quickly; and the ability to produce epicormic shoots and lignotubers sprouts after intense fires. Since high-severity fires are more advantageous to species reproduction, these trees are considered to be fire-maintained. Such communities tend to have adaptations that allow them to burn more readily than other communities. Eucalyptus in particular produces a ground fuel with high energy potential (due to the high levels of oils) to insure flammability (Mutch 1970).

Low- to moderate-intensity fires are not as advantageous to these species because fewer seeds germinate, the seedbed is not as open, less light is available due to survival of overstory trees and shrubs, and more native fungal pathogens are present. Prescribed fire in eucalyptus needs to be of low intensity in order to reduce hazardous fuel loadings. Frequent burns are needed to keep regeneration low. Low-intensity spring burns typically inhibit most eucalyptus and acacia regeneration (Mount 1969).

The fuel beneath GGNRA eucalyptus and acacia stands has been accumulating due to slow decomposition. Organic matter in eucalyptus soil accumulates slowly and litter decomposition remains as duff, sometimes one foot deep (Mount 1969). All eucalypt studies indicate that the amount of available fuel on the forest floor is one of the most significant factors influencing fire spread and fire intensity (McArthur 1962, Cheney 1988). An extreme fire hazard is apparent in Marin County (Howell 1982). Similar eucalypt stands in the Berkeley hills showed 45 to 100 tons per acre of ground surface fuels prior to the devastating fires in 1991.

Monterey pine and Monterey cypress, although native to California, are nonnative to GGNRA. These tree stands are generally found in conjunction with developed areas such as batteries and other military installations throughout the park, and represent an historic attribute of the vegetation. However, their adaptation to the climate and soils has enabled these planted trees to spread through seedlings to cover large expanses beyond the cultural landscape, again encroaching upon communities that would otherwise have little to no fuel buildup or potential for more than low-intensity flashy fires, including coastal scrub and grasslands. Many of the stands, similar to eucalyptus and acacia, form a continuous vegetation cover between wildland interior areas of the park and adjacent urban or developed zones, posing a threat to both the natural communities (due to changes in fire frequency and intensity) and cultural landscapes and features. Both species are fire-adapted, with serotinous cones (cones open after intense heating, allowing seeds to fall onto newly fire-cleared soils) and oily needles, scales, and underlying duff and litter.

Eucalyptus can be expected to produce an intense fire any time after the surrounding grasslands have cured. The dead and down fuel buildups can be expected to be 125 tons per acre or higher. This fuel does not have a fuel model that represents it. The trees have ladder fuels of shedding bark that produces torching and the very high potential of a crown fire. In December 1990, GGNRA experienced a hard freeze, causing large-scale leaf and limb damage to eucalyptus groves. This freeze damage has significantly contributed to increases in aerial and ground fuels.

Nonnative evergreen forests have created a fire hazard in GGNRA due to the nature of the fuels, fire behavior, and locations in proximity to both urban/developed areas and sensitive species. A hazard fuel reduction program using prescribed fire and mechanical manipulation will continue to be implemented in GGNRA nonnative evergreen forests to reduce fuel buildups and lessen the fire hazard. Fire may also be used to manage historic stands of nonnative forests to remove saplings and ground and ladder fuels, thus both preserving the historic stand structure and reducing fire hazard and potential spread into adjacent native habitats.

Wetlands

Wetlands in GGNRA

GGNRA has abundant wetland resources, including wet meadows, seeps, streams, riparian forests, lakes, ponds, and lagoons. Wetlands, according to the definition developed by the U.S. Fish and Wildlife Service and adopted by the NPS, are lands transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface or the land is covered by shallow water (Cowardin et al. 1979). Wetlands generally include marshes, riparian zones, mudflats, rocky intertidal zones, and gravel beaches. Deepwater habitats such as rivers, lakes, and estuaries are not technically wetlands but are classified as aquatic sites using the same classification system. Wetland ecosystems act to buffer hydrologic and erosional cycles, control and regulate cycles of nitrogen and other key nutrients, and create valuable habitat for animal species.

The wetlands in GGNRA have been field-mapped in several watersheds, including the Rodeo Creek watershed, the Presidio of San Francisco, and portions of the Redwood Creek and Bolinas Lagoon watersheds. The remainder of the park has not been field-mapped but contains areas of wetland vegetation that can be extracted from the parkwide vegetation mapping. The majority of wetlands in GGNRA are located in the valley bottoms, with seeps and small intermittent streams reaching into the higher portions of the watersheds.

Detailed wetland classification in the Rodeo Valley watershed will enable GGNRA to begin to assign the important functions of the wetland resources throughout the park. By documenting the vegetation type and life form, as well as the hydrogeomorphic characteristics of a wetland, a functional assessment can be completed that determines each wetland's relative importance in surface water detention, streamflow maintenance, nutrient transformation, sediment retention, fish and wildlife habitat, and other important wetland functions. This information could be used to identify high-value wetlands that require special considerations.

Effects of Fire Management Activities on Wetlands

The major impact of fire management activities on wetlands will result from increased sedimentation. Excess sediment input into a wetland can alter the hydrology and in turn the vegetation composition. Conversely, heavy scouring from increased runoff could affect wetland hydrology by forming new drainage channels that deplete the site of water.

Wetlands burn infrequently and are unlikely to play a role in fire ignition or maintenance, but are important in inhibiting fire spread. When wetlands do burn, the fire usually spreads into them from adjacent vegetation.

Wildlife

The park's diverse habitats support a rich assemblage of wildlife. At least 387 vertebrate species are known to occur within the park boundaries. Species lists compiled from a variety of sources and incomplete inventories include 11 amphibians, 20 reptiles, 53 fish, 53 mammals, and 250 birds (ICE 1999). Terrestrial invertebrates in the park are less well-known, with the exception of butterflies in two areas of the park, Marin Headlands and Milagra Ridge, that support diverse butterfly populations.

Wildlife habitats within the park range from introduced eucalyptus and closed-cone Monterey pine and cypress forests to hardwood, mixed evergreen, Douglas-fir, redwood, and riparian forests; coastal scrub, annual and perennial grasslands; freshwater and saline wetlands and wet meadows; and estuarine, lacustrine, marine, and riverine aquatic habitats.

Mammals

Terrestrial habitats within the planning area support a high diversity of mammals. Meso-carnivores, including the gray fox (*Urocyon cinereoargenteus*), bobcat (*Felis rufus*), and the recently reestablished coyote (*Canis latrans*) inhabit coastal scrub and grasslands. Mountain lions (*Felis concolor*) have been sighted in some undeveloped areas of the park. These carnivores feed on a variety of small and large mammals such as the Pacific black-tailed deer (*Odocoileus hemionus columbianus*), broad-footed mole (*Scapanus larimanus*), pocket gopher (*Thomomys bottae*), deer mouse (*Peromyscus maniculatus*), western harvest mouse (*Reithrodontomus megalotis*), California vole (*Microtus californicus*), and brush rabbit (*Sylvilagus bachmani*). Badgers (*Taxidea taxus*) are also infrequently encountered. Some species, such as the western harvest mouse, appear to be restricted to areas where native perennial grasses persist. In addition to many of the mammals listed above, Muir Woods and other forested areas within the planning area support vagrant shrew (*Sorex vagrans*), Trowbridge's shrew (*Sorex trowbridgii*), Sonoma chipmunk (*Tamius sonomae*), western gray squirrel (*Sciurus griseus*), opossum (*Didelphis virginiana*), and dusky-footed woodrats (*Neotoma fuscipes*). Other mammalian carnivores include the raccoon (*Procyon lotor*), striped (*Mephitis mephitis*) and spotted skunks (*Spilogale gracilis*), long-tailed weasel (*Mustela frenata*), and the recently returned river otter (*Lontra canadensis*).

Seventeen species of bats have been detected within the park. Ten species of bats have been documented in Muir Woods, including four federal and/or state species of concern: Townsend's western big-eared bat (*Corynorhinus townsendii townsendii*), fringed myotis (*Myotis thysanodes*), long-legged myotis (*M. volans*), and Yuma myotis (*Myotis yumanensis*). Many of the bats in Muir Woods have been detected using redwood fire-scar cavities for roosting. At the Marin Headlands, several historic World War II structures were found to be occupied by the Townsend's western big-eared bat and the Yuma myotis, both federal species of concern. The Brazilian free-tailed bat (*Tadarida brasiliensis*) forages over coastal scrub habitat within the Marin Headlands.

Isolated coastal rocks, beaches, and lagoon sand flats in the park serve as haul-outs for harbor seals (*Phoca vitulina*) and California sea lions (*Zalophus californianus*). Up to 250 harbor seals haul out in Point Bonita Cove at Marin Headlands. As the northern elephant seal (*Mirounga angustirostris*) population rapidly increases, the seals are encountered more frequently on sandy beaches throughout the region. California gray whales (*Eschrichtius robustus*), humpback whales (*Megaptera novaeagliae*), and harbor porpoises (*Phocoena phocoena*) use offshore waters and young whales occasionally wander into San Francisco Bay. Southern sea otters (*Enhydra lutris nereis*) are infrequently seen offshore with numbers increasing as the population spreads north.

Birds

Located along the Pacific Flyway, GGNRA provides habitat for a great diversity of breeding, overwintering, and migratory birds. Nineteen species of diurnal raptors have been detected in migration over the ridges of the Marin Headlands. Red-tailed hawks (*Buteo jamaicensis*), red-shouldered hawks (*Buteo lineatus*), and great horned owls (*Bubo virginianus*) nest in many of the large nonnative eucalyptus trees in the park. A wide range of other raptors and at least ten owl species occur within the planning area. In addition, federally threatened northern spotted owls (*Strix occidentalis caurina*) nest in coniferous and mixed-hardwood forests surrounding Muir Woods. Muir Woods also contains potential marbled murrelet (*Brachyramphus marmoratus*) habitat, but no breeding murrelets have been detected in two years of surveys. Numerous species of waterbirds also occur within the park in marine and rocky intertidal habitats, cliffs, beaches, and tidal and wetland areas.

Point Reyes Bird Observatory (now PRBO Conservation Science) encountered 83 bird species during 1997 breeding landbird censuses in coastal grassland, coastal scrub, riparian, and mixed hardwood habitats. From point count censuses in 1999 and 2000, white-crowned sparrows (*Zonotrichia leucophrys*), red-winged blackbirds (*Agelaius phoniceus*), savannah sparrows (*Passerculus sandwichensis*), and song sparrows (*Melospiza melodia*) were the most commonly detected species in grasslands. The most abundant species in coastal scrub were white-crowned sparrows, spotted towhees (*Pipilo maculatus*), and wrentits (*Chamaea fasciata*). In forested habitats, bushtits (*Psaltriparus minimus*), chestnut-backed chickadees (*Junco hyemalis*), dark eyed juncos, Pacific-slope flycatchers (*Empidonax difficilis*), and winter wrens (*Troglodytes troglodytes*) were commonly detected. Based on songbird nest monitoring in riparian habitats along Redwood and Lagunitas creeks, the song sparrow, Swainson's thrush (*Catharus ustulatus*), warbling vireo (*Vireo gilvus*), and Wilson's warbler (*Wilsonia pusilla*) were the most commonly observed nesters. The brown-headed cowbird (*Molothrus ater*) is a nest parasite that negatively affects the reproductive success of open-cup nesting songbirds and occurs throughout the planning area. Many of the landbirds in the planning area are Neotropical migrants, with others identified as species of management concern and riparian species of conservation priority by California Partners-in-Flight.

Amphibians and Reptiles

Small populations of the federally threatened California red-legged frog (*Rana aurora draytonii*) occur within the planning area. Within San Mateo County, historic records indicate the presence of the federally endangered San Francisco garter snake (*Thamnophis sirtalis tetrataenia*). More common terrestrial

amphibians in the planning area include ensatina (*Ensatina eschscholtzii*) and California slender salamander (*Batrachoseps attenuatus*). Common species spending a substantial amount of time for breeding or rearing at streams or ponds include California newts (*Taricha torosa*), rough-skinned newts (*Taricha granulosa*), Pacific treefrog (*Hyla regilla*), and California giant salamander (*Dicamptodon ensatus*). Common reptiles include the Western fence lizard (*Sceloporus occidentalis*), northern alligator lizard (*Gerrhonotus coeruleus*), Pacific gopher snake (*Pituophis melanoleusus*), and western terrestrial garter snake (*Thamnophis elegans*).

Fish

The planning area includes both resident and transitory fish species that occupy marine, estuarine, and freshwater habitats. Common, nearshore resident estuarine and marine fish include Pacific staghorn sculpin (*Leptocottus armatus*), arrow goby (*Clevelandia ios*), and topsmelt (*Atherinops affinis*). The brackish Rodeo Lagoon in the Marin Headlands supports a large population of the federally endangered tidewater goby (*Eucyclogobius newberryi*).

Freshwater streams within the planning area are characterized by naturally low species diversity. Perennial streams may include resident fish such as threespine stickleback (*Gasterosteus aculeatus*) and prickly sculpin (*Cottus asper*). Several important anadromous fish species are present in the creeks and watersheds within the planning area. Anadromous species are those that spawn or breed in streams and rivers and then migrate to and mature in the ocean. Anadromous species that breed and rear in streams within the planning area include coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*). Both species are listed as threatened under the federal Endangered Species Act. Intermittent streams or the intermittent headwater streams may support only steelhead trout.

Invertebrates

Two coastal grassland/scrub areas in the park are known for their high numbers and diversity of butterflies: Marin Headlands and Milagra Ridge. The federally listed endangered mission blue butterfly (*Icaricia icarioides missionensis*) occurs at both sites, while the San Bruno elfin butterfly (*Euphydryas editha bayensis*) is found at Milagra Ridge, where it inhabits rocky outcrops. At least 44 species of butterflies occur in the Marin Headlands and 34 species occur at Milagra Ridge, illustrating the importance of habitat fragments within largely developed landscapes. Various species of skippers, swallowtails, hairstreaks, blues, ladies, admirals, and crescents inhabit these areas. Monarch butterflies (*Danaus plexippus*) are found in clusters overwintering in many areas of the park, often in groves of nonnative trees. Other terrestrial invertebrates have not been well documented.

Limited information is available regarding the freshwater invertebrates that are present within the planning area. Targeted inventories have been conducted in streams such as Redwood Creek. A total of 223 freshwater taxa are known. The only federally listed species is the endangered California freshwater shrimp, which is found within the Lagunitas Creek watershed, an area managed by Point Reyes National Seashore (PRNS). Limited information is also available regarding invertebrates from marine and estuarine habitats within the planning area. A total of 279 marine and estuarine taxa are known.

Nonnative Wildlife

Many species of nonnative wildlife have been identified as problem species within native wildlife habitat in the park. These species negatively affect populations of native animals through competition for resources, predation, and as vectors for disease. Nonnative terrestrial mammals include fallow deer (*Cervus dama*), feral hogs (*Sus scrofa*), red fox (*Vulpes vulpes*), opossum, house cats (*Felis domesticus*), and Norway and black rats (*Rattus norvegicus* and *R. rattus*). Nonnative birds found in the planning area include wild turkeys (*Meleagris gallopavo*), European starlings (*Sturnus vulgaris*), peasows (*Pavo cristatus*), house sparrows (*Passer domesticus*), and rock doves (*Columba livia*). Nonnative invertebrates present in the planning area include Argentine ant (*Iridomyrmex humilis*). Nonnative fish present within various human-made ponds include mosquitofish (*Gambusia affinis*) and various sunfish, while estuarine areas may support yellowfin goby (*Acanthogobius flavimanus*). Nonnative amphibian and reptile species include bullfrog (*Rana catesbeiana*), red-eared slider (*Chrysemys picta*), and the occasional caiman.

Special Status Species

Twenty-five species in GGNRA are protected under the Endangered Species Act as amended (16 USC 1536 [a] [2] 1982) and are managed by the NPS. Within the park's legislative boundary, there are 69 rare or special status wildlife species currently identified as permanent or seasonal residents of the park, or dependent upon park lands and waters for migration. Of these, 12 are listed as federally endangered, 12 are federally threatened, 1 is state endangered, 3 are state threatened, 31 are federal species of concern, and 10 are state designated species of special concern. Numerous other wildlife species (birds in particular) are considered sensitive by the Audubon Society, Partners in Flight, or the California Department of Forestry, or are designated Migratory Nongame Birds of Management Concern by the U.S. Fish and Wildlife Service (USFWS). Nearly all of the native birds documented in the park are protected under the Migratory Bird Treaty Act (16 USC 528-531). Thirty-eight rare or special status plant species are currently identified within GGNRA. Of those species, 9 are federally endangered, 1 is federally threatened, 13 are federal species of concern, and the remaining 15 species are included or proposed for inclusion by the California Native Plant Society.

The USFWS and NOAA Fisheries provided a list of federally threatened, endangered, and proposed species and any designated or proposed critical habitat for consideration during development of the FMP (see Appendix F). Literature reviews, contacts with local biologists and resource agencies, and field surveys were conducted to evaluate the potential occurrence of special status resources in the planning area. For purposes of analysis, special status resources are biological communities, plants, and animals that are (1) identified by state and/or federal agencies as rare, threatened, or endangered or candidates for such designations; or (2) considered sensitive by recognized monitoring agencies and conservation organizations (e.g., California Department of Fish and Game, California Native Plant Society, USFWS). Species listed as species of concern by the USFWS and species of special concern by the California Department of Fish and Game do not have legal protection under the Endangered Species Act but are considered as species that may be candidates for future listing. The listing as species of concern brings these species to the attention of the public and appropriate agency with the aim of obviating the need for future listing through wise management practices.

Special Status Wildlife Species

To evaluate the effects on special status species, a set of species considered likely or possible to experience impacts from fire management activities was selected for assessment based on the presence of suitable habitat within the project area. Appendix F, Special Status Species, evaluates all listed, proposed, or candidate animal species potentially in the planning area and provides a brief summary of presence/absence of suitable habitat and any distribution notes. Vagrant special status wildlife species (e.g., species where individuals have been documented in the park, but where suitable habitat is lacking within the park) will not be discussed further. In addition, most marine and estuarine species are expected to experience little to no impact from fire management activities, because proposed activities are not planned adjacent to coastal resources. Minor impacts from unplanned wildfire and associated suppression activities could occur if wildland fire facilitates coastal erosion and deposition in coastal waters. These marine and estuarine species will not be discussed further. Brief summaries of federally listed species and any designated critical habitat considered likely or possible to experience impacts from fire management activities are discussed separately in the sections below.

San Bruno Elfin Butterfly (Callophrys mossii bayensis) – Endangered

The larval host plant for San Bruno elfin butterflies is *Sedum spathulifolium*, a succulent that grows on rocky, north-facing slopes along the coast (Lambert 2002). Adults are thought to stay within about 100 meters of host plants. Adults have one generation per year, with flight season from late February to early April. Eggs are laid on the ventral surface on the leaves of host plants. The fourth instar larvae pupate at the base of host plants where they remain through the summer, fall, and early winter. Habitat loss and trampling of host plants, larvae, and pupae are the primary threats to these butterflies. The San Bruno elfin butterfly is known to occur only at Milagra Ridge within the planning area.

Mission Blue Butterfly (Icaricia icaroides missionensis) – Endangered

Mission blue butterflies are closely tied to the lupine larval host plants *Lupinus albifrons*, *L. variicolor*, and *L. formosus*, with *L. albifrons* considered to be the preferred host (Lambert 2001). These host plants tend to occur on grasslands on thin, rocky soils within broader coastal scrub habitats (Rashbrook 2002). Lupine are susceptible to fungal outbreaks, which have been documented to cause rapid contractions of lupine distribution at the Marin Headlands. Competition from nonnative plants, eucalyptus, Monterey pine, gorse, and broom also threatens lupine host plants (Rashbrook 2002). Lupine is a fire-adapted species, and fire may enhance suitable lupine habitat for mission blue butterflies. Adults feed on nectar from numerous plants, though they may prefer wild buckwheat (*Erigonum latifolium*), golden aster (*Chrysopsis vilosa*), blue dicks (*Brodiaea pulchella*), and Ithuriel's spear (*Brodiaea laxa*) (Lambert 2001). Habitat loss is probably the primary threat to mission blue butterflies, with trampling of host and nectar plants, larvae, and pupae also of concern (Lambert 2001). Other threats to mission blue butterflies at various stages of their life cycles include parasites, predators, and desiccation and disease during diapause.

Adults have one generation per year, with a flight period from mid-March to mid-May at the Marin Headlands and late May to mid-June at San Bruno Mountain (Rashbrook 2002). Analyses suggest that warmer air temperatures are associated with higher numbers of adults at the seasonal peak and that

rainfall is not related to the peak number of adults (Rashbrook 2002). Eggs are usually laid on the dorsal surface of larval host plants. Ants (*Prenolepis imparis* and *Formica lasioides*) may tend the later-instar mission blue larvae. Mission blue butterflies occur at the Marin Headlands, Tennessee Valley, Milagra Ridge, and Sweeney Ridge within the planning area.

Northern Spotted Owl (Strix occidentalis caurina) – Threatened

Marin County supports a northern spotted owl population of possibly 75 pairs. This population is isolated from spotted owl populations to the north by large areas of grassland and shrubs and constitutes the southern end of the subspecies range. Genetic analysis has shown low levels of genetic diversity within and low levels of gene flow between spotted owl populations in Marin County and Mendocino National Forest (Henke et al. 2003). The Marin County population supports the highest known density of northern spotted owls rangewide. Threats to spotted owls in the planning area include urbanization, intense recreational pressure, disturbance from wildlife photographers and birders, genetic isolation, West Nile virus, possible catastrophic wildfire, expansion in the range of the barred owl (*Strix varia*), and habitat changes due to Sudden Oak Death (Fehring et al. 2002).

Spotted owls in Marin inhabit coniferous forest, including second growth and remnant stands of Douglas-fir (*Pseudotsuga menziesii*), bishop pine (*Pinus muricata*), coast redwood (*Sequoia sempervirens*), and mixed conifer-hardwood habitats comprised of tanbark oak (*Lithocarpus densiflorus*), coast live oak (*Quercus agrifolia*), and California bay (*Umbellularia californica*) (Fehring et al. 2002). Spotted owls tend to nest in older stands of conifer and hardwood trees that create a tall overstory. Spotted owls often select larger trees with defects, such as broken tops or mistletoe (*Arceuthobium spp.*) infestations, for nesting, but also have been found nesting in young bay trees in smaller stands. Preliminary pellet analyses indicated that spotted owls forage primarily on dusky-footed woodrats (*Neotoma fuscipes*) in addition to other forest dwelling small mammals and songbirds (Chow 1996). Within the planning area, known spotted owl locations are currently limited to Muir Woods and the Stinson Gulch area.

California Red-Legged Frog (Rana aurora draytonii) – Threatened

The California red-legged frog is found primarily in wetlands and streams in coastal drainages of central California (USFWS 1994a). Red-legged frogs found north of the Marin-Sonoma county border exhibit intergrade characteristics of the California red-legged frog and the northern red-legged frog.

The frog requires specific aquatic and riparian features. Adult require a dense, shrubby, or emergent riparian vegetation closely associated with deep (>0.7 meters) still or slow-moving water (USFWS 1994a). The highest densities of California red-legged frogs have been associated with deep-water pools with dense stands of overhanging willows and an intermixed fringe of cattails (USFWS 1994a). Aestivation sites are located up to 26 meters from water in dense riparian vegetation (USFWS 1994a).

A recent court decision has eliminated critical habitat within the planning area by changing the habitat definition. Critical habitat had been defined to include essential aquatic habitat, associated uplands, and dispersal habitat connecting essential aquatic habitat. The primary constituent elements for critical habitat are summarized in Table 3-11.

Table 3-11: Primary Constituents of Critical Habitat for California Red-Legged Frog

Essential Aquatic Habitat	Essential Dispersal Habitat	Essential Upland Habitat
Still/slow water	No barriers	Within 90 meters of aquatic habitat
≥0.5 meter freshwater depth	>90 meters wide upland/aquatic area	
Space, food, cover for all life stages		
≥2 suitable breeding sites and permanent water with no more than 2 kilometers between breeding sites		

Source: USFWS, 2001.

San Francisco Garter Snake (Thamnophis sirtalis tetrataenia) – Endangered

This snake is endemic to the San Francisco peninsula and is currently restricted to localities within San Mateo County. This listed species is primarily threatened by the loss and alteration of suitable wetland habitat due to urban development, freeway and road construction, illegal collection, agricultural practices, and trampling (USFWS 1985). It is considered semi-aquatic and is found along the margins of ponds, lakes, streams, and estuaries (above tidal influx) (Barry 1978). It feeds on small amphibians and fish, especially the federally threatened California red-legged frog (*Rana aurora draytonii*) (USFWS 1985). The planning area contains three sites (Sweeney Ridge, Milagra Ridge, Mori Point/Sharp Park) that appear to have suitable habitat for the San Francisco garter snake; however, recent surveys specifically for the snake and habitat assessments have not been conducted. Only Mori Point/Sharp Park has had a documented occurrence of the San Francisco garter snake; however, no recent population data are available. The NPS and the USFWS are currently planning inventory and enhancement activities for the San Francisco garter snake at Mori Point/Sharp Park.

California Freshwater Shrimp (Syncaris pacifica) – Endangered

The California freshwater shrimp is endemic to 17 coastal streams in Marin, Sonoma, and Napa counties north of San Francisco Bay. The shrimp is found in low-elevation (less than 116 meters), low-gradient (generally less than 1 percent), perennial freshwater streams where banks are structurally diverse with undercut banks, exposed roots, overhanging woody debris, or overhanging vegetation. Existing populations are threatened by introduced fish, deterioration or loss of habitat because of water diversions, impoundments, livestock and dairy activities, agricultural activities and developments, flood control activities, gravel mining, timber harvesting, migration barriers, and water pollution. Within PRNS and GGNRA, reproducing populations are found within the Lagunitas Creek watershed along the mainstem from Shafter Bridge in Samuel P. Taylor Park to roughly 1.6 kilometer below the confluence with Nicasio Creek (Serpa 1991) and in lower Olema Creek (Fong 1999). Recent surveys in 2002 at various coastal streams at PRNS have not found any new populations of the shrimp (LoBianco and Fong 2003). However, all shrimp observations have been restricted to sites managed by PRNS. No shrimp have been found on GGNRA-managed lands despite presence of suitable habitat (Fong 1999).

Tidewater Goby (Eucyclogobius newberryi) – Endangered

The tidewater goby is a small benthic fish that occurs in the upper end of California coastal lagoons in salinities less than 10 parts per thousand (USFWS 1994b). While generally found in coastal embayments, gobies are also known to occur in streams. In San Antonio Creek in Santa Barbara County, the goby is known to occur up to five miles upstream of the lagoon habitat (Irwin and Soltz 1984). Within the planning area, tidewater goby is known only from Rodeo Lagoon in the Marin Headlands.

Coho Salmon, Central California Coast (Oncorhynchus kisutch) – Threatened;
Steelhead Trout, Central California Coast (O. mykiss) – Threatened

For most drainages, presence/absence salmonid surveys have been conducted, while in watersheds supporting coho salmon, abundance data on both species are available. The variable life cycle of steelhead makes population analysis more difficult, but also makes steelhead more resilient to adverse environmental conditions. In general, if the habitat requirements for coho were met, steelhead habitat requirements would also be met.

Central California coast coho salmon (hereafter referred to as coho) occur in several creeks within the planning area, as well as the nearshore waters of the Pacific Ocean and estuarine sites such as Bolinas Lagoon and San Francisco Bay. Coho salmon are found in Redwood Creek (Marin County). A single cohort of coho salmon was found in Easkoot Creek (Marin County). Designated critical habitat for coho in GGNRA includes accessible estuarine and stream areas in the coastal watersheds of Marin County except areas above longstanding naturally impassable barriers.

Central California steelhead trout (hereafter referred to as steelhead) occur in several creeks within the planning area. Steelhead are found in Redwood Creek in Marin County, as well as in the drainages to Bolinas Lagoon and Rodeo Lagoon. In San Mateo County, steelhead are found in West Union Creek, a tributary to San Francisquito Creek.

Both species are anadromous species; born and reared in freshwater streams, as juveniles they migrate to estuaries, adjust to saltwater, and then migrate to the ocean to mature into adults. Adult steelhead enter planning area streams in the late winter through spring to reach spawning sites, typically well-aerated areas with small- to medium-size gravel. Most adult coho return to freshwater systems to spawn in fall and winter months after spending 1.5 years in the ocean. Optimal habitat conditions for juvenile coho seem to be deep pools created by rootwads and boulders in heavily shaded stream sections. Habitat preferences for juvenile steelhead are similar, although young-of-the-year steelhead are often forced into shallow-water habitats. Most juvenile coho leave the streams for the estuary and ocean after 1.5 years of residence. The amount of time steelhead rear in freshwater and marine/estuarine habitats is variable, ranging between one to three years.

In April 2002, the U.S. District Court for the District of Columbia approved a NMFS consent decree withdrawing a February 2000 critical habitat designation for steelhead trout. Designated critical habitat for coho includes all accessible estuarine and stream areas in the coastal watersheds of Marin County except areas above longstanding, naturally impassable barriers. Through this designation, NOAA

Fisheries identified ten essential features of critical habitat: substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food, riparian vegetation, space, and safe passage conditions.

Special Status Plant Species

Within the areas considered under the GGNRA FMP, 26 special status plant species[2] are supported by existing habitat (see Appendix F for species listing status). Three are listed by the federal Endangered Species Act as either threatened or endangered; 20 are listed as federal species of concern or federal species of local concern (species for which the USFWS is collecting additional information to determine if they warrant consideration for future listing) (some of these species are also listed on the California endangered species list); and three species are of management concern to the park and are listed by the California Native Plant Society on List 4 – Plants of Limited Distribution (locally rare). Although these species are not actually listed as threatened or endangered under the federal Endangered Species Act, NPS Management Policies 2001 (NPS 2000a) states that the NPS will inventory, monitor, and manage state and locally listed species in a manner similar to its treatment of federally listed species. The policies also state that the NPS will inventory other species that are of special management concern to parks such as locally rare, declining, sensitive, or unique species.

Federal Threatened, Endangered, Candidate, and Proposed Plant Species that May Occur in Affected Areas

All three federally listed species within the planning area have the potential to be affected by FMP actions. These species are described below, and are included in the Biological Assessment that has been prepared in conjunction with the DEIS for review by the U.S. Fish and Wildlife Service and NOAA Fisheries.

Raven's manzanita (*Arctostaphylos hookeri* ssp. *ravenii*) is a perennial prostrate to low-growing shrub. It exists as a single individual east of Lincoln Boulevard (in Area B) of the Presidio on a serpentine outcrop. Clones of this individual have been out planted west of Lincoln Boulevard in suitable serpentine coastal prairie habitat. The management of this species is guided by the Recovery Plan for Coastal Plants of the Northern San Francisco Peninsula (USFWS 2003), which suggests the species is stress-tolerant with sparse competing vegetation, but is relatively intolerant of direct vegetative competition such as shading from shrub or tree canopies. Although most manzanita species benefit from fire – the hard-coated seeds in the soil typically germinate post-fire, and most species also stump sprout – the effects of fire on this one individual and its clones are unknown. Raven's manzanita lacks burls (lignotubers), specialized flattened trunk-like structures that are adapted to rapid vegetative regeneration following fires. There have been no reports of natural seedling establishment around the remnant wild Raven's manzanita nor from the clones, which may indicate a lack of viable seed, seed predation, or lack of sufficient seedling microsites. No data are available on the natural germination ecology of this species, but the Recovery

[2] Additional special status species occur within the park's administrative and legislative boundaries and are managed by other agencies. These agencies include the Presidio Trust for Area B of the Presidio, the City and County of San Francisco for San Francisco watershed lands, the United States Air Force at the Mill Valley Air Force Base on Mount Tamalpais, and the NPS – PRNS for GGNRA lands north of the Bolinas-Fairfax Road that are managed by PRNS staff. These species are monitored regularly by staff at GGNRA and PRNS, but are not included in the following discussion because they are managed by other entities.

Plan suggests that seed germination could be stimulated by burns as with other manzanita taxa farther south on the San Francisco peninsula.

Marin dwarf-flax (*Hesperolinon congestum*) is an annual herb that is found in GGNRA as a small population west of Lincoln Boulevard of the Presidio. It grows within the serpentine coastal prairie-grassland habitat, and is somewhat affected by nonnative plant encroachment and trampling of offtrail use. Population trend monitoring of this and adjacent populations indicates that this species is stable to increasing in numbers in the area, although trends are difficult to interpret due to the wildly fluctuating annual population sizes typical for annual species. Other areas, not under direct management of the NPS, suggest that overall impacts on the species are from nonnative and native plant species encroachment, particularly from shrubs. These species encroach on suitable habitat and limit the annual display of this species. Management of the Marin dwarf-flax is guided by the Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (USFWS 1998). This plan suggests that primary protection and recovery actions should focus on removing nonnative plant species and minimizing trampling of plants, population areas, and suitable habitat around the population. Key research needs in the plan include the need to determine the effects of burning on the species – an issue being investigated in test populations outside GGNRA-managed lands (Thomas 2004).

San Francisco lessingia (*Lessingia germanorum*) is a low-growing, slender-stemmed annual herb of the sunflower family (Asteraceae). Robust plants have diffusely branched stems and grow up to one foot high, spreading close to the ground. Small plants may be very short and nearly erect, with few or no branches. Leaves are narrowly lance-shaped, lobed and toothed or entire, mostly an inch or less long. The leaves and stems are covered with grayish, wooly, loosely interwoven hairs. San Francisco lessingia is now narrowly associated with either sparse vegetative cover or substantial vegetation gaps, usually related to past artificial disturbance of the substrate or the vegetation. Historic populations were probably associated with early stages of succession following natural dune blowouts, or other local disturbances within coastal dune scrub. The management of this species is also guided by the Recovery Plan for the Coastal Plants of the Northern San Francisco Peninsula (USFWS 2003), which indicates that primary impacts on this species are related to the edge effects of adjacent vegetation, including shading, nonnative plants, and wind blockage. This plan suggests that primary protection and recovery actions should focus on removing nonnative plant species, minimizing edge effects, and increasing or enhancing suitable habitat around the population.

Federal Plant Species of Concern, California-Listed Species, and Additional Plant Species of NPS Management Concern that Occur in Areas that May be Affected by the GGNRA FMP

Twenty-three additional special status plant species occur within areas considered by the FMP. These species are briefly described below in relation to their habitat occurrences.

Chaparral. Marin manzanita, Glory brush, and Mason's ceanothus are evergreen shrubs that grow in the limited chaparral community on Bolinas Ridge south of the Bolinas-Fairfax Road. Threats to these species are excessive shade from overcrowding from high shrub densities, lack of disturbance to trigger seed germination and reproduction, nonnative species encroachment (particularly French broom), and possibly suppression of fire.

Grassland and Coastal Scrub. Coast rock cress is a perennial herb found throughout GGNRA, including the Marin Headlands, Presidio, Milagra and Sweeney Ridges, and Pedro Point. It grows on rocky outcrops and serpentine bluffs in coastal grasslands, where it is relatively common within the park. Habitat loss through urbanization (on a statewide scale), nonnative plant species encroachment, and alteration of coastal grasslands to coastal scrub through the establishment of coyote brush and other scrub species are the primary threats to this species. Oakland star-tulip is a perennial lily that was recently discovered in the vicinity of Muir Woods in non-serpentine grasslands, whereas larger and well-documented populations exist in the San Francisco watershed and on Mount Tamalpais. The species is threatened by nonnative plant species encroachment into suitable habitat. San Francisco wallflower is a short-lived perennial forb and is found throughout the Marin Headlands, and at Fort Point and the Presidio, Fort Funston, Sweeney and Milagra Ridges, and Pedro Point in scattered populations. It is found within coastal grassland and coastal scrub communities, as well as on rocky outcrops and coastal dunes. It thrives on new ground disturbances and is threatened by encroachment of dense shrubs. San Francisco gumplant is a perennial forb endemic to San Francisco County, where it inhabits serpentine coastal bluffs and grasslands. It occurs at the Presidio, where threats are confined to nonnative plant encroachment into suitable habitats and the development of (unplanned) social trails that increase natural erosion rates and increase trampling of individual plants. Arcuate bush-mallow, a small perennial shrub, was last observed on Sweeney Ridge in 1994. It does not occur elsewhere within GGNRA. This plant may not be present, or present in very small numbers due to lack of fire. However, seeds of species in this plant family (Malvaceae) typically lie dormant for decades and germinate vigorously after fire.

Forested Areas. California bottlebrush grass is a perennial bunchgrass that appears to be locally common where it occurs within the planning area, although its overall distribution is restricted in California. It occurs in the Marin Headlands, on moist western slopes of Bolinas Ridge, in Muir Woods, and in Oakwood Valley, where it inhabits the understory of Douglas-fir forests and native hardwood (California bay laurel) stands. Known populations appear to be stable with little threat from surrounding plant species or developments.

Wetlands and Riparian Areas. Choris's popcornflower is a small annual forb found in moist depressions in the coastal grasslands of Sweeney Ridge. It is threatened by the establishment and spread of nonnative plant species, especially oxe-eye daisy (*Leucanthemum vulgare*), and by soil disturbance (such as through trail maintenance) while the plant is growing and flowering. Franciscan thistle is a short-lived perennial herb found in freshwater seeps and drainages in the Marin Headlands, Fort Point, and Presidio coastal bluffs. Primary threats to the species are nonnative plant species encroachment – particularly bull thistle (*Cirsium vulgare*), poison hemlock (*Conium maculatum*), and Cape-ivy (*Delaria odorata*) – and changes in the water table from manipulations to trails, fire roads, and culverts above extant populations.

Coastal Dune and Marsh. The majority of special status species within this habitat are restricted to specific sites on the Presidio in areas unlikely to sustain fire management activities. These species include pink sand verbena, Nuttall's milk-vetch, California saltbush, coast Indian paintbrush, north coast bird's-beak, California croton, San Francisco dune gilia, Kellogg's horkelia, coast rein-orchid, Mission Dolores (San Francisco) campion, and pacific cordgrass. Two additional species – San Francisco spineflower and dune tansy – occur at both the Presidio and Fort Funston in sandy coastal scrub and dune habitats.

3.5 Social Environment

Cultural Resources

The NPS recognizes five categories of cultural resources for management purposes.

Archeological resources are the remains of past human activity and records documenting the scientific analysis of these remains. They are typically buried but may extend aboveground; they are commonly associated with prehistoric peoples but are also commonly products of more contemporary society. They shed light on often otherwise unrecorded questions, such as social organization, and have helped researchers to understand the spread of ideas over time and the development of settlement from place to place.

Cultural landscapes are environmental settings that human beings have created in the world that reveal the fundamental ties between people and the land and reflect the human need to grow food, give form to settlements, meet a need for recreation or work, or bury the dead.

Structures are material assemblies that extend the limits of human capabilities, such as buildings to keep people warm and dry. Bridges to cross barriers, ships and trucks to carry goods over long distances, fortifications for protection, and statues and monuments to commemorate human achievement, all are types of structures.

Ethnographic resources represent basic expressions of human culture and contribute to the continuity of tangible and intangible cultural systems, such as traditional arts, native languages, religious beliefs, and subsistence activities. In parks, they include special places in the natural world, structures with historic associations, and natural materials.

Museum objects are tangible manifestations and records of behavior and ideas that span the breadth of human experience and the depth of natural history. They are evidence of intellectual and technical development, of scientific observation, of personal expression and curiosity, and of common enterprise and daily habits. They are invaluable and irreplaceable samples of the world through time and place and of the multitude of life therein.

Cultural Resource Context for GGNRA

These five categories of cultural resources are the tangible manifestations of human beings interacting with their environment and with each other throughout some 100 centuries of time, up to the present day, in the lands now known as GGNRA. To understand the effects of the alternatives on the cultural resources of the park, it is necessary to concisely trace the contexts within which these interactions occurred and within which they were created.

Native American populations in California were once among the densest in all of North America. The lands around San Francisco Bay were occupied by scores of tiny tribes, each of which held territories some 8 to 12 miles across, that are now grouped into two major communities primarily because of linguistic similarities – the Coast Miwok north of the Golden Gate and the Ohlone to the south of the

Golden Gate. Because they lived off the seeds, fish, and animals of their local environments, details of their lives differed somewhat among coastal, bay shore, riverine, and interior valley homelands. Intermarried extended families grouped together in tribes that protected their tiny territories fiercely against the encroachment of neighbors. But adjacent tribes were also bound together by a complex web of intergroup marriages and trading alliances. Coast Miwoks and Ohlones were integrated so seamlessly into their environment that it is easy to overlook just how sophisticated and extensive were their techniques of managing the lands for food, shelter, and other purposes.

The era of Spanish exploration and settlement brought great disruption to the traditional Native American ways of life. Indeed the interaction between the two cultures decimated native populations and brought an end to the Bay Area tribal world. Motivated by a global rivalry for political, military, and economic dominance, Spain's New World colony in Mexico entered a period of expansion, spurred by news of Russian and British activity in the far northwest. In 1769 the Portola Expedition discovered and claimed San Francisco Bay on behalf of the Spanish Crown, and in 1775-1776 the Anza expedition brought settlers from Sonora overland to found a mission and a presidio.

Spanish colonial settlement followed a rather rigid and complex system that had developed over 200 years of northern expansion beginning in 16th-century Mexico City. The Presidio functioned, here as elsewhere, as the military and civil complex and advance guard of territorial settlement, and shared a social and economic function with the mission (Langellier 1992).

Mexico became independent of Spain in 1822, as one consequence of widespread anti-colonial revolution in Latin America. But outward change came slowly to the isolated, neglected, and poor garrison at the Presidio of San Francisco. Within the decade, the Mexican government had decreed the secularization of the missions, dividing their holdings into self-supporting ranchos and replacing the Franciscan missionaries with regular parish priests. The political center of power thus shifted more and more toward a landed elite, and regional land use patterns still recognized today were set in place. The vast ranchos with their equally vast herds of cattle became the basis for much of the economic activity in the area. Decentralized trade became more common, encouraged by visits from "Boston ships" carrying the American flag, and overland parties from the expanding nation far to the east began to intrude more and more on the Hispanic society of California, culminating with its annexation to the United States in 1848.

The westward expansion of the young United States in the name of "manifest destiny" is reflected in the central role of the Golden Gate as the grand entrance by sea to the Pacific West and all its potential. The California Gold Rush of 1849 transformed that future potential into a very sudden, very busy era of settlement, urbanization, industrial growth, resource extraction in the gold fields and forests, and rapid establishment of a world-renowned city at the tip of the San Francisco peninsula.

To the north of the city, new settlers began to develop a regionally significant dairy industry in the 1850s that thrived for 100 years; a number of the original dairy ranches continue to operate, as cattle ranches, within the park boundaries. These dairy ranches played an instrumental part in the development of the industry in California. They were at the forefront of industry modernization; they led the state in dairy production into the 1890s, they became a primary destination for immigrants from Switzerland and the Azores, and they brought a rich ethnic mix to the area that remains to this day. As the ranch complexes

stayed in use until quite recently, they continue to impart a pastoral, scenic, and distinctive regional flavor to the rural historic landscape of west Marin and the northern lands of GGNRA (Livingston 1995).

As the population and economic development in the San Francisco Bay Area soared in the years following the Gold Rush, the transportation network grew apace in order to move people and goods more efficiently. The growth of the port was paralleled by construction of aids to navigation at crucial points along the Golden Gate and along the coast – lighthouses, fog signal stations, life-saving stations, and Coast Guard stations. On land, ancient trails used by the native tribes sometimes became wagon roads and, eventually, paved roadways; some still survive in the form of contemporary hiking trails. Other farm roads, rural highways, streetscapes, ferry piers, and railroad rights-of-way developed in response to local and regional transportation needs.

San Francisco Bay was described by the first European explorer to see it as wide enough to shelter all the navies of the world. Ever since, it has been an important strategic consideration in the military and political balance of power in the Pacific. The Spanish built the first fortifications at the harbor entrance in 1794, and the Americans began their impressive network of seacoast defenses at Fort Point and on Alcatraz even before the Civil War broke out in 1861. By the turn of the 20th century, the major naval base at Mare Island and the widespread port and industrial facilities throughout the area impelled the U.S. Army to build modern concrete and steel fortifications along the Golden Gate on a scale unmatched in the Pacific. Only the much larger city of New York had fortifications on a scale equaling those at San Francisco Bay.

At the start of the 20th century, as the United States assumed control of territories across the Pacific Ocean in the Philippines, in Hawaii, and in the Panama Canal Zone, Fort Mason became the major port of embarkation for troops and supplies going to these overseas outposts. After the attack on Pearl Harbor propelled the United States into World War II, the West Coast became an official theater of war and its defenses were reinforced accordingly for "the duration." During the long tense years of the Cold War that followed, the Army deployed Nike anti-aircraft missiles around the Golden Gate hinterlands – the last in a long line of defenses that date back nearly 200 years.

As these great social, political, and economic trends unfolded, they were enabled and enhanced by technological and engineering advances. These are manifested by the great prisms lit by whale oil, then kerosene, at the Point Bonita Lighthouse; the contrast between the seemingly numberless and intricately layed bricks at Fort Point and the massive concrete gun batteries of the Marin Headlands; and, especially, by the turbulent waters of the Golden Gate spanned by the world-famous bridge that bears its name.

The development of architecture and landscape architecture was informed by, and related to, these technological and engineering advances. The park today contains archeological remains of adobe brick structures, utilitarian and ornamental wooden homes and barracks, and brick and concrete buildings; the profusion of historic structures within the park is a veritable catalog of architectural style over some 200 years. The massive warehouses at lower Fort Mason and the curving row of artillery barracks at Fort Winfield Scott vie for the honor of introducing Mission Revival to the architectural palette of northern California's public structures. The Cliff House at Lands End reflects the early use of reinforced concrete

in the rebuilding of San Francisco after the great earthquake and fire of 1906. The cellhouse on Alcatraz Island was the largest reinforced concrete building in the world when it was completed in 1912.

Great cities require civic amenities, and San Francisco was in the forefront of opening parks and seaside recreational areas for its citizens. Indeed Adolph Sutro's gardens at Sutro Heights overlooking the fanciful Sutro Baths at Nyad Cove are noteworthy in providing healthy and educational outdoor opportunities for people of all social and economic strata. The Presidio in San Francisco and Fort Baker in Marin County also played important roles as pleasant, well-landscaped recreational areas for the local citizenry and for national and international visitors too – presaging their roles in the present national park. Urban areas also have their dark side, and nowhere does that underworld more eloquently speak from the past about prisons, prison life, and penology than at Alcatraz Island.

These diverse and significant historical threads are all related in some way to the land use patterns that developed in the region and to the use of the land for settlement, for production, and for its resource values. The native tribes affected the resources of the area in a sophisticated manner that is perhaps so subtle, compared to what followed, that it appears they had no impact at all upon the "wilderness." Yet the detailed composition of the regional ecosystems was clearly influenced by human beings for thousands of years. Widespread cattle grazing is widely perceived to have brought the earliest broad changes by European peoples to the Bay Area landscape. These changes accelerated dramatically in the American era with widespread logging deforesting most of the timber stands within present park boundaries. Siltation from increased erosion in logged areas affected natural wetlands, while San Francisco Bay on a larger scale was affected by silt-laden runoff from water-cannon mining in the Sierra foothills and by purposeful filling of the shoreline for development projects such as the 1915 Panama Pacific International Exposition. The abundant natural resources of the area, as in the West as a whole, were the fuel for the economic engine that built houses and ships, drove vehicles, watered mouths and fields, and gave mineral riches to the economy. They are the historical foundation of the West that today's generation has inherited.

Where resource exploitation was most egregious, however, it became the rallying point for a small but growing national conservation movement, one that, in many ways, can rightly call the Bay Area its birthplace. In 1908 Congressman William Kent donated the largest old-growth redwood grove in the north bay to the nation as a national park on the condition that it be named for naturalist John Muir. It was one of the first uses of the Antiquities Act, formulated to protect archeological sites, to preserve natural wonders. In 1916, the Sierra Club, founded in the Bay Area, lost its bitter battle to preserve Hetch Hetchy Valley in Yosemite from being filled as a reservoir. But in losing a battle, it may have won a war, for the organization thrived in future years on a crest of national outrage over the outcome. In 1928, Mount Tamalpais State Park was established to preserve some of the most scenic natural acres in the Bay Area. And about the same time, one of the best local park organizations in the country, the East Bay Regional Park District, began to create a greenbelt along the crest of the East Bay hills.

Thus the stage was set for the establishment of GGNRA in 1972. As post-war suburban sprawl threatened the open space in the region, the once-powerful military-industrial complex in the area began to subside. The historic coincidence of the anti-growth movement with a revitalized conservation movement took

advantage of the unparalleled opportunity created by the closure of the large and largely undeveloped Army posts ringing the Golden Gate headlands. Thus was formed GGNRA, as community activism met public need and created a great national park to preserve open space, natural habitat, scenic wonders, and historic values in the San Francisco Bay Area (Rothman 2002).

Cultural Resources by Category

Fire management actions such as prescribed fire, suppression activities, and mechanical treatments have the potential to affect cultural resources such as archeological sites, structures, ethnographic resources, and cultural landscapes within National Landmark and National Register Historic Districts, as well as museum collections and other properties managed by the park as cultural resources. For a listing of historic properties within GGNRA, excluding archeological sites, see Appendix D. Cultural resources in Golden Gate are subject to the provisions of the National Historic Preservation Act (NHPA), which requires identification and assessment of park resources for their eligibility for the National Register of Historic Places (Section 110) and consideration of the effects of any undertaking on resources that are on, or determined eligible for, the National Register (Section 106). It is NPS policy that every effort be made to minimize the effects of such undertakings and avoid adverse effects on historic resources (NPS 2000a).

The environment with potential to be affected – both positively and negatively – by fire management activities at GGNRA may now be discussed by specific resource category with an understanding of their historical context.

Archeological Resources

There are 52 archeological sites included in the Archeological Survey Management Information System for Golden Gate National Recreation Area, and numerous additional sites are presumed to exist. Their significance is assessed through the use of research agendas based upon historical contexts. Archeological resources from indigenous populations of Native Americans within the present boundaries of GGNRA typically consist of sites, such as village sites, camps, rock shelters, procurement sites such as food gathering and hunting spots or quarries for tool making, food processing sites such as shell middens, funerary sites, and trails. Isolated artifacts relating to many of the above functions may appear in areas with greater or lesser association to these sites. Human remains have been identified in association with shell middens within the park, and it may have been a widespread cultural practice to associate the burial of the dead with the activities of the living.

Historic period archeological resources are of a different nature, and consist primarily of two types: remains of buildings and structures, and trash or refuse dumps. Besides the known archeological resources from the prehistoric and historic eras, there are almost certainly numerous archeological resources that remain to be discovered within park boundaries. This is because only a small percentage of the lands within GGNRA have yet been surveyed to professional standard, because archeological sites within surveyed areas are so numerous, and because such resources regularly are brought to the park's attention through maintenance activity, development, visitor use activity, and other means. At present, the park uses a model based upon soil type slope ratio and proximity to sources of water to predict areas of potential archeological sensitivity.

A low-intensity fire may actually be beneficial to the management of archeological resources, in the sense that the removal of dense vegetation may open up previously inaccessible areas for survey and identification. However, removal of ground cover, whether by fire or mechanical methods, may make sites more vulnerable to looting or erosion. In general, quick-moving fires, in which the heat impulse is directed largely upward, have relatively little impact on buried archeological resources, while fires that move slowly and direct heat downward have greater impact, with sites consisting of inorganic material being less sensitive to low and medium temperatures than those containing organic material. Alterations to drainage patterns through ground disturbance or change in vegetative cover may have impacts on archeological and other cultural resources. Archeological sites on the surface or subsurface could be damaged by heat from prescribed burning or wildfires, disturbed by the clearing of containment lines around prescribed burns or wildfires, or damaged by the operation of heavy equipment over sites or into sites if heavy equipment use includes soil disturbance as part of fuel reduction projects. The use of staging areas for fire management activities and equipment also has potential to damage archeological resources if the staging areas are not sited away from areas of known and predicted sensitivity.

Much as they may affect landscape resources in unanticipated ways, the application of fire-retardant chemicals during wildland firefighting may have unforeseen effects upon buried and unburied archeological resources. More research is needed in order to be able to identify these effects at any useful level of detail.

Cultural Landscapes

Parklands contain extensive areas of historic period cultural landscapes, significant in the areas of farm life and agriculture, military affairs, and designed landscape architecture. In particular, many of the dairy ranches of West Marin, the former Army posts along the Marin and San Francisco headlands, and the public parks and recreational complexes along the San Francisco shoreline retain a high degree of integrity relating to their period of historical significance. The most extensive cultural landscapes are the former military lands and the rural agricultural landscapes. These are also the areas where fire management activities will have the most effect on historic landscape resources through wildfires, by prescribed burns, by provision of access for fire equipment and vehicles, and by mechanical fuel load reduction activity.

These landscapes consist of clusters of, and individual, buildings, structures, and small-scale features; the circulation networks connecting them; the land use patterns characteristic of the landscape type; boundaries and boundary markers; water features; depositional features; vegetation patterns and components; and the topography upon which all these lie. Particular activities, lack of activity in some cases, and certain fire conditions have the potential to put at risk a broad range of values that directly affect the integrity of landscape resources. (See Figures 3-12, 3-13, and 3-14.)

The very existence of historic buildings and the safety of their occupants are affected by lack of defensible space, excessive fuel loading nearby, and proximity to sources of water. Creating defensible space and reducing dangerous fuel loads have the obvious beneficial effect of reducing structural fire danger, but must take historic vegetation material, boundary demarcations, and land use patterns into account in order to avoid adverse impacts on these character-defining features of historic landscapes.

Placeholder page

Figure 3-12 Cultural Landscape Inventory – Marin County

Placeholder page

Figure 3-13 Cultural Landscape Inventory – San Francisco

Placeholder page

Figure 3-14 Cultural Landscape Inventory – San Mateo County

The use of power tools, motor vehicles, and heavy equipment without careful allowance for the integrity of roads, pathways, tracks and trails, plantings, and drainage features could adversely affect features such as road surfaces, road prism, circulation network alignment, gates, fences, and cattle guards. Properly informed by cultural landscape information, however, such equipment can be of enormous value in providing access to overgrown areas, especially fire roads, and restoring the historic feel of long-neglected areas.

Historic patterns of land use have a tendency to change over time and to be obscured by neglect and by uncultivated vegetation growth. Landmark trees, open vistas, ease of walking, field and garden planting patterns, the open spacing of orchards, evidence of grazing, and specific species composition all diminish without active human management. Fire and fire management activities can have both beneficial and detrimental effects on historic land use patterns. Fire set under proper prescription can keep open fields in grassland, avoid the choking feel and high fire hazard of spreading scrub, and avoid damage to historic fence lines, significant vegetative species, and important trees. Where fire use is not appropriate, mechanical fuel reduction activities can have the same beneficial effect provided cultural resource values are taken into account. Mechanical fuel reduction is particularly beneficial in managing the spread of planted trees, such as eucalyptus, Monterey cypress, and Monterey pine, beyond their intended extent.

Erosion, whether because of the denuding of soil cover after fire or because of human-caused fire management activity, has the potential for major adverse effect on cultural landscape resources such as the quality and alignment of water features, the circulation patterns, roads, paths and trails, the integrity and function of drainage systems, the suitability of the land for historic grazing and growing purposes, and the very feeling of the pastoral landscape.

The application of fire-retardant chemicals during wildland firefighting may have unforeseen effects upon the post-fire growth of vegetation within an historic landscape, but more research is needed in order to be able to identify these effects at any useful level of detail.

Structures

Fire management actions, or lack of action, will clearly affect the safety of many of the park's approximately 700 historic structures. Basic fire safety measures such as regular inspections, provision of emergency exits, and installation of smoke alarms and sprinkler systems have a great deal of positive benefit for the preservation of historic buildings. But these structural fire safety actions, important as they are, lie largely outside the scope of the affected environment for the FMP, and are addressed through NPS Director's Order 58.

The most substantial beneficial impacts of wildland fire management activities can be anticipated from the creation and maintenance of defensible space around historic buildings and structures through pruning or removal of dense, overgrown, and highly flammable vegetation growing nearby. The maintenance of access for firefighting equipment and personnel via fire roads, alleys, and adjacent spaces is also of importance in the preservation of historic building resources. Direct negative impact of such activities on the historic integrity of buildings themselves is unlikely, although indirect adverse effects on nearby landscape elements are possible if activities are not planned and carried out with sensitivity.

Ethnographic Resources

Ethnographic sites within GGNRA that have the potential to be affected by fire management activity are largely considered to be places, landscapes, and features with specific cultural meaning to Ohlone and Coast Miwok peoples. No such sites have presently been identified by the NPS or have been brought to the park's attention to date by Ohlone or Coast Miwok tribal members. However, the NPS is presently developing an ethnohistory study, in association with notable scholars, to better formulate an ethnographic context for Native American cultural associations within GGNRA. In addition, as part of the NEPA process for the FMP DEIS, the GGNRA will consult with representatives of local tribes to determine if such sacred sites are located within GGNRA lands. Additional ethnographic sites, such as traditional gardens, may be associated with the predominant Azorean culture of the West Marin dairy ranching families.

As ethnographic resources are identified, the effects of fire management activities on those resources will be defined through the disciplines of ethnography, cultural landscapes, archeology, horticulture, and natural sciences, as appropriate. In every case, culturally associated groups will be consulted to the extent feasible and required by law, regulation, and policy. Fire management activities may have positive effects, such as restoring significant vistas or triggering growth in fire-dependent species of interest, as well as negative effects, such as increasing erosion or harm to individual signature trees.

Museum Objects

Structural fire management actions aside, there is little chance for fire management activities to directly affect park museum collections. However, indirect effects of fire management activities on museum collections may include increased curation responsibilities due to additional pre- and post-fire management and fire incident surveys, additional collecting of museum objects revealed during fire management activities, and additional consultation from subject matter experts that may be required in order to properly identify and assess potential museum artifacts.

Human Health and Safety

Public Safety and Wildland Fire Hazard

Marin County lands in the wildland urban interface zone are at risk for catastrophic fire such as a repeat of the Mount Tam fire in 1929, the Oakland Hills fire in 1991, and the Vision Fire in 1995. Approximately 40 percent of the land in Marin County (332,928 acres) is in public ownership, much of it contiguous to privately held properties at the edge of the wildland urban interface (Marin County Civil Grand Jury 2003). GGNRA has an expansive and complex boundary with many Marin County residential areas including Tam Valley, Homestead Valley, Muir Beach, Stinson Beach, Marin City, and Sausalito. In San Mateo County, GGNRA lands border San Bruno, Pacifica, Woodside, and King's Mountain. San Francisco lands are within the boundary of the City and County of San Francisco.

Numerous factors have contributed to the high fire hazard level:

- Wildfire suppression efforts creating current high fuel loads. The natural vegetation in California is adapted to fire and relies on periodic low-intensity fires to maintain a healthy balance. The

removal of fire from the landscape has resulted in huge accumulations of fuel, overcrowded forests, and decadent chaparral stands (MCFD 2000).

- Continued expansion of tracts of highly flammable, nonnative plants such as *eucalyptus globulus* that can successfully out-compete less flammable native plants, especially in disturbed areas.
- Spread of Sudden Oak Death, increasing fuel loads and hazards in the oak woodland forests, especially in Marin County.
- Construction of new housing on the perimeters of developed areas up to the interface with open space.
- Restricted access to communities due to narrow roads and roadside parking.
- Limited funding for vegetation management projects, staffing, and equipment purchases.

In evaluating wildfire risk in 2003, the Marin County Civil Grand Jury cited statistics that a repeat of the 1929 Mill Valley fire, which destroyed 116 homes valued at $1 million, would today destroy 850 homes in approximately the same footprint. Fuel loading prior to the 1929 fire was estimated at 12 tons per acre; the same area and acreage today has an estimated fuel load of 25 tons per acre. The Grand Jury concluded that "Mill Valley, Corte Madera, Larkspur, Kent Woodlands, San Anselmo, Ross, Fairfax, Novato, Woodacre and parts of West Marin especially appear vulnerable, although other communities are also at risk" (Marin County Civil Grand Jury 2003). Many of the risk factors present in Marin County today – narrow roads, restricted access, extensive tracts of blue gum eucalyptus – are similar to those that contributed to the devastating 1991 Oakland Hills fire (Tunnel Fire).

The potential property damage for a fire spreading from the wildland urban interface is equally high. While the 1929 fire caused $1 million damage, the ~~more recent~~ Vision Fire of 1995 resulted in structural damage of $23 million with the loss of 48 homes and damage to 18 others. Utility repairs following the Vision Fire were $1.3 million and rehabilitation of slopes and roads to control erosion cost approximately $1.3 million (MCFD 2004). Suppression of the fire exceeded $6 million.

A new factor is the presence of Sudden Oak Death (SOD), which is widespread in the interface lands of Marin County and recently appeared in both San Mateo and San Francisco counties. SOD has left thousands of trees dead in the oak woodlands adjacent to and within residential areas of Marin, greatly increasing the volume of hazardous fuels and elevating the potential intensity of a wildland fire. The partially collapsed, dead, and weakened trees present areas with higher fuels scattered in the woodlands that can create hot spots as they burn, providing a means for a ground fire to spread to convert to a crown fire – one of the most difficult wildfire types to control (MCFD 2000). As trees become infected with SOD, they become susceptible to secondary insect infestations and pathogens that speed decay. The sudden collapse of SOD-infected trees poses a new and significant threat to the public and firefighters and, if collapse occurs within range of a power line, could present a new source of fire starts as well (Shelley 2002).

Federal Government Response

Fire management planning in the NPS is based on the policies and philosophy set forth in the National Wildland Fire Management Policy (2001), which places public and firefighter safety as the primary goal of federal wildfire management programs. Federal policy acknowledges the public safety hazard existing in critical areas of the wildland urban interface between federal lands and private holdings. In 2001, following a catastrophic wildland fire season in 2000,[3] President Clinton asked the Secretaries of Interior and Agriculture to develop a joint implementation plan for reducing fire hazard and high fuel loading in the wildland urban interface and reintroducing fire back into the environment in federal wildlands as an important ecological element. The ensuing report, *Managing the Impact of Wildfires on Communities and the Environment, A Report to the President In Response to the Wildfires of 2000*, provided an implementation plan based on a cooperative approach to reducing fire hazard, the incremental success of which could be gauged by monitoring the progress of a series of measurable objectives. The report, its accompanying budget request, Congressional direction for substantial new appropriations for wildland fire management for the subsequent fiscal years, and resulting action plans and agency strategies have collectively become known as the National Fire Plan.

The National Fire Plan requires that all Department of the Interior (DOI) and U.S. Forest Service (USFS) areas with burnable vegetation have fire management plans that keep pace with changes in federal wildland policy. This required new FMPs to be developed reflecting changes in federal policy such as the increased emphasis on interagency cooperation and hazard reduction in the wildland urban interface.

To increase progress in implementing the principles of the new federal wildland policy, funding of the Wildland-Urban Interface Initiative of the National Fire Plan was increased and eligible projects expanded to cover both agency and local community projects. This program has allowed homeowners' associations, local fire agencies, and federal land managers to tackle longstanding fire hazards in Marin County, including strategically reducing areas of high fuel loading, improving access for emergency vehicles, and constructing shaded fuel breaks. Funding has also been provided for fire education programs that encourage homeowner participation in reducing fire hazard around their homes and in their communities. Cooperation and communication have been facilitated by the leadership of FIRESafe Marin, a nonprofit agency formed in 1991 in response to the Oakland Hills fire. FIRESafe Marin provides a forum for exchange of information on projects and funding opportunities among federal, state, and local land management and fire agencies and nonprofits such as homeowners' associations. NPS staff has also attended Fire Safe San Mateo County meetings through 2004.

Since fiscal year 2001, the federal government has funded 60 projects in Marin County throughout the interface zone on national parklands, private parcels, water district lands, and state and county parklands (M. Prado 2004). Projects have been located in the interface zone of federal lands and the neighboring communities of the Marin City, Sausalito, Muir Beach, Mill Valley, Tam Valley, Homestead Valley,

[3] The 2000 fire season was one of the worst in 50 years. Approximately 123,000 fires burned more than 8.4 million acres. The total acreage burned was more than twice the 10-year national average. At times, nearly 30,000 personnel were on the fire lines, including the military and firefighters from other countries. More than $2 billion from federal accounts was spent suppressing wildland fires; this amount does not include state and local firefighting suppression costs, direct and indirect economic losses to communities, loss of property, and damage to ecosystems (Waggoner 2004).

Stinson Beach, and Kent Woodlands. Where federal lands adjoin locally managed open space lands, the potential exists for a fire to spread from one area of undeveloped land to another and then into the more developed areas of Marin. Wildland-Urban Interface Initiative funding has been used by the Marin Municipal Water District, the Marin County Open Space District, and the Marin County Fire Department to implement the series of shaded fuel breaks envisioned by the Mount Tamalpais Vegetation Management Plan. Zones of reduced fuels are to created on both sides of ridgetop fire roads to provide firefighters with a defensible space from which to launch fire suppression actions, and lower branches of larger trees are pruned while retaining as much forest canopy as possible (MCFD 2004). Future project proposals may include fuel reduction in national parklands in San Mateo County near the cities of Pacifica and San Bruno and the community of King's Mountain on Skyline Boulevard.

Human Health

The principal impact of FMP activities on public health is the inhalation of particulate matter generated as smoke from prescribed fires and unintended wildland fire. Particulate matter is considered such a significant health hazard that it is one of the six criteria pollutants monitored under the Clean Air Act. (See also the air quality discussion in this chapter.) Particulate matter, found in the air-liquid droplets and small solid particles of minerals and soot, can penetrate deep into the lungs. Studies indicate that 90 percent of all smoke particles emitted during wildland burning are PM_{10}, and 90 percent of PM_{10} is $PM_{2.5}$ (Sandburg et al. 2002).

Healthy adults are not usually at risk from particulate matter; they may experience runny noses and coughing but these symptoms usually subside as the smoke disperses. People with heart or lung diseases, such as congestive heart disease, chronic obstructive pulmonary disease, emphysema, or asthma, can be at risk. People with these conditions may find it difficult to breathe, or may cough or feel short of breath. Children and the elderly are generally more susceptible to the harmful effects of smoke (CARB 2003).

Ninety percent of fire emissions are in the form of carbon and water vapor. The portion of carbon not converted to carbon dioxide becomes particulates, carbon monoxide, and volatile organic compounds. Carbon monoxide (CO) is the most abundant air pollutant (Agee 1993) and is a criteria air pollutant under the Clean Air Act and monitored in the Bay Area Air Basin by the Bay Area Air Quality Management District (BAAQMD). The more efficiently a fire burns, the less CO is produced. Impacts of CO on firefighter safety depend on the amount of CO produced, the duration of the exposure, and the level of physical activity. Firefighters working strenuously in a smoldering fire may become dizzy, weak, and disoriented. They can quickly recover by moving to fresher air away from the blaze (DeBano et al. 1998). Volatile organic compounds (VOCs) that are considered a health hazard are polynuclear aromatic hydrocarbons (PAHs). Though not a criteria pollutant, PAHs can have impacts on human health at higher concentrations. Backing fires[4] and smoldering fires produce higher levels of particulates and PAHs since the gases have higher residence times in these types of combustion conditions (DeBano et al. 1998).

BAAQMD is responsible for monitoring PM_{10} and $PM_{2.5}$ levels under the Clean Air Act and issuing permits for stationary sources, such as power plants, that contribute particulates to the ambient air quality

[4] Fires set by firefighters to burn against an advancing fire to deprive it of fuels.

of the Bay Area Air Basin. Smoke from wildfires is inventoried and managed differently from smoke from prescribed fires. 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 to develop State Implementation Plans (SIP) and Smoke Management Programs (SMP). In accordance with the California Smoke Management Guidelines, BAAQMD manages smoke emissions from prescribed burning 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.

Firefighter safety standards fall under the Occupational Safety and Health Act. Exposure to carbon monoxide and individual particulate matter compounds in wildland fire smoke are of primary firefighter safety interest. Limiting firefighter exposure to smoke is the best way to improve a firefighter's working environment. This is best done by smoke management techniques and crew rotation.

The amount and type of smoke and particulates produced will vary during each phase of combustion of a fire. During pre-ignition, the fuel's temperature is being raised to ignition temperature and all the moisture present in the fuel is being evaporated. During pre-ignition, only small amounts of white smoke are produced by combustion and the white smoke is predominately water vapor. In the flaming phase, fuel reaches the ignition temperature and erupts into flames. The fuel goes through a chemical change and large amounts of heat and gases are released. Rapid oxidation occurs and large amounts of smoke are produced. The smoke is lifted off the ground by the heat that is being produced and begins to disperse. The combustion process is very efficient during this phase. The residual (smoldering) phase occurs when the flaming front has moved on and some of the unconsumed fuel is still going through the combustion process – slowly, with little heat being released. A convection smoke column does not form and smoke is not readily dispersed. Instead it is concentrated close to the ground (PFMT 2004).

Smoke management techniques for prescribed burning include temporary and permanent fuel exclusion, implementation under specific moisture regimes, mass ignition techniques and other means of increasing combustion efficiency, and emissions redistribution. Each strategy is intended to reduce the generation of particulate matter or redistribute emissions. When fire is used to reduce fuel loadings, eliminating an undesirable species, disposing of quantities of biomass waste in advance, and isolating stumps that are prone to smoke can help in meeting state standards and resource management objectives. Conducting prescribed burns when small fuel moisture is low and large fuel and forest floor moisture levels are high can reduce emissions by making less fuel available overall for combustion. Also important is to mop up a prescribed fire quickly and efficiently to reduce smolder. Avoidance and dilution are strategies that direct smoke away from sensitive receptors or dilute the concentration of smoke. Based on the results of pre-fire modeling, prescriptions are set to take advantage of meteorological conditions that maximize mixing and direct smoke away from developed areas (DeBano et al. 1998).

Firefighter equipment can also play a key role in limiting an individual's exposure to fine particulates. Recent studies find that firefighters are exposed to the highest levels of particulate matter during mop-up

when areas of residual burning are controlled. Wearing respiratory protection greatly reduces exposure to particulate matter and air toxins but also makes breathing more difficult under heavy physical exertion, as respirators tend to increase resistance to air flow, making breathing more difficult (R. Bible 2002).

When fire is needed for ecosystem maintenance or restoration, especially in those ecosystems that are fire-adapted or maintained, these strategies are less applicable because they all alter the necessary or ecological fire regime. Altering an ecosystem's fire regime (intensity, frequency, seasonality, or spatial distribution) is manifested by changes in community structure and function and species diversity and distribution to some degree, and is well documented.

Herbicide Use

Fire management and vegetation management projects in GGNRA use herbicides, on a case-by-case approval basis, to control nonnative plant species within specific management areas. Various brand names of herbicides containing glyphosate are used to prevent resprouting of cut tree stumps within nonnative evergreen forests or shrub lands, especially on blue gum eucalyptus, acacias, cotoneaster, and various brooms. Foliar applications are approved in limited scenarios where nonnative vine or shrub species create a dense and dominant component of the site, and have included Cape-ivy and eupatory. These species can form dense thickets of impenetrable vegetation near developments and other critical resources, posing a fire hazard.

If there are trees within a grove that are to be retained due to cultural resources issues, application of herbicides to the cut stumps is avoided to avoid spread of the systemic treatment through the roots to the trees that were not to be treated with herbicide. In that case, a thick layer of chips could suppress some proportion of the regrowth, or nailing heavy roofing paper to the stump or applying landscape fabric onto the cut stump could serve to depress resprouting.

Glyphosate is a translocating herbicide that moves from the area where it was applied down to the roots of the plant via the active tissue – the cambium. It remains in the roots. Glyphosate is applied by painting it on the tree stump immediately after the tree is cut. If the trees are in a riparian area, no foliar spraying may occur, especially if the habitat supports anadromous fish. During the dry season (July 1 to November 15), cut stumps of nonnative trees and shrubs may be treated with herbicide.

Foliar herbicide applications beyond the riparian corridor are not approved where saturated soils are present, at wind speeds over 5 miles per hour, or when weather conditions facilitate herbicide movement toward drainages.

If glyphosate is inadvertently dripped or sprayed onto soil, the product will bind with the soil. When used in accordance with label directions, when the product is bound it is no longer available for plant uptake and will not harm offsite vegetation if roots grow into the treatment area or if the soil is transported offsite. The strong affinity of this product to soil particles prevents the product from leaching out of the soil profile and entering groundwater. The affinity between this product and soil particles remain until this product is degraded, involving primarily a biological degradation process carried out under both aerobic and anaerobic conditions by soil microflora. When sprayed on leaves, the half-life for glyphosate is 1.6 to

26.6 days. In water, the half-life is 3.5 to 70 days, In soil, the half-life is 2.8 to 60 days. In water, the half-life is 3.5 to 70 days (Badzik 2004).

All herbicide use is administered through each park's integrated pest management coordinator. All herbicides must be applied by a state-licensed pesticide applicator. All use is reported monthly to the coordinator, the county, and the State of California.

Visitor Experience and Visitor Use

GGNRA is unique not only in its diversity and quantity of natural and cultural features, but also in its proximity to a major urban population that also has worldwide status as a tourist destination. This juxtaposition makes GGNRA's resources and recreational opportunities readily accessible to a large number of people, and enhances the importance of the special qualities for which it was set aside. Park visitors can be local residents who have the park as part of their "backyard" as well as visitors from all over the world who have come to San Francisco to see many different attractions as part of their visit. GGNRA is visited by over 16 million people annually (NPS 2003d). Broken down into the three park units (see Chapter 1, Section 1.3, Planning Area), visitation for 2003 was as follows: Golden Gate National Recreation Area – 13.85 million, Muir Woods National Monument – 719,350, and Fort Point National Historic Site – 1.56 million.

The park exposes visitors to many of the resource values that exemplify America's national park system. Within the park, visitors can touch upon millions of years of natural history and thousands of years of human presence. This landscape evolved from a rugged coastal ecosystem – its sheltered estuaries teeming with waterfowl, bears, bobcats, salmon, and whales – and was the setting for American Indian villages, Spanish missions, Mexican ranches, Gold Rush cities, Civil War to Cold War forts, and today's metropolitan complex. The park contains the largest assemblage of historic buildings and the most complete collection of military resources of any single unit of the national park system.

Equally significant is the park's role in preserving an extraordinary convergence of land and water, city and nature, wildlife and people. The continental and ocean plates of the Earth's crust collide along its miles of ocean coastline, spawning the geological formations of the San Andreas Fault, which runs 40 miles through the park. Rivers flowing from the Sierra Nevada join the sea at the Golden Gate; marine, estuarine, and terrestrial ecosystems overlap; migratory birds and butterflies converge and plants respond to changing seasons.

These special geologic and climatic factors have created 19 distinct ecosystems that sustain nearly 2,500 species of plants and animals. The fragile and fragmented habitats protected by the park constitute a refuge for almost 100 rare, threatened, and endangered species, among them the northern spotted owl, coho salmon, and mission blue butterfly. The natural diversity of the California Biogeographical Province preserved within and near the greater Bay Area's major cities offers stupendous opportunities for learning about and practicing sustainability and stewardship. It was this rich biodiversity that led to the park's inclusion in the Central California Coast International Biosphere Reserve, designated by the United Nations in 1989.

The area supports miles of hiking trails, five campgrounds, hundreds of historic sites/structures and numerous beaches. There are five visitor centers in the park and more than 10 retail facilities run by park concessionaries or the park association. Overnight stays are available at four walk-in campsites in the Marin Headlands, two hostels (one at Fort Mason and another in the Marin Headlands), and local hotels and inns in areas outside the park boundaries. Activities include hiking, water sports, horseback riding, fishing, bike riding, camping, wildlife viewing, dog walking, sun bathing, and interpretive and educational opportunities. Visitors to the park come as individuals, as families, and as part of private and commercial tour groups including – thanks to a very active educational focus in the park – educational groups (schools, summer programs, youth groups, after school programs, etc.). They come to recreate, to learn, and to attend special events.

The park preserves not only natural systems and historic settings, but also a culturally vibrant and recreationally dynamic center consistent with its urban and Pacific Rim context. The miles of coastal and forested trails, ocean and bay beaches, and scenic vistas afford an array of activities, from traditional ranger-led walks, camping, and hiking to boardsailing, hang-gliding, biking, and jogging. Special events range from museum exhibitions and theater to art, music, and cultural heritage festivals.

As a nationally recognized model of park partnerships and public involvement, the park affords opportunities for thousands of people to participate in site stewardship, habitat restoration, and interpretive activities. The parks continue to expand this interaction through cultural, environmental, and educational programs offered at a variety of sites.

An important benefit of GGNRA is its contribution to Bay Area open space. With over five million inhabitants, each area of open space in the nine Bay Area counties provides opportunities for respite, relaxation, contemplation, and passive recreation for the millions of Bay Area inhabitants. An important function of open space is its soundscape, which is often remote from the noisy influences of urban experience. In place of the high ambient levels of background traffic noise ~~or the irregular and discordant~~ industrial or heavy equipment noise, the sounds in parts of GGNRA are often those that are lost in a city – bird noise, rustling leaves, distant waves, or barking sea lions. While people often need to block out urban sounds to better communicate or concentrate, natural sounds are sought out for their beauty and restorative qualities.

Though much of GGNRA is undeveloped and far from heavily traveled roadways, portions of the park are within line of sight of portions of multilane freeways, including Highway 101 east of the Marin Headlands and Alta Ridge in southern Marin County, Highway 1 west of Milagra and Sweeney Ridges and Cattle Hill and east of Mori Point and Pedro Point, and Interstate 280 east of the Phleger Estate. A community noise map included in the San Mateo County General Plan (1986) indicated that noise levels would exceed 60 dBA CNEL[5] by 1995 within 2,000 feet of Interstate 280. However, only the very eastern edge of Phleger Estate is within 2,000 feet of the interstate and noise levels decrease from the noise

[5] CNEL, community noise equivalent level, is a noise descriptor used in land use planning that presents a time-weighted average of noise energy over a 24-hour period with 5- and 10-decibel penalties applied to evening and nighttime noise to account for people's sensitivity to higher noise levels in the evening.

source at 6 dB for distance doubled. Noise levels of 75 dBA L_{eq}[6] at 250 feet from the freeway would be attenuated to 69 dBA L_{eq} at 500 feet and 63 dBA L_{eq} at 1,000 feet. At 4,000 feet, within the more interior portion of the Phleger Estate, that noise source would be attenuated to 51 dBA L_{eq} and even further reduced by intervening topography and/or screening vegetation. Since the majority of the Phleger Estate is beyond 4,000 feet of the interstate, traffic noise would therefore have little influence on the interior noise levels of the park. Similar to much of GGNRA, the most prominent sources of noise would be aircraft and jet overflights; other high levels of sound (rather than noise) are generated by the wind and rustling of vegetation.

Noise monitoring to support the Draft Marin Countywide Plan (2004) finds that noise generated by traffic, the primary noise source in the county, has remained relatively stable over the past two decades but that higher noise levels are being generated earlier in the morning, indicating a lengthening commute period. Topographic barriers, as well as ocean and wind sounds, protect much of the GGNRA parklands in southern Marin County from vehicle noise from Highway 101. Alta Ridge, with a clear line of sight to Highway 101, experiences higher noise levels on its east-facing slope. Smaller yet busy roadways within Marin County, such as Panoramic Highway, have lower traffic-generated noise levels. County monitoring for the Countywide Plan update recorded noise levels throughout the county for 24 hours on a summer Sunday in 2001. A monitoring station on Highway 1 north of Stinson Beach recorded elevated noise levels within one or two decibels of 60 dBA L_{eq} from approximately 8 A.M. through 7 P.M. The noise level meter sited at the Marin City shopping center, adjacent to Highway 101, recorded nearly continual noise levels of 65 dBA L_{eq} during the same period time period. The absence of vehicle traffic at 2 A.M. resulted in readings of 45 dBA L_{eq} and below at both locations. Overflights by jets from both Oakland and San Francisco International Airports have increased in Marin County, producing short-term noise levels of up to 70 dBA.

Without the influence of aircraft and jet overflight, noise levels in the interior of GGNRA would be similar to noise levels recorded in San Mateo open space for the recent annexation study by Midpeninsula Regional Open Space District (2004). That study found that noise levels, without the influence of aircraft and jet overflights, would generally range from 40 to 50 dBA $L_{eq(h)}$ depending on wind, with waves and bird noise as the most prominent natural sound sources. Depending on wind patterns and visibility, jets departing from San Francisco International Airport may be shifted to a pattern near the airspace above Milagra Ridge, dramatically increasing noise. Noise level monitoring conducted for a development project in Pacifica in 1997 demonstrates noise levels readings influenced by both vehicle and jet traffic. CNEL readings are high – higher than recommended for residential areas without special noise dampening insulation and windows. The two stations, approximately 1.5 and 2.0 miles north of Milagra Ridge, recorded 66.7 dBA CNEL and 64.4 dBA CNEL, respectively. Since these readings were recorded, noise levels generated by jet overflights have been dropping as more and more aircraft comply with higher levels of noise reduction standards.

[6] L_{eq}, or equivalent noise level, represents the level of steady state noise having the same energy as the time-varying noise measured. $L_{eq\,(h)}$ represents the time-weighted average for a 60-minute (hourly) period.

FMP-generated noise would be added to these relatively low noise levels in Marin County and higher noise levels at the Pacifica parks. The decibel levels of common noise environments and noise-generating equipment are as follows (League for the Hard of Hearing 2004).

- 40 – quiet office, library
- 65–95 – power lawn mower
- 74 – front loader
- 85 – hand saw
- 90 – tractor
- 95 – electric drill
- 100 – skidder
- 110 – power saw
- 110 – leaf blower
- 120 – jet plane (at ramp)
- 125 – chain saw
- 130 – jackhammer, power drill
- 130 – percussion section at symphony
- 140 – airplane taking off
- 150 – jet engine taking off
- 150 – artillery fire at 500 feet

During project implementation, FMP actions may involve the use of chain saws, brushcutters, weedships, haul trucks, front loaders, skidders, and chippers. Noise would be heard by visitors to the park and could alter the visitor experience.

Park Operations

GGNRA currently has about 230 full-time employees (FTEs) and an operating budget of approximately $21.4 million, consisting of $20.1 million in base funding as well as $1.3 million in other funding from locally generated reimbursements, lease revenue, permit fees, and cost-recovery programs. In fiscal year 2003, the park also received $10 million in nonrecurring project funding from a variety of sources (fee demonstration, leasing and concession revenues, NPS servicewide special funding), and had over $35 million of multiyear capital improvement projects underway, funded through congressional appropriations.

Visitation to the three national parks in the planning area exceeded 16 million visitors in 2003. In addition to unscheduled daily visitation, the Office of Special Park Uses issued 750 permits in fiscal year 2003 for events ranging from the Dipsea race (Mill Valley to Stinson Beach) to the Alcatraz triathlon. Over 190,000 people per year participate in permitted events in GGNRA.

Muir Woods National Monument, an old-growth redwood forest with unique values, high visitation, and high ignition potential, is located within and managed operationally as a part of the park. Provision of emergency vehicle access and egress routes for evacuation is a primary concern.

Maintenance of the extensive parklands and widespread facilities in Marin, San Francisco, and San Mateo counties is a major, ongoing task. Structures, historic and non-historic, need basic maintenance and repair; utilities must be kept up; trails, roadways, and parking lots are in need of repair. Landscaping and irrigation, tree pruning, fences, gates, restroom cleaning, and trash pick-up give a basic sense of the scope of work needed to maintain park facilities and resources at an acceptable level. Substantial facilities for the Maintenance Division are located at Stinson Beach, Fort Cronkhite, and Fort Baker in Marin County, and at Crissy Field, Fort Mason, and Fort Miley in San Francisco. The environment within which maintenance operations are performed is most affected, in terms of fire management considerations, by the reduction of hazardous fuel loads, the creation of defensible space around structures (or lack thereof), and the condition of main road and fire road access between the widely separated locations of the park.

Law enforcement, search and rescue, emergency medical response, structural firefighting, and wildland firefighting operations are, naturally, extensive in a park in an urban area with such high visitation, essentially open access, a wide range of resources, and nearly unparalleled recreational opportunities from hiking and biking to sail-boarding and hang-gliding. Major firefighting bases are located at Fort Cronkhite and at the Main Post of the Presidio of San Francisco. Law enforcement operations are based primarily at Fort Winfield Scott and the Cavalry Stables at the Presidio and at Fort Cronkhite in the Marin Headlands. The environment within which law enforcement and firefighting operations are carried out is affected in ways similar to those described in the previous paragraph for maintenance operations.

All park operations, but especially maintenance, law enforcement, and structural and wildland firefighting operations, are affected by the state of the roadways that link the widely separated areas of the park. These roads stretch 40 miles from the neighborhood of the coastal Bolinas Lagoon in the north to the Phleger Estate in the hills of San Mateo County in the south. Park roadways are generally two-lane, winding paved roads, with limited pullouts and shoulders. They are not designed for high-speed travel. Certain choke points, such as Highway 1 at Stinson Beach and at Tam Valley, or Frank Valley Road at Muir Woods, can become very crowded during peak visitation periods. Vegetation and fuel loading adjacent to roadways varies widely from managed landscaping to grassland, coastal scrub, and forest – including areas of dense eucalyptus woods. The primary north-south route through the park is Highway 1, the Pacific Coast Highway or Cabrillo Highway. But many locations within the park are nestled within east-west running valleys, and direct access between adjacent locations is often limited to park vehicles using steep, winding, dirt fire roads.

Natural resource specialists research and monitor ecosystems and the physical environment in order to preserve and restore healthy systems and populations. Cultural resource specialists monitor projects and perform research to ensure the stabilization, preservation, and restoration of historic structures, landscapes, and archeological resources.

GGNRA is an acknowledged leader in enlisting organizations into partnerships that leverage the park's ability to preserve resources, educate the public, and provide recreational opportunity to visitors. Many of these partners occupy and maintain park buildings through cooperative agreements and other legal authorities. Partners range from the Marine Mammal Center at Fort Cronkhite to the Bay Area Discovery Museum at Fort Baker. The creation and maintenance of defensible space around partner-occupied

buildings are the primary environmental effects on partner operations. Park operations are substantially supplemented by community volunteerism, especially in the areas of habitat restoration, educational programming, and historic preservation at the Nike site in Fort Barry.

Socioeconomics

Regional Setting

The socioeconomic environment affected by GGNRA fire management operations includes San Francisco, San Mateo and Marin counties, each of which encompass GGNRA lands. Table 3-12 provides a summary of selected demographic data for these counties.

As indicated in Table 3-12, the three counties comprise nearly 650,000 acres of land and contain a combined population of over 1.7 million. Total employment for the area is nearly one million jobs. In addition, the region attracts a significant volume of local and international tourists, with 14 million tourists reported per year in San Francisco County and two million in San Mateo County. Marin County Chamber of Commerce does not provide data on countywide visitation rates, however, given the attraction of GGNRA and Point Reyes National Seashore, the county also is a large draw for tourists and local visitors.

Table 3-12: Selected Regional Economic Characteristics

	San Francisco	San Mateo County	Marin County	Total
Total Size (acres) Source (A)	29,890	287,420	332,670	649,980
Population (2001) Source (A)	793,700	720,100	259,400	1,773,200
Employment (2000) Source (A)	435,200	411,300	139,700	986,200
Annual Visitors Source (B)	14 million	2 million	NA	NA
Visitor Spending ($ millions) (2002) Source (C)	$4,645	$1,925	$502	$7,072
Visitor-Related Jobs (2002) Source (C)	48,830	34,850	6,160	89,840

Sources: (A) California Department of Finance, (B) San Francisco and San Mateo Visitors Bureaus, (C) Dean Runyan Associates and the California Division of Tourism.
Note:
NA = not available

According to a 2002 report published by the California Division of Tourism, visitors to the three counties accounted for over seven billion dollars in spending. Associated visitor-related employment totaled approximately 90,000, or nearly ten percent of the area-wide employment.

Golden Gate National Recreation Area

GGNRA encompasses nearly 75,000 acres of land in San Francisco, Marin, and San Mateo counties, or nearly 12 percent of the total three-county land area. The park currently employs 230 full-time equivalent staff. The current GGNRA operating budget is $20.1 million in base funding, $1.3 million in other project funding, and $10 million in non-recurring project funding. The Fire Management Office has an annual operating budget of $400,000 and employs seven full-time staff. Compared to total employment levels in the affected area, the fire management payroll has a relatively minor beneficial impact on the local economy.

In 2003, a total of 13,457,900 people visited GGNRA, representing 84 percent of total visitation to San Francisco and San Mateo counties. In part due to its urban environment, GGNRA has achieved one of the highest volumes of annual visitors in the national park system. Visitation averaged about one million people per month from November through February, and averaged approximately 1.2 to 1.3 million monthly visitors during the spring, summer, and fall months.

As shown in Table 3-13, the vast majority of park visitors are day travelers. An estimated 80 percent of visits are from people residing in the area. An additional 15 percent are day visitors from other regions. Lodging guests and camp visitors make up five and less than one percent of total visitors, respectively. The recreational visitors to GGNRA contribute substantially to the local economy. In 2001, visitor groups spent an average of $42 per day (visitor groups also called "party days" are based on size of party, length of stay and other factors), resulting in a total of $212.8 million in total spending in the area.

Table 3-13: GGNRA Visitation and Spending by Visitor Segments in 2001

Year 2001	Local Day Visitors	Non-Local Day Visitors	Hotel Visitors	Camp Visitors	Total
Recreation Visits	10,700,470	2,006,339	730,102	20,991	13,457,902
Segment Shares in Recreation Visits	80%	15%	6%	1%	100%
Party Days	4,093,163	767,468	244,286	6,770	5,111,687
Average Spending Per Party Day	$30	$45	$225	$87	$42*
Total Spending ($ millions)	$122.79	$34.54	$54.85	$0.59	$212.77

Sources: GGNRA, NPS Park Visitation Report, MGM2

Note:

* Weighted average.

As shown in Table 3-14, of the total dollars expended by visitors ($212.77 million), an estimated 78 percent ($166.40) was retained in the local economy. The remaining 22 percent of spending is associated with goods and services manufactured and imported from out of the area. Local spending also contributed to $63 million in personal income (wages and salaries), $95.18 million in value added (employee compensation, profits, and indirect business taxes) and 3,859 jobs. The largest share of spending occurred

in local restaurants and bars, followed by retail expenditures, admission fees, and overnight accommodations.

Table 3-14: Economic Impacts of Visitor Spending by Sectors

Sectors	Sales (millions)	Personal Incomes (millions)	Jobs	Value Added (millions)
Direct Effects				
Motels, Hotels, B&Bs and Cabins	$ 25.90	$ 9.17	481	$ 13.93
Campsites	$ 0.14	$ 0.05	3	$ 0.08
Restaurants and Bars	$ 59.68	$ 21.19	1,613	$ 29.52
Admissions and Fees	$ 27.98	$ 9.89	764	$ 16.18
Retail	$ 33.04	$ 16.85	810	$ 26.32
Others	$ 19.66	$ 5.87	188	$ 9.15
Total	**$ 166.40**	**$ 63.02**	**3,859**	**$ 95.18**
Secondary Effects	$ 88.63	$ 32.31	1,125	$ 55.10
Total Effects	$ 255.03	$ 95.33	4,984	$ 150.28

Sources: GGNRA, NPS Park Visitation Report

As direct spending dollars circulate through the local economy, they result in secondary beneficial economic effects. Secondary effects measure the spin-off impacts of expenditures as money cycles through the regional and local economy. For example, increased spending by visitors at local restaurants may create additional jobs in those businesses. Business owners may also experience an increase in income, which they then spend locally on ordinary consumer goods and services. The secondary impacts associated with visitor spending account for an additional $88.6 million in local sales, $32 million in personal income, 1,125 jobs and $55 million in value added. In summary, visitors to GGNRA spent $212.8 million in sales in 2001, which supported a total of $255 million in local sales revenues, $95 million in personal income, 4,984 jobs, and $150 million in value added.

Chapter 4 – Environmental Consequences (part 1)

4.1 Regulations and Methodologies

Introduction

This chapter provides a detailed analysis and discussion of the probable environmental consequences, or impacts, of implementing each of the three alternatives. The chapter begins with a discussion of methods used to conduct the environmental impact assessment, including general definitions related to the impact analysis. These are followed by a description of the methods used to assess the type and relative level of impact for each impact topic (e.g., air quality, water quality), including relevant policies, regulations, and assumptions.

Following the sections on impact assessment methodology, the environmental impacts related to each impact topic for Alternatives A, B, and C are addressed. The analysis for each impact topic includes the following:

- Identification of the types of impacts associated with the various actions comprising the alternative;
- Characterization of the impacts, including their duration and intensity;
- Available mitigation measures that would be applied and the effectiveness of these measures on reducing impacts;
- An assessment of cumulative impacts;
- A statement on the potential for implementation of an alternative to impair resources; and
- A conclusion summarizing the findings of the section.

Definition of Terms

Three separate aspects of impacts are described for each impact topic for each alternative: the type of impact, the duration of the impact, and the intensity of the impact. For purposes of this analysis, these descriptors are defined as follows:

Type of impact. The type of impact describes the nature of the overall effect of the impact on the environment. Impacts are described as either beneficial or adverse.

NEPA requires consideration of the direct, indirect, and cumulative impacts of proposed actions. The CEQ regulations (Section 1508.7) define a cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions." Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. "Reasonably foreseeable future actions" include planning or development activities that currently are being implemented or would be implemented in the reasonably foreseeable future.

Duration of impact. The duration of impact is the relative length of time the impact would affect a given resource or value. Under NEPA, impacts are either short-term or long-term and are defined for each impact topic either by specific terminology of time or qualitatively by the passage of a condition. It is important to note that an action that has short-term adverse effects on a resource may have long-term beneficial impacts on the same resource.

Intensity of impact. Intensity describes the degree of the effect on a resource or value. The intensity of each impact is judged as having a negligible, minor, moderate, or major effect. These four designations are used for beneficial as well as adverse impacts.

Impairment. The NPS Organic Act of 1916 and the NPS General Authorities Act of 1970, as amended, require park managers to ensure that park resources and park values remain unimpaired. The discussion of each type of potential effect has a conclusion statement regarding whether or not implementing the alternative would cause resource impairment. Further information on the NPS policy on impairment can be found in Chapter 1, Section 1.4, under "Legislative and Policy Framework."

Cumulative Impact Scenario

Appendix C lists projects that can be considered part of the context of the impact assessment for cumulative effects. The context can vary from impact topic to impact topic. For example, the context for assessing potential cumulative effects on a creek may be all the past, current, reasonable foreseeable future projects that occur on public or private lands that drain to or would occur in that particular creek. The cumulative impact scenario for an isolated rare plant population may be the other two existing populations of the same plant within a relatively short distance. As a starting point for cumulative impact assessment, projects listed in Appendix C are considered in relation to the impact topic under review. Those projects that could contribute cumulatively to the impact area in question are included in the assessment of cumulative impacts. In certain cases, such as air quality effects, additional actions that generate similar impacts are included in the assessment, such as prescribed burning conducted by other agencies in western Marin County. However, the additional prescribed burning would not be relevant to the cumulative projects list of other impact topics in the DEIS, such as visitor experience or special status species. Effects on the tidewater goby are limited to only the three extant water bodies in Marin County where the goby is still found.

Regulations and Methodologies by Impact Topic

The sections that follow describe applicable regulations, policies, and methods used to assess the environmental consequences of the three alternatives on the following impact topics:

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

Air Quality

Vegetation

Wetlands

Wildlife and Important Habitat

Special Status Species (e.g., Threatened, Endangered, Rare, and Sensitive Species)

Cultural Resources

Human Health and Safety

Visitor Use and Visitor Experience

Park Operations

Socioeconomics

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

Policies and Regulations

Watershed resources and processes, including soils, hydrology, and water quality, receive protection under a series of policies and regulations.

Soil resources are subject to the NPS Management Policies 2001 "no impairment" clause that guides NPS decision making to protect the integrity of the important resources and values within the parks (NPS 2000a). The NPS is directed to protect geologic features from the adverse effects of human activity, while allowing natural processes to continue (NPS 2000a). Management action taken by the parks would prevent, to the greatest extent possible, unnatural erosion, physical removal, contamination, and other potentially irreversible impacts on soil (NPS 2000a).

Hydric soils, which are associated with wetland features such as bogs, marshes, and some wetlands, are afforded special protection by Executive Order 11990, Protection of Wetlands, and Clean Water Act Section 404 as regulated by the U.S. Army Corps of Engineers and the State Regional Water Quality Control Board. Specific procedural guidance to NPS staff on the protection of wetlands and areas of hydric soils is outlined in Director's Order 77-1, Wetland Protection (NPS 2002). Assessment of potential FMP impacts on hydric soils and wetlands is addressed in the "Impacts on the Biological Environment" section of this chapter.

NPS Management Policies 2001 states: "The Service [NPS] will manage watersheds as complete hydrologic systems, and will minimize human disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams. These processes include runoff, erosion, and disturbance to vegetation and soil caused by fire, insects, meteorological events, and mass movement. The Service will achieve the protection of watershed and stream features primarily by avoiding impacts on watershed and riparian vegetation, and by allowing natural fluvial processes to proceed unimpeded." (NPS 2000a).

The Clean Water Act requires the NPS to "comply with all Federal, State, interstate, and local requirements, administrative authority, and process and sanctions respecting the control and abatement of water pollution." The NPS Freshwater Resource Management Guidelines (found in the NPS Natural Resource Management Guidelines [NPS-77]) requires the NPS to "maintain, rehabilitate, and perpetuate the inherent integrity of water resources and aquatic ecosystems."

Assessment Methodology

Water resources, water quality, and soils are interrelated in their reactions to the treatments proposed by the alternatives. Due to these relationships, the analyses of impacts on these resources have been grouped together. Effects upon soils and watersheds are assessed by considering the likely scale of the effect – whether fire would affect all or part of the watershed, and as a result, the likely effect upon water yield, peak flows, sediment yield, nutrient yield, and/or stream system response.

Watershed impacts range from erosion and sedimentation to hydrology and impaired water quality. Hydrology refers to hydrologic processes such as flooding, erosion, deposition, and maintenance of channel patterns. Aquatic habitat refers to the attributes that support or provide habitat within stream or pond systems. Water quality refers to the suitability of surface water for beneficial use, including cold-water or warm-water aquatic wildlife habitat and recreational use.

Long-term impacts on soils include changes to soil chemistry, creation of subsurface hydrophobic layers, changes in soil particle composition or mixing, or loss of the soil profile that may take two years or decades to recover.

Short-term impacts are defined as effects on soil processes that are abated through natural processes or aided by use of standard protective practices within two years of the action.

Actions with negligible impact are those that are either inherently benign or that have effects mitigated to a less-than-detectable level by the procedural standards, such as erosion control practices, implemented as part of the proposal. Actions with negligible impact would be limited in scope and effect to watersheds. For example, a low-intensity prescribed fire may have several limited effects on watersheds, such as a short-term reduction in protective vegetation cover and consequent slight increase in the rate of soil erosion in an area remote from sensitive water resources.

Type of Impact

The following terms and definitions apply:

Beneficial: Protects or enhances properties of native soils, promotes or restores natural soil and hydrologic processes, and protects or improves water quality and aquatic habitat.

Adverse: Degrades the characteristics of native soils, exposes soils to accelerated rates of erosion, results in loss of native soils, contributes to slope failure, alters or degrades natural hydrologic conditions, degrades water quality, or degrades aquatic habitat.

Duration of Impact

The following terms and definitions apply:

Short-term: Impacts are limited to the first two years after treatment or wildland fire.

Long-term Impacts persist two years after treatment or wildland fire.

Intensity of Impact

The following terms and definitions apply:

Negligible: Imperceptible or undetectable.

Minor: Slightly perceptible and localized, without the potential to expand if left untreated; correctable by standard practices for erosion and sediment control.

Moderate: Apparent and localized, with limited potential to expand if left untreated; correctable by standard practices for erosion and sediment control.

Major: Substantial, highly noticeable, with the potential for landscape (watershed)-scale effects. Impacts would compound if left untreated. Treatment requires a site-specific engineered solution.

Air Quality

As in many other national parks near urban areas, the response to wildland fire in GGNRA has been full suppression. One of the results of suppression is the buildup of fuels within the park, increasing the potential for a high-intensity wildland fire to occur. Prescribed burning and mechanical fuel reduction, as proposed in the FMP alternatives, both result in the emission of harmful pollutants to the air but are the primary means to reduce fuel loading. A reduction in fuels lessens the potential for a large destructive fire that could generate much higher air pollution emissions and have significant impacts on regional air quality. The air quality assessment will evaluate the potential impacts of pollutants generated by the maximum allowable acreage that can be treated by prescribed burning and mechanical treatment for each of the FMP alternatives.

Policies and Regulations

Federal Clean Air Act and the Environmental Protection Agency

The Clean Air Act (CAA) charges the Environmental Protection Agency (EPA) with identifying national ambient air quality standards (NAAQS) to protect public health and welfare. Standards have been set for seven pollutants: ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter less than 10 microns (PM_{10}), very fine particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), and lead (Pb). Section 176 of the CAA requires federal actions to conform to state implementation plans for achieving and maintaining the air quality standards. Federal actions cannot cause or contribute to new violations, increase the frequency or severity of any existing violation, interfere with timely attainment or maintenance of a standard, delay emission reduction milestones, or contradict the State Implementation Plan. If a NAAQS is exceeded within an air basin, the entire air basin is considered a nonattainment area and is then subject to more stringent planning and pollution control requirements. The Bay Area Basin is currently in nonattainment status for state and federal standards for ozone and state standards for particulate matter. The current federal and state ambient air quality standards and the federal and state attainment status for the Bay Area Air Basin are presented in Chapter 3, Table 3-4.

The EPA has developed regional haze regulations to improve visibility or visual air quality in national parks and wilderness areas across the country. In developing these rules, the EPA recognized that both prescribed and wildland fires contribute to regional haze and that there is a complex relationship between what is considered a natural source of fire versus a human-caused source of fire. In many instances, the purpose of prescribed fires is to restore a fire regime to forest ecosystems to prevent future catastrophic fires that can detrimentally affect an air basin's air quality. The EPA works to support state and federal land managers in the development of enhanced smoke management plans to minimize the effects of fire emissions from prescribed fires on pubic health and welfare.

Regional Haze and the Western Regional Air Partnership

On a regional scale, smoke emissions can contribute significantly to haze and degradation of visibility. Regional haze issues in the U.S. are being addressed through a national regional haze process that has set as its goal the restoration of natural visibility conditions by 2064 in Class I areas of the country. Established by the CAA, Class I areas are places where pollution prevention is given a special priority; they include national parks established before 1977 with a total acreage above a certain minimum requirement. The air quality standard and the degree of visibility in Class I areas were established to serve as baseline barometers to track changes in emission levels since 1977. Examples of Class I areas are Point Reyes National Seashore, Grand Canyon National Park, and Yosemite National Park. GGNRA was designated as a Class II area, where some incremental increase in emission levels is allowed based on the proximity of a population center.

To develop solutions on a regional scale, the federal government has set up five regional haze working groups made up of groups of states. California participates in the Western Regional Air Partnership (WRAP) comprising all states west of Kansas. Each state in the WRAP will develop an implementation plan to augment the state's smoke management plan by 2018 – the deadline to adopt control measures that will effectively allow the state to meet the 2064 goal. Effectiveness of the control measures must be supported by modeling the projection of conditions to that date. Because the issue of regional haze is being addressed by this long-term regional process, the assessment of the effects of FMP implementation on visibility is limited in scope to the impairment of local visibility.

California Clean Air Act and the California Air Resources Board

The federal government has ceded responsibility and authority to establish air quality standards and regulations to the states. Therefore, all NPS areas are required to comply with state laws on these matters regardless of the type of legal jurisdiction that applies to other activities within the NPS unit.

To protect public health and welfare, the California Air Resources Board (CARB) has set ambient air quality standards that are stricter than federal standards. Under the 1988 California Clean Air Act, air basins are designated as attainment, nonattainment, or unclassified for the state standards.

State implementation plans (SIPs) identify measures designed to bring the nonattainment areas into attainment. Basic components of SIPs include legal authority, an emissions inventory, an air quality monitoring network, control strategy demonstration modeling, emission-limiting regulations, new source

review provisions, enforcement and surveillance strategies, and other programs necessary to attain standards.

The CARB is responsible for disseminating regulations about air quality, including state ambient air quality standards and area designations; emissions from motor vehicles, fuels, and consumer products; and airborne toxic control measures. Title 17 of the California Code of Regulations, titled Smoke Management Guidelines for Agricultural and Prescribed Burning, provides direction to air pollution control and air quality management districts for the regulation and control of agricultural burning, which includes prescribed burning. The guidelines are intended to allow the use of prescribed burning as a management tool while minimizing smoke impacts on the public.

San Francisco Bay Area Air Quality Management District (BAAQMD)

BAAQMD is the air quality management district for the planning area and has primary responsibility for enforcing and issuing permits under the CAA for prescribed burning. GGNRA prescribed burns must comply with BAAQMD's Regulation 5 and smoke management program, which govern open burning in the Bay Area Air Basin. For all prescribed fires, BAAQMD requires GGNRA to submit an individual smoke management plan at least one month before the proposed burn. BAAQMD then issues a forecast 72 hours before the proposed date and gives a final commitment to permit the burn on the day of the burn itself, though forecasts with increasing confidence can be obtained at 96 hours, 72 hours, 48 hours, and 24 hours before the burn day to support moving forward on all the logistical planning needed to conduct a prescribed burn.

Federal Policies and NPS Guidance

NPS Management Policies 2001 directs superintendents to comply with all federal, state, and local air quality regulations and permitting requirements when conducting prescribed burns (NPS 2000a). In addition to the requirements of the CAA, specific guidance has been developed by the EPA to address prescribed burning. These are supplemented by guidance and policies such as the Federal Wildland Fire Management Policy (Interagency Working Group 2001) and the EPA's Interim Air Quality Policy on Wildland and Prescribed Fires (EPA 1998). These policies established the need and requirements for state and tribal smoke management programs to (1) mitigate impacts on air quality (even when below the NAAQS) and public safety (such as visibility on roads and airports) posed by smoke intrusions into populated areas, (2) prevent significant deterioration of air quality and NAAQS violations, and (3) address visibility impacts in Class I areas. With the adoption by a state of a smoke management program, certain PM_{10} exceedances attributable to fires, including some prescribed fires and managed wildland fires, can be excluded from air quality data sets used to determine violations for a state. Through these policies, federal agencies are directed to consider ambient air quality above the NAAQS for $PM_{2.5}$ and PM_{10} as the principal indicator of adverse impacts on public health. Poor visibility is used as the principal indicator of adverse impact on public welfare. The EPA's Natural Events Policy addresses public health impacts from wildland fires (EPA 1996).

An objective of CARB and NPS directives is to minimize smoke impacts on people and on sensitive receptors in and near national parks. Sensitive receptors can include towns, villages, hospitals, schools, nursing homes, campgrounds, trails, scenic vistas, and Class I areas. Selection of sensitive receptors is

based on guidance from the California Code of Regulations Title 17, Smoke Management Guidelines for Agricultural and Prescribed Burning, and consideration of the local setting, including demographics, wind patterns, and local climatic conditions.

NPS-77 (Reference Manual 77: Natural Resource Management) states: "The National Park Service will seek to perpetuate the best possible air quality in parks because of its critical importance to visitor enjoyment, human health, scenic vistas, and the preservation of natural systems and cultural resources. The Park Service will assume an aggressive role in promoting and pursuing measures to safeguard [air quality related values] from the adverse impacts of air pollution. In cases of doubt as to the impacts of existing or potential air pollution on park resources, the Park Service will err on the side of protecting air quality and related values for future generations" (NPS 1991).

Assessment Methodology

Fire management actions could affect air quality in the project area through smoke emissions from wildland and prescribed fires. The impacts of particulate matter and other pollutants on firefighter and public health from exposure to smoke are discussed in this DEIS under "Human Health and Safety" below.

The emission levels generated by the use of machinery for fire management actions (i.e., mechanical fuel reduction projects, site preparation for prescribed burns, etc.) has been determined by the NPS Air Resources Division to be negligible in comparison to levels generated by smoke emissions; therefore, the impact assessment focuses on emissions generated by smoke.

BAAQMD data do not reflect the level of emissions produced by the No Action alternative (Alternative A), as no prescribed burning has occurred in GGNRA parklands recently enough to be accounted for in BAAQMD data sampling used to discuss ambient air quality in the Bay Area.

Method of Estimating Smoke Emission

The First Order Fire Effects Model 5.21 (FOFEM) was used to generate emission factors for PM_{10}, $PM_{2.5}$, VOC (volatile organic compounds), CO (carbon monoxide), NO_x (nitrogen dioxide), and SO_2 (sulfur dioxide) for the maximum allowable fire management actions under each alternative. FOFEM is a computer-based model that provides quantitative predictions for planning prescribed fires and conducting impact assessments, and for long-range planning and policy development. FOFEM is the standard modeling program used to demonstrate conformity with applicable environmental impact rules and regulations. The model also provides fire effects information on potential tree mortality, fuel consumption, mineral soil exposure, and smoke generation (Reinhardt 1997). The smoke module of FOFEM does not predict smoke dispersion or model the impairment of local visibility.

The FOFEM smoke module requires a number of inputs related to burn characteristics, such as fuel category, cover type, fuel loading, moisture content, and percent of crown burn. For this assessment, GGNRA fire management staff described representative burn parameters for each burn unit. The area of each cover type in a given prescribed burn unit was determined based on the expertise of the fire management staff and vegetation mapping of the planning area. The burn unit cover types were then correlated with the Society of American Foresters (SAF)/Society for Range Management (SRM)

vegetation types for use in the FOFEM model. Where a direct correlation between cover types was not possible, a surrogate SAF/SRM cover type was selected. Table 4-1 provides a cross-reference for cover types.

Table 4-1: Vegetation Cover Types Used in Air Quality Emissions Analysis

Fire Management Vegetation Class	SAF[1]/SRM[2] Type
Valley grassland, annual grassland	SRM 208
Ceanothus, mixed chaparral	SRM 215
Pacific Douglas-fir	SAF 229

Notes:
[1]Society of American Foresters (SAF)
[2]Society for Range Management (SRM)

The results of the FOFEM model were used to develop average emission factors (per acre) that are used to quantify the amount of pollutants generated by the maximum prescription burning allowed for each alternative. For a given prescribed burn unit and pollutant, the emissions were quantified by the following equation:

$$E = \sum_{c=1}^{n} EFc * Ac, \text{ where}$$

E = emissions in tons/year

Efc = emission factor for coverage c in tons/acre

Ac = area of coverage in acres

Separate FOFEM runs were used to develop emission factors for wildland fires in natural forest, since these typically burn under drier conditions and consume more fuel, particularly crown and branch fuels, and produce higher emissions. NPS Air Resources Division staff provided burn parameters based on recent wildland fires to model these emissions. Emission factors for grassland and coastal scrub are the same for these fuel types in both prescribed burning and wildfires (see Table 4-4). The cover and vegetation type from the PRNS FMP analysis were used as surrogates for the GGNRA analysis.

Pile Burning

A number of assumptions were made to calculate burn pile emissions, as FOFEM provides emission factors in pounds per acre and not in pounds per burn pile. First, the emission factors generated by FOFEM were normalized to tons of fuel load (pre-burn) to give emission factors on a pound-per-ton basis. Second, the tonnage of each burn pile was calculated using assumptions taken from the U.S. Forest Service General Technical Report NW-GTR-364 (USFS 1996), which involves the following steps:

Step 1. Calculating pile tonnage to be equal to pile volume x 30 pounds per square foot x 0.2 (packing ratio).

Step 2. Giving a tonnage of 0.108 ton per burn pile for the four cubic yard piles typically constructed at GGNRA and used in the GGNRA FMP.

Step 3. Modeling the burn piles after Pacific Douglas-fir wood. [Note: FOFEM, a forestry model, does not have built-in emission factors for eucalyptus among the vegetation types considered in the software package. FOFEM does not fully model "pile burns;" rather, it models them like natural burns and may therefore underestimate emissions generated.]

Both the prescribed and wildland fire emission factors predicted by FOFEM are higher than similar emission factors in the EPA's Compilation of Air Pollution Emission Factors (AP-42) for the same region. However, the AP-42 derived emission factors are generalized for large regions and "can vary by as much as 50 percent with fuel and fire conditions" (EPA 1996). Since fuel loading in many areas of GGNRA may be heavier than normal due to decades of fire suppression, the emission factors used here can be considered to better represent GGNRA conditions. Emission factors used for prescribed burning, wildfire, and pile burning are shown in Table 4-2.

Table 4-2: Smoke Emission Factors by Fire Type

GGNRA Cover Type	FOFEM Surrogate	Code	Emission Factors (pounds/acre)						
			Fire Type	PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Coastal Scrub	Ceanothus	SRM 208	Prescribed	190	161	49	404	198	62
Grass	Valley Grassland	SRM 215	Prescribed	11	9	3	23	12	4
Native Forest	Pacific Douglas-fir	SAF 229	Prescribed	2863	2445	1480	32319	24	114
Coastal Scrub	Ceanothus	SRM 208	Wild	190	161	49	404	198	62
Grass	Valley Grassland	SRM 215	Wild	11	9	3	23	12	4
Native Forest	Pacific Douglas-fir	SAF 229	Wild	3640	3085	1867	40836	31	145
Nonnative Trees	Pacific Douglas-fir	SRM 229	Pile	2660	2254	1329	28606	162	145

Source: NPS 2004.
Notes:
PM_{10} = suspended particulate matter, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds, CH_4 = methane, CO = carbon monoxide, NOx = nitrogen oxides
Grass = Society for Range Management (SRM) 208 vegetation areas
Brush = SRM 215 vegetation areas
Forest = Society of American Foresters (SAF) 229 vegetation areas

Annual inputs for wildland fire are based on 39 acres burned per year during three to five fire starts, a conservative estimate of wildland fire in GGNRA according to the fire management officer (Naar 2004). The wildfire acreage consists of 25 acres of grassland, 12 acres of shrublands, and 2 forested acres. The low incidence and limited acreage of wildland fire annually in the study area are due primarily to a very low incidence of deliberate and unintentional fire starts by the public and the wetter than usual

summertime conditions in the coastal portions of GGNRA as compared to the hot drier inland summer of the rest of the coast range.

The number of acres of wildfire is consistent throughout the alternatives. Emissions generated by mechanical treatment are also assumed to be consistent and negligible in each alternative (see discussion below under "Emissions from Mechanical Treatment"). Therefore, the difference in estimated annual emissions for the three alternatives is due to the maximum allowable acreage of prescribed fire under each alternative.

Emissions from Mechanical Treatments

Negligible levels of air pollutants would be generated by fuel reduction projects and during preparation of burn units for prescribed burning projects. Motorized equipment used in thinning and site preparation activities could include chain saws, brushcutters, mowers, chippers, excavators, skidders, frontloaders, and haul trucks. The types of equipment shown in Table 4-3 are a representative sample of the types of equipment used in GGNRA. FMPs prepared for other western national parks have consistently found that pollutants generated by equipment contribute a very small amount to overall emissions where plans include prescribed burning. For example, in the emission estimates calculated for equipment use in mechanical fuel treatment and preparation for prescribed burning for the PRNS FMP, emissions from equipment did not exceed 2 percent of the total emissions generated. In most cases, emission levels calculated were less than 1 percent of the total (NPS 2004a). The Yosemite FMP found equipment emissions were consistently less than 1 percent of the total emissions generated by equipment use in all actions. Table 4-3 shows the factors that were used to calculate emissions from equipment use for the PRNS and Yosemite FMP alternatives, which yielded the relatively negligible emission levels from equipment in those assessments. The contribution of vehicle and equipment emissions to total emissions would be of similar equivalence for the GGNRA FMP; therefore, the NPS Air Resources Division considers emissions from equipment use a negligible contributor to air quality impacts from FMP implementation.

Table 4-3: Emission Factors for Equipment Use in Fire Management Activities

Operating Parameters			Emission Factor (pounds per hour)1			
Machine Type	**Fuel Type**	**Average HP**	**CO**	**PM**	**NOx**	**VOC**
Chainsaw	Gasoline	6	3.4	0.05	0.01	1.1
Mower	Gasoline	50	30.6	0.26	0.26	0.39
Skidder	Diesel	200	4.4	0.57	3.0	0.95
Haul truck	Diesel	200	4.4	0.57	3.0	0.95

Source: NPS 2004.

Average HP = average horsepower, CO = carbon monoxide, PM = particulate matter, NOx = nitrogen oxides, VOC = volatile organic compounds (total hydrocarbons) such as methane (CH_4).

Type of Impact

The following terms and definitions apply:

Beneficial: Improves or maintains air quality while lowering the potential for significant short-term pollutant release events.

Adverse: Degrades current air quality.

Duration of Impact

The behavior of a smoke plume from a fire, including the direction and elevation of the plume and resulting concentrations at ground level, is highly dependent on elevation and dynamic meteorological conditions at the time. Under prescription conditions, air quality emissions generated by prescribed burning or wildland fire would disperse within a timeframe roughly the same as the duration of the fire management action. An exception to this would be if smoke from a fire became trapped at low altitudes in an inversion layer that can occur in the fall or winter.

The following terms and definitions apply to the analysis:

Short-term Effects on air quality last less than three days beyond the duration of the fire management action.

Long-term Effects on air quality persist beyond the duration of the fire management actions, or are annually recurrent throughout the implementation period of the FMP.

Intensity of Impact

Localized Effects of Smoke (Visibility)

The assessment of effects of FMP actions on regional haze focuses on the impairment of local visibility. Effects of smoke on traffic safety are addressed under "Impacts on Human Health and Safety" below. The following terms and definitions apply:

Negligible: Smoke would be barely perceptible or detectable and affect an undeveloped area (no recreational facilities or trails, no habitable structures, etc.).

Minor: Smoke would be detectable but localized within an area of low-density development for recreational or private use, of short duration (several hours), and have no lasting effects.

Moderate: Smoke would be readily perceptible but localized in an area of low-density development, and be sufficient to limit use of the area for one day or less without damage to property or lasting effect.

Major: Smoke would be readily noticeable, and would occur in a developed area with a potential hazard to human health or create property damage or lasting effect.

Effects on Bay Area Air Basin Air Quality and Conformance with the State Implementation Plan

The NPS has developed interim guidelines for determining potential airborne pollution impacts on human health and park resources (NPS 2003c). Thresholds set for intensity of effect are based in part on the emission thresholds, which define *de minimus* projects for purposes of providing determination of conformance with national ambient air quality standards and the SIP.

The Bay Area Air Basin is rated as being in nonattainment with federal standards for ozone precursors (NOx and VOC). For purposes of CAA conformance, the Bay Area Air Basin is not considered a "transport" area – an area that receives pollution from an adjoining air basin. These factors help define the level considered *de minimus* above which projects are considered as contributors to the air basin nonattainment status for ozone precursors.

Federal actions with the potential to produce NOx or VOC emissions exceeding the *de minimus* level must include a conformity determination showing how the action incorporates SIP strategies for reducing the levels of ozone precursors to the federal standard and achieving attainment. Federal actions with the potential to produce emissions below the *de minimus* level are exempt from the conformity requirement. Conformity requirements do not apply to the state standards for emissions. Only federal standards are addressed by the SIP. For federal actions and planning efforts, such as an FMP, where conditions do not involve a new air pollution source but rather are ongoing, impact levels and potential for impairment are assessed relative to the natural condition (attainment status) in addition to incremental change from the No Action alternative (Alternative A).

For considering the potential intensity of effect of the FMP on levels of pollutants with which the Bay Area Air Basin is currently in attainment status (SO_2, PM_{10}, and NOx), the following thresholds apply:

Negligible: Less than 50 tons per year (each pollutant).

Minor: More than 50 tons per year and less than 100 tons per year (each pollutant).

Moderate: More than 100 tons per year.

Major: More than 250 tons per year.

For considering the potential intensity of effect of the FMP on levels of pollutants with which the Bay Area Air Basin is currently in nonattainment status for federal standards on ozone (represented by VOC), the following thresholds apply:

Negligible: Net decrease in emissions from current levels.

Minor: 1 to 5 tons per year.

Moderate: More than 5 tons per year and less than the conformity *de minimus* levels (conformity *de minimus* levels = 100 tons per year).

Major: More than or equal to the conformity *de minimus* levels (conformity *de minimus* levels = 100 tons per year).

Vegetation

Policies and Regulations

NPS Management Policies 2001 states that "the National Park Service will maintain as parts of the natural ecosystems of parks all native plants and animals" (NPS 2000a). The policies go on to state that "all cultural and natural resource values will be considered in defining specific treatment and management goals," and that:

- Flowering plants, ferns, mosses, lichens, algae, fungi, and microscopic plants are included;
- The natural abundances, diversities, dynamics, distributions, habitats, and behaviors of these native species are preserved and protected; and
- The introduction of nonnative species into units of the national park system should be prevented.

The policy manual NPS-77, Natural Resource Management (NPS 1991) also provides general guidelines on vegetation management.

Assessment Methodology

The park's vegetation was interpreted and mapped from 1994 aerial photographs. Plant communities were delineated in this mapping effort using field data collected in 2001, and the classification of alliances and associations (roughly based on Sawyer and Keeler-Wolf 1995) was completed in 2003. For purposes of this document, these alliances and associations have been grouped together into 10 broad "fire management communities" that are described in Chapter 3 (Affected Environment). These fire management communities all share species with similar growth forms, structural attributes, and/or fire behavior characteristics; thus it is assumed that they would respond similarly to treatments that would be applied under the FMP. The grouping of vegetation types into fire management communities and the extent of area covered by each community was conducted using a Geographic Information System (GIS).

The primary assessment of impacts on vegetation considers potential impacts of all fire management activities, regardless of vegetation community. This is followed by special considerations and impacts unique to individual communities, including the following parameters:

- Fire ecology (past and present) of the dominant species in the vegetation community, including fuel loads and potential for vegetation type changes;
- Areal extent and relative abundance or rarity of the vegetation community in the project area and in the region; and
- Abundance and species richness of nonnative plants within or adjacent to the vegetation communities affected.

The abundance, as defined by extent of coverage, of an individual vegetation community is important when considering impacts because the park is mandated to protect and maintain all native plant communities. In a vegetation community that is rare in the FMP area or the region, such as chaparral, adverse impacts may be more significant.

The presence and abundance of nonnative plants in or around the affected vegetation community are an important consideration, as many nonnative plant species are stimulated to grow or reproduce as a result of fire or other disturbance. Some nonnative plant species can have substantial adverse effects on native vegetation, including the following:

- Nonnative plants can out-compete native plants for light, nutrients, water, and growing space, which, in the worst case, can lead to extinction or local extirpation of rare plant species;
- Nonnative plants can degrade the quality of wildlife habitat by out-competing native food sources, or altering nesting or resting habitat;
- Nonnative plants can disrupt the genetic integrity of native plants if crossbreeding occurs; and
- Nonnative plants can change fire regimes by converting habitat types (e.g., converting a shrub or forested landscape with little understory to one that has a continuous herbaceous layer, or converting an open grassland to forest).

Fire can also be used as a tool, in conjunction with other management activities, to control nonnative plant species, and the abundance and density of these plants in comparison to the native plant component can be an important factor in evaluating the potential effects of treatment actions. For example, a site with 100-percent cover of a nonnative grass could benefit from seasonal burning to favor native perennial grass species.

Much of the information on individual vegetation communities focuses on a few dominant or typical species and the effects of fire on these species. Information on individual plant species was largely derived from the Fire Effects Information System (FEIS), available online at http://www.fs.fed.us/database/feis/. This database includes comprehensive bibliographies for each species. Community information was developed from a variety of sources included in Appendix B of this document.

Type of Impact

The following terms and definitions apply:

Adverse: Decreases the areal extent or native species richness of a plant community, results in a native plant community type conversion, or increases nonnative plant species abundance or richness.

Beneficial: Increases the areal extent or native species richness of a plant community, or decreases nonnative plant species abundance or richness.

Duration of Impact

The following terms and definitions apply:

Short-term: Would be measurable for two years or less.

Long-term: Would be measurable for longer than two years.

Intensity of Impact

The following terms and definitions apply:

Negligible: Would result in no measurable changes in plant community areal extent, or in native or nonnative species richness within a plant community.

Minor: Changes in plant community areal extent, or in native or nonnative species richness within a plant community, would be measurable, and would affect less than 5 percent of the total extent of that plant community in the planning area.

Moderate: Changes in areal extent, or in native or nonnative species richness within a plant community, would be measurable, and would affect between 5 and 25 percent of the total extent of that plant community in the planning area.

Major: Changes in areal extent, or in native or nonnative species richness within a plant community, would be measurable, and would affect over 25 percent of the total extent of that plant community in the planning area.

Wetlands

Policies and Regulations

Wetlands are addressed separately from the vegetation analysis because they are defined by unique attributes of vegetation, hydrology, and soils and protected by specific regulations and orders. Wetlands are lands that are transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface, or the land is covered by shallow water. Wetlands buffer the effects of hydrologic and erosional cycles, influence biogeochemical cycles of nitrogen and other key nutrients, and create valuable habitat for animal and plant species.

As a result of these important attributes, wetlands are protected by a specific set of laws and regulations. The protection of wetlands within NPS units is facilitated through the following:

- Executive Order 11990, Protection of Wetlands.
- NPS Director's Order 77-1, Wetland Protection, and its accompanying Procedural Manual 77-1 (DO 77-1 and PM 77-1).
- Rivers and Harbors Act, Section 10.

- Clean Water Act, Section 404.
- The "no net loss" goal outlined by the White House Office on Environmental Policy in 1993.

Executive Order 11990 requires that agencies work to minimize the destruction, loss, or degradation of wetlands. Director's Order 77-1 and Procedural Manual 77-1 provide specific procedures for implementing Executive Order 11990. Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act authorize the U.S. Army Corps of Engineers (USACE) to grant permits for construction and disposal of dredged material in waters of the United States, which include wetlands.

Assessment Methodology

For this assessment, wetlands that could be subject to impacts were identified using the GGNRA vegetation map and field-mapped wetland data, when available. These data layers then were overlain with the boundaries of the 10 fire management units. This information provided a conservative and broad estimate of the extent of known and potential wetlands within the planning area.

The parameters that were considered in the assessment of impacts on wetlands include the following:

- Plant species composition of the wetland;
- Hydrologic features that maintain the wetland; and
- Wetland soils.

These parameters parallel those used by the USACE, the agency granted the authority under the Clean Water Act to regulate wetlands. It is assumed that if these parameters are altered as a result of fire management activities, the wetland would be subject to impacts, which could be either beneficial or adverse.

Type of Impact

The following terms and definitions apply:

Adverse: Shifts plant species composition to a higher percentage of nonwetland indicator species or allows invasion by nonnative species; alters hydrologic features/factors that are required to maintain the wetland; alters soil properties that are required to maintain the wetland; or reduces areal extent of wetlands.

Beneficial: Enhances native wetland vegetation, soils, or hydrology, or increases areal extent of wetlands.

Duration of Impact

The following terms and definitions apply:

Short-term: Would be measurable for two years or less.

Long-term: Would be measurable for longer than two years.

Intensity of Impact

The following terms and definitions apply:

No Effect: No measurable changes in the areal extent of wetlands, or in wetland vegetation, soils, or hydrology, would result.

Minor: Changes in the areal extent, or in wetland vegetation, soils, or hydrology, would be measurable but would affect less than 5 percent of the total extent of the wetland type in the FMP project area.

Moderate: Changes in the areal extent, or in wetland vegetation, soils, or hydrology, would be measurable but would affect less than 20 percent of the total extent of the wetland type in the FMP project area.

Major: Changes in the areal extent, or in wetland vegetation, soils, or hydrology, would be measurable and would affect 20 percent or more of the total extent of the plant community in the FMP project area.

Wildlife and Important Habitat

Policies and Regulations

NPS Management Policies 2001 states that "the National Park Service will maintain as parts of the natural ecosystems of parks all native plants and animals" (NPS 2000a). The policy statement includes bacteria, mammals, birds, reptiles, amphibians, fishes, arthropods, worms, and microscopic animals. The NPS is to preserve and restore the natural abundance, diversities, dynamics, distributions, habitats, and behaviors of these native species. Additionally, the NPS is to prevent the introduction of nonnative species into units of the national park system (NPS 2000a). NPS-77 (Natural Resource Management Guidelines) also provides general guidelines on wildlife management (NPS 1991).

The NPS also is required to comply with the Fish and Wildlife Coordination Act (1934), the Marine Mammal Protection Act (1972), the Bald and Golden Eagles Protection Act (1940), the Convention on International Trade in Endangered Species (1973), and maritime and other international agreements. In addition, the NPS is required to comply with the Migratory Bird Treaty Act (1918) as amended, which prohibits taking, killing, or possessing migratory birds, nests, or eggs. California Department of Fish and Game regulations govern fishing in coastal areas leased by GGNRA.

Assessment Methodology

Many of the impacts of fire management actions on wildlife can be assessed by considering the effects of actions on wildlife habitat as represented by general vegetation types. In general, adverse effects on wildlife can be minimized by reducing and limiting habitat fragmentation – that is, by preserving and restoring large areas as well as patches of habitat, and maintaining connections within and among habitat types. Larger patches of habitat tend to support higher numbers and diversity of wildlife species than smaller ones, and connections between habitat patches enable the movement of wildlife between areas, enhancing reproduction and survival. Small patches of habitat can serve as stepping stones for wildlife

moving between larger blocks, or as isolated refuges for wildlife in areas that have been highly developed by humans.

The value of habitat patches for wildlife is also affected by adjacent human activities and development. Severe disruption of habitat corridors can impede wildlife movements. Impacts radiating into habitat patches, such as impacts from noise, nonnative species, and human use, can adversely affect habitat quality. Core areas that are more isolated from these impacts generally provide higher quality habitat for wildlife.

Impacts on wildlife have been assessed in terms of the following:

- Changes in the amount and distribution of wildlife habitat;
- Changes in the size and connectivity of habitat patches; and
- The existing integrity/quality of affected habitats (including past disturbances), and the relative importance of affected habitats.

Type of Impact

The following terms and definitions apply:

Adverse: Would negatively affect the size, continuity, or integrity of wildlife habitat.

Beneficial: Would positively affect the size, continuity, or integrity of wildlife habitat.

Duration of Impact

The following terms and definitions apply:

Short-term: Would be expected to last for less than two years.

Long-term: Would last two years or longer.

Intensity of Impact

The following terms and definitions apply:

Negligible: Would not be measurable or perceptible.

Minor: Would be measurable or perceptible and would be localized within a relatively small area; however, the overall viability of the resource would not be affected. Without further impacts, minor adverse effects would be reversed, and the resource would recover.

Moderate: Would be sufficient to cause a change in the resource (e.g., abundance, distribution, quantity, or quality); however, the impact would remain localized. The change would be measurable, but negative effects could be reversed in the long term.

Major: Would be substantial, highly noticeable, measurable, and could be irreversible (permanent). The resource would be unlikely to recover.

Special Status Species

Policies and Regulations

Numerous species of plants and animals have undergone local, state, or national declines, which have raised concerns about the species' possible extinction if they are not protected. As a result, the U.S. Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG) have established lists that reflect the species' status and the need for monitoring, protection, and recovery. The NPS also recognizes a number of species as locally rare or of special concern, such as plants listed by the California Native Plant Society (CNPS), even though they are not yet officially protected by legislation. Collectively, species in all of these categories are referred to in this document as "special status species."

The federal Endangered Species Act (ESA) of 1973, as amended, provides that federal agencies will use their authorities by carrying out programs for the conservation of endangered and threatened species. Furthermore, federal agencies are required to consult with the USFWS before taking actions that (1) could jeopardize the continued existence of any federally listed plant or animal species (e.g., listed as threatened or endangered) or species proposed for listing, or (2) could result in the destruction or adverse modification of critical or proposed critical habitat. The USFWS has provided the species listed under the ESA that must be considered for this EIS.

The Council of Environmental Quality's Regulations for Implementing NEPA (Section 1508.27) requires consideration of whether an action may violate federal, state, or local laws or requirements imposed for the protection of the environment. For this reason, species listed or proposed for listing as endangered or threatened under the California Endangered Species Act are included in this analysis.

Other applicable legislation, policies, and agreements that provide the authority for NPS policies on management of threatened and endangered species include the following:

- Other state wildlife statutes or agreements pursuant to Section 6 (ESA);
- Migratory Bird Conservation Act (1918);
- Fish and Wildlife Coordination Act (1934);
- Marine Mammal Protection Act (1972);
- Magnuson-Stevens Fishery Conservation and Management Act (as amended 1996);
- Bald and Golden Eagles Protection Act (1940);
- Convention on International Trade in Endangered Species (1973); and
- Maritime and other international agreements.

The USFWS takes lead responsibility for coordinating and implementing provisions of the Endangered Species Act for all terrestrial plants, animals, and freshwater aquatic species listed as endangered,

threatened, and candidate species. NOAA Fisheries has lead responsibility under the ESA for listed marine taxa such as *Cetacea* (all whales and porpoises), *Pinnipedia* (Steller sea lions, Hawaiian monk seals, etc.), sea turtles, and anadromous fish (steelhead, coho salmon, etc). NOAA Fisheries is also the lead for the Marine Mammal Protection Act (1972) and Magnuson-Stevens Fishery Conservation and Management Act.

The federal, state, and CNPS categories for special status species are defined as follows:

- Federal endangered: Any species that is in danger of extinction throughout all or a significant portion of its range.
- Federal threatened: Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.
- California endangered: Any species that is in danger of extinction throughout all or a significant portion of its range in the state.
- California threatened: Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its state range.
- California rare (plants only): A native plant that, although not currently threatened with extinction, is present in small numbers throughout its range, such that it may become endangered if its present environment worsens.
- CNPS List 1A: Presumed extinct in California.
- CNPS List 1B: Rare or endangered in California and elsewhere.
- CNPS List 2: Rare or endangered in California, more common elsewhere.
- CNPS List 3: More information needed.
- CNPS List 4: Plants of limited distribution.

Assessment Methodology

Special Status Plants

Fire plays a role in the life history of many special status plant species by maintaining open habitat, encouraging reproduction, and affecting competing species. Fire may injure or kill individual plants while the effects on the species as a whole are beneficial because competition has been reduced or openings (i.e., habitat) created. Fire suppression activities can adversely affect these same species because of ground disturbance. Mechanical treatments can enhance habitat for special status plant species through removal of fuel loads and forest canopies, or can exacerbate problems through opening previously densely vegetated areas and allowing aggressive nonnative species to become established. Prescribed fires can be beneficial or detrimental, depending on the timing, frequency, and intensity of management-ignited fires. For example, detrimental effects can occur if fires are ignited outside the normal season or

beyond the normal intensity to which the species is adapted. Keeping these factors in mind, the following parameters have been used to evaluate the consequences of the various alternatives on special status plants:

- The species affected and its degree of local, regional, national, and global rarity.
- The numbers of plants or proportion of the species range affected by the action.
- The response of the species to fire or disturbance (if known).

Type of Impact. The following terms and definitions apply:

Adverse: Would lead to loss or alteration of habitat, loss of individuals or populations of special status plants, or reduction in reproduction.

Beneficial: Would lead to increases in suitable habitat, an increase in areal extent or density of plants, or an increase in reproduction.

Duration of Impact. The following terms and definitions apply:

Short-term: Would immediately affect the population or species, but would have no long-term effects on population trends or species viability.

Long-term: Would lead to a loss in population or species viability – exhibited by a trend suggesting decline in overall species areal extent or abundance.

Intensity of Impact. The following terms and definitions apply:

Negligible: Imperceptible or not measurable (undetectable).

Minor: Small, measurable, perceptible, and localized, without the potential to increase if left alone.

Moderate: Apparent, measurable, and sufficient to cause a change in the resources (e.g., abundance, distribution, quantity, or quality). Less localized than a minor impact.

Major: Substantial, highly noticeable, and with the potential for landscape-scale effects and major irreversible population effects.

Special Status Wildlife

Like other wildlife species in the planning area, special status species have adapted to natural fire regimes. In many areas, however, a history of fire suppression has led to dense, overgrown stands, with high accumulations of forest fuels. This affects special status species by altering habitat and placing these species and their habitats at risk for a high-intensity, stand-replacement fire. In addition, stand-replacement fire could create unsuitable habitat conditions that would last for many years.

Fire control activities could also adversely affect special status species through direct disturbance of animals and habitats. Even management actions designed to benefit habitat, such as prescribed fire, can have inadvertent adverse effects on special status species. With these factors in mind, the following parameters have been used to evaluate the effects on special status animals of the various alternatives:

- The species affected and its degree of local, regional, national, and global rarity.
- The rarity of the genotype or subspecies, regionally, nationally, or globally.
- The numbers of animals or proportion of the species range affected by the action.
- The response of the species to fire or disturbance (if known) on a population or subpopulation level.

Type of Impact. The following terms and definitions apply:

Adverse: Likely to result in unnatural changes in the abundance or distribution of a special status species. This could occur through direct disturbance, mortality, or through destruction or alteration of habitat.

Beneficial: Likely to protect and/or restore the natural abundance and distribution of a special status species. This could occur through protection and restoration of structure, successional state, or distribution of habitat.

Duration of Impact. The following terms and definitions apply:

Short-term: Would result in immediate changes in the abundance and distribution of a special status species, but a return to the original condition would occur within two generations of that species.

Long-term: Would result in changes in the abundance and distribution of a special status species that persist for more than two generations of that species.

Intensity of Impact. The following terms and definitions apply:

Negligible: Would be imperceptible or unmeasurable (undetectable).

Minor: Would be slightly perceptible and localized in extent; without further actions, adverse impacts would reverse and the resource would recover.

Moderate: Would be readily measurable (apparent) and extend farther geographically than a minor impact; adverse impacts would eventually reverse and the resource would recover.

Major: Would be substantial, highly noticeable, and affecting a large geographic area; changes would be irreversible with or without active management.

Cultural Resources

Policies and Regulations

NPS Management Policies 2001 states that, "all cultural resource and natural resource values will be considered in defining specific treatment and management goals" (NPS 2000a). Furthermore, "The treatment of a cultural landscape will preserve significant physical attributes, biotic systems, and uses when those uses contribute to historical significance… Treatment decisions will consider both the natural and build characteristics and features of a landscape, the dynamics inherent in natural processes and continued use, and the concerns of traditionally associated peoples." Archeological resources are to be "managed in situ, unless the removal of artifacts or physical disturbance is justified by research, consultation, preservation, protection, or interpretive requirements" (NPS 2000a). They will be "maintained and preserved in a stable condition to prevent degradation and loss," and their condition is to be "documented, regularly monitored, and evaluated against initial baseline data."

Section 106 of the National Historic Preservation Act (NHPA) requires federal agencies to consider the effects of their actions on properties listed on, or eligible for inclusion in, the National Register of Historic Places, and to provide the Advisory Council on Historic Preservation with a reasonable opportunity to comment. To fulfill this requirement, consultation with the State Historic Preservation Officer was initiated on May 23, 2003. A programmatic agreement on the GGNRA FMP constituting Section 106 compliance is presently under development among GGNRA, the State Historic Preservation Officer, and the Advisory Council. The NPS also extended an opportunity for consultation with associated American Indian tribes and the public, to take into account the effects of the FMP on historic properties within the park. This programmatic agreement will be modeled upon a nationwide template developed by the National Association of State Historic Preservation Officers, the Advisory Council, the Department of the Interior, and Department of Agriculture land management agencies.

Impact analysis for the FMP, as a whole, follows procedures as described in the regulations implementing the NHPA (36 CFR 800.4), and is consistent with the requirements of NEPA. These include procedures for identifying historic resources in the area of potential effect, weighing the effects of a proposed undertaking against those qualities that make the historic properties eligible for the National Register, applying the criteria of effect to determine the level of effect, and identifying ways to minimize those effects. Compliance with Section 106 for specific sites and fire management will be carried out on an individual basis according the stipulations of the programmatic agreement on the GGNRA FMP.

Assessment Methodology

This impact analysis methodology includes consideration of the same five categories of cultural resources described in Chapter 3, Affected Environment: archeological resources, cultural landscapes, structures, ethnographic resources, and museum objects.

Cultural resource impacts in this document are described in terminology consistent with the regulations of the Council on Environmental Quality and the Advisory Council for Historic Preservation and in compliance with the requirements of both NEPA and the NHPA.

Type of Impact

Impacts are considered either adverse or beneficial to historic properties when analyzed under NEPA. However, impact type is not viewed in this manner when conducting analysis under Section 106 of the NHPA. For the purposes of assessing effects on historic properties under the NHPA, effects are either adverse or not adverse. Effects under both NEPA and the NHPA are considered adverse when they diminish the significant characteristics of a historic property.

Duration of Impact

Impacts on historic properties could be of short-term, long-term, or permanent in duration. Analysis of the duration of impacts is required under NEPA, but is not required, and is usually not considered separately, in assessing effects under NHPA.

Intensity of Impact

The following terms and definitions apply:

Negligible: Impacts would be barely perceptible.

Minor: Impacts may be perceptible and noticeable, but would remain localized and confined to a single element or significant characteristic of a historic property (such as a single contributing element of a larger historic district).

Moderate: Impacts would be sufficient to cause a noticeable but not substantial change in significant characteristics of a historic property, but not sufficient to compromise its qualifications for the National Register.

Major: Impacts would result in substantial and highly noticeable changes in significant characteristics of a historic property leading to the compromising of its qualifications for the National Register.

Human Health and Safety

Policies and Regulations

As described in the policies and regulations discussion under "Air Quality" above, the 1977 Clean Air Act (CAA) mandates the protection of human health and the prevention of significant deterioration of air quality and establishes acceptable levels of emissions for a range of pollutants. The California Air Resources Board is charged with protecting air quality in the state and developing a State Implementation Plan (SIP) to interpret and enforce the emission standards set by the federal EPA. The Bay Area Air Quality Management District (BAAQMD) is the air management district charged with monitoring and implementing the CAA, including approvals for prescribed burning, in the nine-county Bay Area Air Basin.

According to Section 4.7.1 of the NPS Management Policies, the NPS has a responsibility to protect air quality under both the 1916 Organic Act and the Clean Air Act, both to protect scenic vistas and the visitor experience and to protect public health. Policies direct the superintendents to "make reasonable

efforts to notify visitors and employees when air pollution concentrations within an area exceed the national or state air quality standards established to protect public health." (Please refer to the air quality methodology and assessment sections below for more information on air quality policies and regulations.) In considering the potential adverse effects of air emissions on public health, federal agencies are directed to consider the ambient air quality above the national ambient air quality standards (NAAQS) for $PM_{2.5}$ and PM_{10} as the principal indicator of adverse impacts (EPA 1998).

The highest priority for federal firefighting strategy, tactics, and policy is the protection of the lives and promotion of the safety of firefighters and the public. NPS Director's Order 18 (NPS 2003a) states that "...firefighter and public safety must be the first priority in all fire management activities." NPS Management Policies 2001 states that "all wildland fires would be effectively managed, considering resource values to be protected and firefighter and public safety...." and all actions taken involving wildland fire have as their overriding goal providing for firefighter and public safety (NPS 2000a). Firefighter worker safety and right to a safe work environment are protected by the Occupational Safety and Health Act of 1970 (29 USC 651 – 678; PL 91-5969).

In addition to indicating a public health risk, high levels of visible particulates can result in poor visibility and contribute to a traffic safety hazard. Section 4.4.5.3 of NPS Management Policies 2001 addresses herbicide use within the park. Herbicides are a subset of pesticides, which are defined by the Federal Insecticide, Fungicide and Rodenticide Act as any substance or mixture that is used in any manner to destroy, repel, or control the growth of any viral, microbial, plant, or animal pest. Fuel reduction projects that involve removal of certain nonnative plant species, such as eucalyptus and black acacia, typically involve the use of herbicides to prevent resprouting of cut tree stumps. All proposals to use herbicides in the park must submit a Herbicide Use Request to the GGNRA integrated pest management (IPM) coordinator, who reviews the requests on a case-by-case basis. The proposals are judged on potential environmental effects, cost, staffing, and other considerations. The decision to use herbicides is based on a determination by the IPM coordinator that all other available options are either not acceptable or not feasible.

Assessment Methodology

Fire management activities and the potential for injury, illness, and other direct and indirect impacts are evaluated for their potential to affect the public, park staff, and fire personnel during implementation of fire management activities at GGNRA. The analysis includes the impacts of prescribed fire, suppression, wildland fire use, and mechanical treatment on the health and safety of the public, park staff, and fire personnel. The analysis also assesses the potential exposure of park visitors to high noise levels and impacts of FMP actions on the soundscape of the park.

Type of Impact

The following terms and definitions apply:

Beneficial: Would result in a reduction in human health and safety concerns or improve human health or safety.

Adverse: Would result in additional or exacerbated public health and safety concerns.

Duration of Impact

The following terms and definitions apply:

Long-term: Would have a permanent effect on human health and safety (e.g., contamination of a water source for domestic use would be a long-term impact).

Short-term: Would be temporary and/or intermittent and be associated with the implementation phase of fire management actions (e.g., safety concerns related to smoke from a prescribed burn).

Intensity of Impact

The following terms and definitions apply:

Negligible: Imperceptible or undetectable effect upon the public, staff, or fire personnel.

Minor: Slightly detectable or localized effect upon the public, staff, or fire personnel.

Moderate: Clearly detectable impact that could have a readily perceivable effect on public health and safety and extend over a sizeable area.

Major: Substantial, highly noticeable impact and/or an impact that would extend over a large area of the park. The impact would initiate or resolve a significant public or firefighter safety or health hazard.

Visitor Use and Visitor Experience

The assessment of effects on visitor use and the visitor experience focuses on several aspects of this broad topic that were raised as potential issues during the scoping period for the FMP. The alternatives are assessed for potential to affect viewsheds and the aesthetic aspect of park landscapes, causes changes to public access patterns to parklands, and cause changes to the park soundscape.

Policies and Regulations

NPS Management Policies 2001 makes numerous references to aesthetics and visitor experience as central issues in the considerations that go into resource protection and park planning. Section 1.4.6 describes the "park resources and values" that are subject to the NPS "no impairment" standard, including a park's scenery, scenic features, natural visibility (both in daytime and at night), natural landscapes, natural soundscapes, and smells, which all contribute to the visitor experience. Important national park values also include the opportunity "to experience enjoyment of the above [listed] resources, to the extent that can be done without impairing any of them" (NPS 2000a).

NPS Management Policies 2001 Section 4.7.1, Air Quality, states that the NPS "has a responsibility to protect air quality under both the 1916 Organic Act and the Clean Air Act (CAA)." This responsibility would be reflected in the FMP by discussions of potential effect of FMP actions on air quality, air quality effects on public health and air quality effects on the visitor experience. NPS Management Policies 2001 directs the NPS to "perpetuate the best possible air quality in parks to (1) preserve natural resources and

systems; (2) preserve cultural resources; and (3) sustain visitor enjoyment, human health, and scenic vistas" (NPS 2000a).

As discussed under "Impacts on Air Quality" below, scenic resources are extremely sensitive to air pollution. Even a very small amount of fine particulate matter in the air can affect the ability to perceive colors, contrast, texture, and form of features, landmarks, and panoramas. Visual air quality is very important to park visitors. Specific vistas are often mentioned in legislation or congressional reports concerning the establishment of an NPS unit. Protection of scenic resources is addressed in Director's Order 77, Natural Resource Management (NPS 1991).

One of the potential effects on visitor access and visitor experience is the need for park staff to close public access to work areas or burn areas due to unsafe conditions during or just following implementation of FMP actions. NPS Management Policies 2001 addresses the need for occasional temporary closures or delays in public passage in order to ensure public safety. Section 8.2.2.1, Management of Recreation Use, advises superintendents to "use their discretionary authority to impose local restrictions, public use limits, and closures, and designate areas for a specific use or activity (see 36 CFR 1.5). Any restriction of appropriate recreational uses will be limited to what is necessary to protect park resources and values, to promote visitor safety and enjoyment, or to meet park management needs" (NPS 2000a).

Director's Order 47 addresses the problem of excessive/inappropriate levels of noise in the park (NPS 2000a). It directs park managers to measure baseline acoustic conditions, determine which existing or proposed human-made sounds are consistent with park purposes, set acoustic management goals and objectives based on those purposes, and determine which noise sources are affecting the park and need to be addressed by management. It also requires park managers to evaluate and address self-generated noise such as FMP actions, and constructively engage with those responsible for other noise sources that affect parks to explore what can be done to better protect parks.

NPS Management Policies 2001, Section 4.9, Soundscape Management, addresses the generation of noise in conjunction with NPS actions in and adjacent to parks:

> "The Service will monitor human activities that generate noise that adversely affects park soundscapes, including noise caused by mechanical or electronic devices. The Service will take action to prevent or minimize all noise that, through frequency, magnitude, or duration, adversely affects the natural soundscape or other park resources or values, or that exceeds levels that have been identified as being acceptable to, or appropriate for, visitor uses at the sites being monitored."

Assessment Methodology

The effects of each alternative were evaluated by analyzing potential impacts on the physical components affected and, using best professional judgment and information from relevant studies, assessing how the change may be experienced by the visitor. The following aspects of the proposed actions under each alternative were assessed:

- **Visual Aspects.** Would fire management actions be readily visible from views within the park or important views of the park? In which areas of the park would landscape modification be most noticeable or intrusive? Could the action affect a scenic vista along a road or a scenic view? Are there any ways in which the effects of the fire management action could be made less visible or restoration accelerated?

- **Visitor Experience and Access.** Would the project intrude on a visitor's park experience? Would the project curtail visitor access to parts of the park? For how long? Are there ways to provide an alternative experience during the closure?

- **Noise.** Would the sounds of the fire management action be readily perceptible within the park? From adjacent properties? In which areas of the park would the sound be most noticeable or intrusive? Would the sounds be continuous or intermittent? Are there any ways in which the effects of the sound could be mitigated or lessened?

As these questions indicate, the assessment will examine effects on the current aesthetic environment, soundscape, and visitor use patterns as well as the effect of modifications to the current condition. While aesthetic considerations can be quantitatively monitored, it is difficult to address potential changes to views. This is perhaps the most subjective of all the environmental impact assessment topics. Unfortunately, there is no objective, numerical standard or threshold that can be employed to state what constitutes an aesthetic effect. As is often the case in NPS management, judgment is necessary. Effects on aesthetics also must be analyzed in the context of cumulative effects of a number of different activities or actions, both within and outside parks. What could be insignificant alone (for example, one helicopter trip near a popular overlook) could become significant and highly intrusive in the context of other actions (one helicopter trip in combination with nine diesel buses and a nearby, audible, and clearly visible vegetation management project).

Visitor experience and aesthetic appreciation are tied closely to actions influencing natural resources. The enhancement or degradation of air quality, vegetation, and cultural resources has a corresponding effect on the quality of the visitor experience. Impacts on these issue areas are assessed under separate headings.

Type of Impact

The following terms and definitions apply:

Beneficial: Would enhance visitor appreciation of the natural landscape, the quality of visitor experience, or the visual quality of the landscape, or promote the native soundscape.

Adverse: Would degrade visitor appreciation of the natural landscape, the quality of visitor experience, or the visual quality of the landscape, or disrupt or intrude upon the native soundscape.

Duration of Impact

The following terms and definitions apply:

Short-term: Action would be temporary, with a duration restricted to the finite time period of project implementation.

Long-term: Action would be associated with a programmatic change or would continue indefinitely, or viewshed disturbance would be readily apparent for more than two years.

Intensity of Impact

The following terms and definitions apply:

Negligible: Would result in little or no noticeable change in visitor experience.

Minor: Would be detectable but localized within a topographically confined area; would result in changes in visitor experience when visitors or park neighbors are close to the project site but would not appreciably alter important landscape or soundscape characteristics.

Moderate: Would be readily noticeable, and/or change the visual character, soundscape, or visitor experience of larger vistas of the park or be seen from the park by modifying one or more secondary features of a vista, but not the keystone features of the vista.

Major: Would be highly noticeable, intrusive to the visitor experience, and/or change the character of the landscape or soundscape in significantly large areas, and/or change important vistas seen from the park or of the park by modifying the keystone features of the vista.

Park Operations

Policies and Regulations

Like most federal agencies, the NPS relies on federal appropriations to fund its core activities, although there is increasing use of alternative revenue sources, such as fees, to supplement operations. The NPS requests direct Congressional funding and reports on the other federal revenue sources through an annual budget document submitted to Congress entitled "Budget Justifications," or more popularly called the "Green Book."

Financial resources currently available to GGNRA include a base operating budget of approximately $21.4 million, which represents about 230 FTE (full-time equivalents, or one person for a full year). This work force is supplemented by over 5 million total volunteer hours each year.

In addition to the above operational funding, the park receives fee revenues and special national park project and program funding for specific maintenance, natural and cultural resources, and other projects. In addition, the park receives approximately $539,000 annually in FirePro and Wildland Interface funding for hazardous fuel reduction and fire prevention activities.

Assessment Methodology

Impacts were evaluated by assessing changes that would be required to meet the operational requirements outlined in each of the alternatives. Relative costs were generated using staff estimates of funding and labor required to implement these actions. These effects were compared to existing operations, staffing, and funding at the park.

Existing staffing levels were inventoried and assessments were made of current park operations. In addition, professional judgments by individuals who are most knowledgeable about various activities were used to anticipate the operational changes that would be needed under each action alternative. Estimates were made of the personnel required to:

- Provide education and information services to the public regarding fire activities;
- Research, plan, develop, and ensure regulatory compliance of proposed FMP actions;
- Conduct mechanical treatments to reduce hazardous fuels;
- Conduct prescribed fires to preserve natural and cultural resources and reduce hazardous fuels; and
- Monitor the effects of FMP actions.

The estimates of operational changes were compared to existing staffing levels. It should also be noted that precise impacts on staffing and funding are difficult to project until site-specific projects are proposed. Thus, the estimates are intended to provide a general description of potential effects, considering the variability within the range of possible operational scenarios.

The discussions of impacts address operations that would be new, undergo major change, or show susceptibility to increases or decreases in operational activity.

Type of Impact

The following terms and definitions apply:

Adverse: Would represent an increase in operating costs.

Beneficial: Would represent a decrease in operating costs and operational efficiency.

Duration of Impact

The following terms and definitions apply:

Short-term: Would last only until all actions are completed.

Long-term: Would have a permanent effect on operations.

Intensity of Impact

The following terms and definitions apply:

Negligible: There would not be a measurable difference in costs from existing levels.

Minor:	Additions or reductions in cost would be less than 15 percent of existing levels.
Moderate:	Additions or reductions in cost would be between 16 and 30 percent of existing levels.
Major:	Additions or reductions in cost would be more than 30 percent of existing levels.

Socioeconomics

Policies and Regulations

The NPS regulations for NEPA state that "social and economic impacts are considered an integral part of the human environment in the NPS and should be analyzed in any NEPA document where they are affected. Socioeconomic impacts include those to minority and low-income communities as specified in the Environmental Justice Executive Order (EO 12898; Feb. 11, 1994)." This executive order – Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations – requires all federal agencies to incorporate environmental justice into their missions by identifying and addressing disproportionately high and adverse human health or environmental effects of their programs and policies on minorities and low-income populations and communities.

This section examines the socioeconomic environment that might be affected by the fire management activities in and around the park under the three alternatives. Choosing different alternatives may affect the flow of dollars through the local economy.

Impacts of Fire Management Operations

Fire programs affect the economy in several ways. The direct impacts are associated with the core fire management payroll and the amount of local goods and services purchased directly by the department. An increase in staffing would be expected to have a net positive benefit to the area since most of the money paid to fire staff is spent locally in the form of housing, food, services, and local purchases. Spending by the fire management department on supplies and private contracted services also funnels dollars directly into the economy. Any increase or decrease in the core fire management budget spending would thus have some positive or negative effect on the local economy. The extent of the impact is determined, in part, by the amount of spending by the GGNRA fire management unit compared to the overall economy.

Suppression of major fires also affects the local economy. Increases in fire staffing and private contracts to restore burned areas can have a positive net impact on the local economy, while property damage and loss of visitation can have adverse short-term impacts.

Visitor Spending

In addition to the direct economic impact associated with GGNRA's staffing and spending in the area, the indirect impact associated with spending by park visitors is also factored into the analysis. This indirect benefit results from spending on food, lodging, fees, gifts, and other retail items. Modifications in fire operations for prescribed burns and mechanical treatments would have a negative economic impact if park visitation rates and associated spending were reduced by either shortened or rescheduled plans due to road closures, park or facility closures, smoke, or noise.

Fire suppression activities also may affect visitation rates and associated tourist spending depending upon the size, location, and extent of an unplanned fire. To date, most of the temporary area closures that have occurred at GGNRA have resulted from wildland fires and not fuel reduction projects. The loss of spending by visitors in the local economy from larger wildfires is partially offset by increased spending on temporary fire personnel and requirements for structural repairs or replacement, utility repairs, slope rehabilitation, and other activities required to restore the area.

Assessment Methodology

In addition to any possible effects on minority and low-income populations and communities, alternatives were evaluated for their potential direct impacts, such as property loss, and indirect economic effects, such as from park closures, on the regional economy and resident/tourist population as a whole.

Type of Impact

The following terms and definitions apply:

Adverse: Would degrade or otherwise negatively alter the characteristics of the existing environment, as the relate to local communities (including minority and low-income), visitor population, regional economics, and concessionaires and contractors.

Beneficial: Would improve on characteristics of the existing social and economic environments, as they relate to local communities (including minority and low-income), visitor population, regional economies, and concessionaires and contractors.

Duration of Impact

The following terms and definitions apply:

Short-term: Temporary and typically transitional impacts associated with implementation of an action.

Long-term: Permanent impacts on the social and economic environments.

Intensity of Impact

The following terms and definitions apply:

Negligible: Undetectable and expected to have no discernible effect on the social and economic environment.

Minor: Slightly detectable and not expected to have an overall effect on the character of the social and economic environment.

Moderate: Detectable and could have the potential to initiate an increasing influence on the social and economic environment.

Major: Substantial, highly noticeable influences on the social and economic environments, and could be expected to alter those environments permanently.

4.2 Environmental Impact Analysis

Impacts on the Physical Environment

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

Analysis

As described in Chapter 3, fires are natural events that maintain healthy watersheds, but they can also impair watershed processes. Watershed attributes such as water yield, peak flows, sediment yield, nutrient yield, stream system response, and water quality can be affected by fire management activities. These impacts will vary depending on the extent of activity in the watershed, the type of soils and slopes within the watershed, and the proximity of the activity to streams.

Fire management activities can affect soil resources through disruptions to the soil horizon, erosion, compaction, and changes to soil properties. These impacts on soils can in turn affect the hydrology of the watershed by increasing sedimentation, changing the surface flow, and impairing water quality. These impacts will have an effect on the quality of the aquatic habitat within the watershed.

Impacts on Soils

Disruption of the soil horizon can occur from most fire management activities, including the creation of fire lines during suppression and prescribed burning and the removal of plants and their roots during mechanical removal. These activities will disturb or bury the upper soil layers that are rich in nutrients, organisms, and seeds and potentially impair the watershed processes.

Erosion can be accelerated by wildland fires, prescribed burning, and fuel reduction projects that remove the overlying vegetation and duff from surface soils and leave soils exposed to wind and water. Erosion selectively removes nutrients, organic materials, and fine particles from topsoil, reducing soil productivity. A decrease in productivity can have a consequent effect on the density, vigor, and range of plant species that will survive or repopulate an area, and can also create conditions under which nonnative plant species are better competitors than native vegetation. Bare ground can remain bare for a longer period of time on steeper slopes, or when soils are susceptible to becoming hydrophobic. Clay-rich soils subject to very high fire intensity may fuse at the soil surface, decreasing porosity, slowing infiltration of water, and increasing the rate of surface soil erosion.

The severity and duration of accelerated erosion depend on several factors, including soil texture, slope, recovery time of protective cover, the amount of residual litter and duff, and post-burn precipitation intensity. On a larger scale, the transportation of soils through erosion can result in changes to the landscape such as the formation of gullies or the sedimentation of ponds and wetlands and clogging of stream channels.

Compaction can likewise lead to increased surface runoff and result in erosion. Activities that compact the soil, such as use of heavy equipment, will decrease the capacity of the soil to infiltrate water and therefore create downstream effects.

Changes in soil characteristics occur during wildfires, and to a lesser extent with cooler prescribed burns. Hydrophobicity can result when fire increases soil temperatures, causing the volatilization of hydrophobic materials into the soil. A hot wildfire, such as those that may occur in forested areas of the park or where fuels have built up, may create hydrophobicity deeper in these soils. However, the impermeable layer that develops in the upper soil horizon may have beneficial impacts by controlling the loss of moisture to evaporation. This maintains soil moisture and encourages seedling establishment.

Plant nutrients may also be lost through volatilization during a fire. Fires can release important plant nutrients, such as phosphate, sulfate, and nitrogen, as organic matter is volatilized through combustion both into the air and forced down into the soil. In a hot wildfire, the loss would be greater than in a prescribed burn, as the effects would extend deeper into the soil and would not leave much organic matter on the surface. Conversely, ash deposits from the fires themselves can increase the amount of nutrients available to plants post-fire, especially nitrogen, and can spur rapid plant growth following the fire. Extremely hot fires may also kill beneficial fungi and bacteria that live in soils or wildlife that tunnel near the surface.

Impacts on Watersheds and Water Quality

Water yield in a watershed can increase after a fire or mechanical thinning due to a decrease in both transpiration and water infiltration. Infiltration can be reduced several ways, from increased compaction by heavy equipment to the formation of hydrophobic soils by intense fires. The removal of litter and debris by either method will also lead to decreased infiltration and increased surface flow. The combined effect of these changes can temporarily increase water yield and overland flow, leading to increased peak flows for months or years afterwards. This could exacerbate levels of soil erosion; increase sedimentation levels in streams, wetlands, and other water bodies; and degrade water quality. Increased erosion could also cause changes to surface hydrology, including overland, undirected flow; channelized surface water flow; and flow to drainage infrastructure.

Sediment yields can increase after fires or tree removal due to this increased overland water flow and the associated erosion. Sediments can wash into streams and scour the bank and streambed, or settle on the stream bottom and cover important rock or cobble habitat. This problem becomes more severe if the streamside vegetation has also been burned, since the banks then become even less stable. If a fire is particularly hot, woody debris that helped stabilize the channel may be consumed, increasing water velocity and streambank erosion. Extremely high levels of sediments can injure fish or other aquatic organisms by clogging their gills or obscuring the presence of food.

Nutrient yields increase after fires from the breakdown of plant materials. Some materials will volatize into the atmosphere, while the remainder is left as ash in readily mobile forms on the soil surface. When nitrogen and other nutrients found in ash make their way into the aquatic ecosystem, they can increase production of algae and aquatic plants. Decay of this excessive biomass can deplete water of oxygen and lead to fish kills.

Stream system response, both physical and biological, can change as the result of fire management activities. A stream channel may initially aggrade and widen after a fire in response to higher peak flows

of water, increased sediment, and loss of riparian vegetation. As vegetation becomes reestablished, the channel usually returns to pre-fire size within several years.

Water quality can be affected by sediment and nutrient input as well as inputs from other fire management activities. For example, herbicides used in fuel reduction and wetting agents or saltwater used during suppression actions can degrade water quality.

Most of the impacts on soils have a direct effect on the hydrology of a watershed. Fire management actions that accelerate levels of soil erosion can increase sedimentation levels in streams, watersheds, and other water bodies and degrade water quality. Bare, hydrophobic, or compacted soil can increase the level of surface water flow, create scour, and decrease the amount of infiltration to groundwater. Water quality can be affected by increased sedimentation as well as contamination by saltwater, herbicides used for fuel reduction, and fire-retardant agents. Most fire retardants contain fertilizer type compounds such as ammonia and nitrogen and could cause changes in pristine terrestrial and aquatic ecosystems. Additionally, ammonia itself can be quite toxic in aquatic habitats. Some retardants also contain preservatives that release cyanide that can be fatal to aquatic life.

Impacts on Aquatic Habitat

These water quality impacts can lead to impairment of aquatic habitats within a watershed. Aquatic organisms rely on specialized habitats within streams or other water bodies that can be blanketed by a pulse of sediment from upstream. Runoff of herbicides into water bodies could kill the algae at the base of the food chain and lead to food shortages in the small invertebrates that depend on it. High levels of saltwater dropped into a water body could increase the salinity to such an extent that sensitive organisms could be affected. Lastly, the input of fire retardant into a stream could prove fatal for aquatic organisms.

Beneficial Effects of Fire Management Activities

Many of the impacts discussed above are part of natural watershed processes that can create beneficial effects under normal conditions. Disturbances such as erosion and sedimentation can deliver nutrients and woody debris to aquatic habitats and maintain complex and productive ecosystems (Bisson et al. 2003). Modifications to normal watershed conditions, such as the amount of vegetative cover, can alter the natural processes of infiltration and evapotranspiration and lead to a disruption in the water balance. For example, studies from Southeast Asia and Australia have demonstrated rapid reduction of water yield and soil moisture after the planting of eucalyptus trees (Samra et al. 2001). Conversely, actions that remove vegetation can lead to an increase in water yield by decreasing evapotranspiration (loss of water by evaporation from the soil and by transpiration from the plants). In one post-fire study, a 5-percent reduction in evapotranspiration resulted in a 30-percent increase in the annual runoff in a watershed (Zwolinski, 2000). This could be a beneficial effect in a watershed where current flow levels are below historic levels.

Fires can have other beneficial impacts on watersheds. Riparian vegetation can recover quickly from fires, and research indicates that the closer a plant is to the water table, the higher the potential for regeneration after a fire event (Russell and McBride 2001). This suggests that riparian areas are very resilient to fires and could benefit from the mosaic of habitat and regeneration of growth that is created.

Likewise, soil productivity, which is dependent on organic matter, recovers quickly in burned areas that are left undisturbed (Beschta et al. 2004). The short-term decrease in soil productivity in the uplands of a watershed would be accompanied by an increase in nutrients in the downstream aquatic ecosystem (Bisson et al. 2003). Provided that these processes occur in watersheds where aquatic species are healthy and habitats remain productive, diverse, and interconnected, the effects on the ecosystem would be beneficial.

Overall, fire management actions such as prescribed burning and mechanical removal of nonnative vegetation can be an important component of watershed management, in combination with other actions that improve the natural processes and connections. In addition, fire management activities would limit the potential for catastrophic fire that could burn along the entire vertical gradient in the watershed, creating extensive hydrophobic soils resulting in increased sediment loads to watersheds. In the long term, fire management activities would have beneficial effects on watersheds by reducing the severe impacts of a catastrophic fire that could extensively burn an entire watershed.

Actions Common to All Alternatives

Wildland-Urban Interface Initiative

Projects conducted under the Wildland-Urban Interface Initiative would be subject to project review to ensure that they would minimize adverse impact on soils, erosion, or water resources.

Defensible Space/Vegetation Clearing Around Buildings

Clearing around structures could leave soils unvegetated and/or disturbed and vulnerable to erosion. Ensuring that these activities do not denude the soil, or incorporating erosion control measures, would avoid effects on soil or water resources.

Roadside Fuel Reduction

As described in Chapter 2, maintenance standards for existing fire roads would be developed by park staff and would include guidance on grading and vegetation removal. Maintenance standards would include such actions as outsloping of roads to prevent rill and gully erosion. In addition, unnecessary fire roads may be eliminated, and others may be reconfigured or rerouted to address erosion problems. These actions would be conducted to reduce erosion potential, and should have a beneficial impact.

Suppression

Wildland fire and the suppression and restoration actions that follow wildland fire all have the potential to affect watershed resources within the park. Depending on the intensity and duration of a wildland fire, immediate and long-term changes in soil properties and watershed processes can occur.

Suppression activities can cause soil compaction, profile mixing, erosion, contamination, and overheating of soils. Manual or mechanized earthmoving to create firebreaks and roads or smother burning materials can mix the layers of the soil horizon and bury the fertile topsoil layer and the native seedbed within the topsoil, reducing the success of post-fire native plant revegetation. Removal of covering vegetation and uprooting of plants and tree roots by heavy equipment expose disturbed soils to erosion by water and wind.

Saltwater used for suppression can create an adverse effect on the soil chemistry. The duration and intensity of this effect would depend on the site conditions, the amount of saltwater applied for suppression, and the rainfall and runoff patterns following the fire. Likewise, use of fire retardants for suppression can introduce harmful substances to an aquatic ecosystem.

Based on the average size of historic wildfires in GGNRA annually, the impacts created by suppression activities would create no more than short-term, minor adverse effects in any one watershed. In combination with the applicable mitigation measures listed in Chapter 2, impacts on watersheds from suppression activities would be adverse, short-term, and negligible or minor.

Treatment of Muir Woods FMU

Fire management projects at Muir Woods National Monument would include prescribed burning and mechanical removal. These actions could affect watershed resources by causing erosion, soil compaction, and sedimentation into water bodies. The acreage of proposed projects in Muir Woods National Monument (part of the Redwood Creek watershed) are small in scale compared to the size of the watershed. Therefore, the impact on watershed resources would be minor. The beneficial impacts of these activities would be to restore the natural hydrologic and nutrient cycles in the watershed. Combined with the applicable mitigation measures listed in Chapter 2, the impact of fire management activities at Muir Woods National Monument on watershed resources would be beneficial, long-term, and moderate.

Treatment of San Francisco County Project Area

See "Defensible Space Clearing Around Structures" above. Mechanical removal of nonnative evergreen trees could have short-term adverse impacts on soil and soil erosion. For tree removal actions in areas with highly erosive soils or steep slopes, tree stumps would be left in place and cut as close to ground surface as feasible.

Public Information and Fire Education Programs

Fire information and education actions proposed for all alternatives would have no beneficial or adverse effects on soil or water resources in the planning area.

Fire Cache

For the purposes of this document, it is assumed that the activities performed at the fire cache(s) would be consistent with the surrounding resource objectives and would be done in accordance with best management practices (BMPs) for soil and water quality protection. For example, vehicle washing would be done on a wash rack designed to prevent contamination of surface waters.

Fire Effects Monitoring

Monitoring plans would be reviewed to ensure that fire-related monitoring has no adverse effect on soils or water resources. In general, monitoring and evaluation would benefit watershed resources as it would enable managers to make corrective actions if necessary.

Alternative A

Mechanical Fuel Reduction

Mechanical fuel reduction in Alternative A would occur in nonnative forests along the Wildland Urban Interface. These activities could lead to watershed effects such as erosion and soil compaction and create adverse, short-term, and minor impacts. However, the removal of nonnative trees from within a watershed could help improve the hydrological cycle by restoring natural infiltration and evaporation processes. Combined with the applicable mitigation measures listed in Chapter 2, mechanical treatments in Alternative A would have a beneficial, long-term, and moderate effect on watershed processes.

Pile Burning

Most mechanical removal projects would include pile burning. The piles would be small in size and create very localized compaction and hydrophobic soil. These impacts would be minor on a watershed scale and would not affect soil or hydrology resources.

Prescribed Fire

Prescribed burning under Alternative A would be focused in Marin County and would largely burn grassland and coastal scrub. Prescribed burning activities such as fire line creation and the burn itself could cause watershed impacts such as disruption of the soil horizon and soil properties, erosion, sedimentation, and changes to hydrology. If large-scale burns are planned for one watershed, the burn could potentially disrupt a large enough percentage of the watershed to cause a moderate impact. However, the maximum acreage to be burned under Alternative A during any one year is 100 acres (in Marin County), and the burning is unlikely to occur within one watershed. This acreage is less than 5 percent of most watersheds in Marin County. Given the small scale of the prescribed burning activities, Alternative A would have an adverse, short-term, and minor impact on soil and water quality within a watershed.

Positive effects from burning could be realized in the restoration of watershed processes such as infiltration and evaporation. In addition, the return of a more natural fire interval would prevent fuel buildup and decrease the potential for a catastrophic fire that could have a major impact on watershed processes.

With the inclusion of the applicable mitigation measures listed in Chapter 2, the prescribed burning activities in Alternative A would have beneficial, long-term, moderate impacts on watershed processes.

Research

Alternative A would include an element of research into the effects of fire on vegetation. Part of the research could be to determine the effects of fire on soil, hydrology, and aquatic resources in the watershed. This research would have a beneficial impact, as the results could inform future decision making that prevents future impacts on the watershed. Since these research burns would be synonymous with the burns described above, the possible adverse impacts would be the same.

Cumulative Impacts

Under Alternative A, FMP actions would be occurring in conjunction with the implementation period of several NPS and community projects, particularly in Marin County. For example, several current and proposed projects and plans have components that could affect the 8.9-square-mile Redwood Creek watershed, including:

- The Big Lagoon Restoration Project at Muir Beach, which will explore alternatives for restoring or enhancing ecological processes near the mouth of Redwood Creek, reduce flooding of local infrastructure, restore the creek channel and wetlands, reconfigure facilities to improve hydrologic processes, and provide an visitor access and a range of visitor experiences.
- Ongoing NPS habitat restoration actions along Redwood Creek, including removal of nonnative plants and planting of native plant species.
- Recent floodplain restoration along Redwood Creek on the Banducci property and the continuation of the effort under Phase II improvements.
- Recent work to reduce flooding potential at Pacific Way leading to Muir Beach.
- Roadway improvements and parking lot reconfiguration to reduce resource damage and promote sustainable resource management at Muir Woods National Monument and Muir Beach as part of the Comprehensive Transportation Management Plan.
- Possible improvements to the Coastal Trail in the vicinity of Muir Beach as part of the Trails Forever Project.

These projects should be considered when developing implementation strategies for the various project areas described in the FMP. The combined impacts of unrelated projects and fire management activities within a watershed should not exceed the threshold for minor impacts (i.e., slightly perceptible and localized, without the potential to expand if left alone). For example, fire management planning should ensure that prescribed burning or mechanical treatments create only negligible impacts in the upper reaches of a watershed during the timeframe when a concurrent project is being implemented downstream.

Other watersheds in Marin and San Mateo counties containing NPS lands could be affected by the implementation of projects funded by the Wildland-Urban Interface Initiative on private lands, and by habitat restoration or nonnative plant removal projects or fire management actions conducted by Marin County Fire Department or other local land management agencies. Fire management in the San Francisco project area could affect the drainage of Lobos Creek, which is shared with land managed by the Presidio Trust. PRNS and GGNRA both have lands within the larger watershed draining to Bolinas Lagoon.

To avoid adverse cumulative impacts on the Redwood Creek watershed and other park watersheds in Marin and San Mateo counties, fire management actions should be scheduled, sited, and coordinated with other actions that contribute to stream sedimentation. Consideration should be given to any transportation,

trail improvement, maintenance, habitat restoration, or other project that disturbs the soil or would otherwise affect the hydrology or water quality within a watershed.

Conclusion

Fuel reduction achieved by fire management actions under Alternative A would benefit watershed conditions and hydrologic processes by reducing the risk of catastrophic fire and returning fire intervals. These effects overall would be beneficial, long-term, and moderate. Effects of prescribed fire on water quality due to increased erosion would be adverse, minor, and short-term until vegetation is reestablished. Impacts from soil disturbance by mechanical treatments would be adverse, short-term, and negligible to minor. The effects of the removal of nonnative evergreen forest on the watershed effects within the areas treated by mechanical means would be beneficial, long-term, and minor to moderate.

Suppression activities would adversely affect soils due to compaction and ground disturbance. Because the number of acres burned by wildfires each year remains quite low, impacts on watersheds would be adverse, short-term, and minor.

In sum, actions implemented under this alternative would have adverse, short-term, and minor effects on water quality. In the long term, the actions of Alternative A would have a beneficial, long-term, minor-to-moderate effect in restoring the natural hydrology of the area.

A large-scale unplanned fire could have adverse, potentially long-term, and major impacts on both water quality and features of watersheds, including riparian zones and watercourses.

Impairment

Because the actions under this alternative would have only short-term and minor adverse effects, no impairment of soil and water resources within park watersheds is expected.

Alternative B

Mechanical Fuel Reduction

Alternative B includes mainly mechanical fuel reduction throughout the park, particularly in the WUI FMU. Although the total acreage of projects per year would be greater than in Alternative A, the impacts would not change significantly. With the implementation of the mitigation measures described for Alternative A, the overall impacts on watersheds from mechanical removal under Alternative B would be beneficial, long-term, and minor.

Pile Burning

Impacts would be the same as under Alternative A.

Prescribed Fire

In Alternative B, prescribed burning would occur in the Muir Woods FMU and the Park Interior FMU, with a maximum of 120 acres per year throughout the park. This level of impact is similar to Alternative A. With the implementation of the mitigation measures described for Alternative A, the effects of

prescribed fire on watersheds under Alternative B would be adverse, short-term, and minor for soil and water quality, and beneficial, long-term, and moderate for overall watershed health.

Research

Impacts would be the same as under Alternative A.

Cumulative Impacts

Under Alternative B, nearly twice as much mechanical fuel reduction could occur as compared to Alternative A. The acreage of prescribed burning is nearly identical in the two alternatives. The majority of mechanical fuel reduction under Alternative B would occur on parklands in Marin County close to the park boundary with residential development. Fuels in the interface zone are predominately nonnative evergreen forest and nonnative shrubs such as French or Scotch broom and fennel. Where tree stumps are left in place, surface soil disturbance is limited to compaction or disturbance from skidders or vehicles used to transport cut timber.

Most of the projects included in the consideration of cumulative effects are well away from the WUI zone on the eastern edge of GGNRA lands. Restoration efforts and nonnative plant removal undertaken by park stewards are often focused in the interior of the park, where efforts to contain the spread of nonnative plants can be more effective than on the park's interface. Cumulative impacts from prescribed burning projects would be essentially the same as described for Alternative A and would incorporate the same mitigation measures that require consideration of fire management actions on a watershed scale with emphasis on erosion control.

Cumulatively, effects from other actions when combined with the effects from Alternative B would be short-term, minor, and adverse due to the potential for an increase in the level of erosion from prescribed burning. Many of the projects considered for the cumulative impact assessment, such as the Big Lagoon project and the floodplain expansion on the Banducci property, are focused on resolving long-standing resource problems and enhancing ecological function. Long-term, moderate beneficial impacts would accrue throughout the affected watersheds through the reduced potential for a catastrophic fire to occur in conjunction with the resource benefits gained from other concurrent projects.

Conclusion

Fire management actions under Alternative B, especially the prescribed burns in the park interior, would improve the long-term watershed conditions and natural hydrology by reducing the risk of catastrophic fire and returning fire intervals. These effects overall would be beneficial, long-term, and moderate. Effects of prescribed fire on water quality due to increased erosion would be adverse, minor, and short-term until vegetation is reestablished. Impacts from soil disturbance due to mechanical treatments would be adverse, short-term, and negligible to minor. However, the watershed effects within the areas treated by mechanical means would be beneficial, long-term, and minor to moderate.

The same types of watershed impacts would result from typical wildland fires in the park each year. Suppression activities would affect soils due to compaction and ground disturbance. Mitigation Measure FMP-6 describes the requirements for resource advisors to work with firefighters to minimize the

potential effect of suppression efforts. Mitigation Measure FMP-7 requires burned area rehabilitation teams to be requested for any multiday wildland fire incident. Because the number of acres burned by wildfires each year would remain quite low and a rehabilitation plan would be required to stabilize burned areas and reduce soil erosion and potential damage to adjacent properties, impacts on watersheds would be adverse, short-term, and minor.

A large-scale unplanned fire could have adverse, potentially long-term, and major impacts on both water quality and features of watersheds, including riparian zones and watercourses.

Impairment

Because the actions under this alternative would have at worst short-term, minor adverse effects on watershed resources, no long-term impairment of watersheds would result from this alternative.

Alternative C

Mechanical Fuel Reduction

Alternative C includes more mechanical fuel reduction in Marin County, with the same acreages in San Francisco and San Mateo County as Alternative B. The increased acreage in Marin is located in the park interior areas. Although the total acreage of projects per year would be greater than under Alternatives A and B, the impacts would not be significantly different. With the implementation of the mitigation measures described for Alternative A, the impacts on watershed resources of mechanical removal under Alternative C would be adverse, short-term, and minor for soil and water quality, and beneficial, long-term, and moderate for overall watershed health.

Pile Burning

Impacts would be the same as under Alternative A.

Prescribed Fire

Under Alternative C, prescribed burning would occur mainly in the Park Interior FMU, with a limited amount in the Wildland Urban Interface and Muir Woods FMUs. A maximum of 320 acres per year would be burned throughout the park. While this is an increase in acreage from Alternatives A and B, the intensity of impact would not exceed minor. The size of even the largest anticipated prescribed burn would not be enough to affect more than a small fraction of any watershed. However, the beneficial impacts of prescribed burns would increase with the increased acreage.

With the implementation of the mitigation measures described for Alternative A, the effects of prescribed fire on watersheds under Alternative C would be adverse, short-term, and minor for soil and water quality, and beneficial, long-term, and moderate for overall watershed health.

Research

The impacts of this alternative would be similar to Alternatives A and B. However, the beneficial impacts could be greater due to the opportunity for more research burns.

Cumulative Impacts

Under Alternative C, there is potential for cumulative effects on soils and water resources to occur if fire management actions and construction projects proposed for the same watershed are timed to occur simultaneously. With the application of mitigation measures that address the potential effect on the watershed scale and the project scale, potential project effects would be short-term, minor, and adverse, as in Alternative A. Under Alternative C, long-term, moderate beneficial impacts on the watershed would be achieved by reducing the potential for a catastrophic fire through a faster rate of reduction at key areas of high fuel loading, compared to Alternative A.

Conclusion

Fire management actions under Alternative C, in particular prescribed fire, would improve watershed conditions and natural hydrology by reducing the risk of catastrophic fire and returning more natural fire intervals. This alternative would have the greatest effect on the park's watersheds, and would be beneficial, long-term, and moderate. Effects of prescribed fire on water quality due to increased erosion would be adverse, minor, and short-term until vegetation is reestablished. Impacts from soil disturbance due to mechanical treatments would be adverse, short-term, and negligible to minor. However, the watershed effects within the areas treated by mechanical means would be beneficial, long-term, and minor to moderate.

The same types of watershed impacts would result from typical wildland fires in the park each year. Suppression activities would affect soils due to compaction and ground disturbance. Because the number of acres burned by wildfires each year would remain quite low, impacts on watersheds would be adverse, short-term, and minor.

A large-scale unplanned fire could have adverse, potentially long-term, and major impacts on both water quality and features of watersheds, including riparian zones and watercourses.

Impairment

Because the actions under this alternative would have at worst short-term, minor adverse effects, no impairment of park watershed resources is expected.

Impacts on Air Quality

Analysis

The smoke management techniques listed in Chapter 2, Section 2.7 "Mitigation Measures," will apply to all the proposed FMP alternatives. These and additional strategies are described in the 2002 U.S. Department of Agriculture General Technical Report, Wildland Fire in Ecosystem, Effects of Fire on Air Quality and in the National Wildfire Coordinating Group's Fire Use Working Team publication "The Smoke Management Guide for Prescribed and Wildland Fire: 2001 Edition." Prescribed burns, pile burning, research burning, and flexible suppression strategy actions would be conducted incorporating these mitigation measures to lessen the effects of smoke and other emissions on human health, ecological health, air quality, and visibility. (Note: The effects of air emissions, such as particulates from smoke, on

respiration and roadway visibility are addressed in this DEIS under "Impacts on Human Health and Safety" below.)

Actions Common to All Alternatives

Wildland-Urban Interface Initiative

GGNRA has experience with implementation of the federal Wildland-Urban Interface Initiative program for the past three years. The NPS funds community projects by local fire agencies, local land management agencies, or homeowners' associations for treatment of fire hazard areas within the wildland urban interface. Projects on the federal side of the interface are the responsibility of national parks. The NPS also grants funding to community groups, other land management agencies, and local fire departments for fuel reduction projects on private lands within the interface zone with the national park. These projects are not directly managed by the NPS and will be addressed as part of the cumulative impact assessment.

To date, all projects funded by the Wildland-Urban Interface Initiative within GGNRA have been sited in Marin County. Though this program has also funded public education projects at GGNRA, the majority of the funding has been for mechanical fuel reduction projects near the federal interface with residential communities in Marin County. There are instances where projects involved pile burning to dispose of debris from felled nonnative trees or pruned vegetation. In most cases, it is more cost-effective to chip and distribute woody debris onsite. Where inaccessibility to a chipper or resource constraints or other factors limit or prohibit chips from being broadcast at the site, burn piles are an effective solution to reduce debris. Where projects involve trees infested with pitch pine canker or SOD, the prescribed treatment is to leave all material onsite and avoid transportation. If there is too much debris to leave onsite, burn piles would be used to reduce the amount of downed fuel at the site. For these projects, the construction, ignition, and monitoring of pile burning will be supervised by NPS staff or the Marin County Fire Department and necessary burn approval will be attained from BAAQMD. Occasionally, burn piles may not be practical when residential development is near a park fuel reduction project site and nuisance smoke and soot impacts on property would be difficult to avoid. Experience over the last three years indicates that two to three projects per year may include pile burning. For Alternative A, it is estimated that approximately 25 burn piles would be completed each year. This amount of burn piles is included as part of the project description under each alternative. Emissions are estimated in Table 4-4.

Table 4-4: Emissions from Pile Burning for Projects Funded by Wildland-Urban Interface Initiative under Alternative A

Number of Burn Piles	Emissions (pounds per year)					
	PM_{10}	$PM_{2.5}$	VOC (as methane)	CO	NO_x	SO_2
25	0.03	0.02	0.01	0.3	0.0	0.0

Source: NPS Air Resources Division 2004.

Notes:

PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SO_2 = sulfur dioxide

Defensible Space/Vegetation Clearing Around Structures

Similar to roadway fuel reduction projects, emissions from equipment use during defensible space clearing around structures are considered insignificant in comparison to overall emissions generated by fire management actions and wildland fire, and would have a negligible effect on air quality Prescribed burning and pile burning are not associated with clearing around structures. These actions would have a short-term, negligible adverse effect on regional air quality and no effect on visibility.

Roadside Fuel Reduction

Roadway fuel reduction primarily involves equipment, including trucks, chippers, chain saws, and brushcutters. Normally, cut vegetation is chipped and redistributed onsite. In certain cases along fire roads, some pile burning may be needed to reduce excess fuels that should not be left onsite. The emissions from pile burning are included in the overall emissions calculations for each alternative. The emissions that would be generated by equipment and vehicle use have been determined to have a negligible effect on air quality according to the NPS Air Resources Division. Roadway fuel reduction would make a short-term, negligible adverse contribution to regional air quality; there would be no effect on visibility.

Suppression

Smoke from unplanned ignitions is a complex mixture of carbon, tars, liquids, and gases. The major pollutants from fire that are monitored by BAAQMD under the Clean Air Act are particulates (PM_{10} and $PM_{2.5}$), volatile organic compounds (VOC), carbon monoxide (CO), and nitrogen oxides (NOx). NOx is produced in relatively small quantities compared to the other pollutants (see Chapter 3, Section 3.3, discussion under "Air Quality").

As described in the air quality methodology discussion above, the First Order Fire Effects Model (FOFEM) is used to generate the amounts of air emissions representative of a typical annual occurrence of wildland fire in GGNRA. The vegetation types, number of occurrences, and size of occurrences were provided by GGNRA fire management staff (Naar 2004). In order to derive realistic emission totals, the inputs into FOFEM for wildland fire are based on a rough estimate of the occurrence of wildland fire in the principal vegetation types.

The annual wildfire scenario used as the baseline for analysis in this EIS is estimated at 39 acres of annual wildland fire (Naar 2004). Of the 39 total acres, 12 acres (31 percent) contain coastal scrub vegetation, 25 acres contain grasslands (64 percent) and the remaining 2 acres (5 percent) are forested areas. The estimated emissions produced annually by the current level of wildland fire occurring in GGNRA is the same under the three FMP alternatives.

Table 4-5 shows the output of the FOFEM fuel model types and emission factors used to derive emissions for wildland and prescribed fire in grasslands, coastal scrub, and Douglas-fir forest. As there is little difference in the amount and type of emissions produced by prescribed burning in grasslands or coastal scrub compared to wildland fire in grasslands or coastal scrub, the same emission factors are used for both types of fire in these two plant communities. To estimate emissions from wildland fire and prescribed fire in Douglas-fir forest, the same fuel model type was used but specific factors associated with that model

type, such as an increased involvement of the forest canopy, were modified to represent a wildfire and produce more realistic emission levels for this higher-intensity and higher-emission burn.

Table 4-5: FOFEM Emissions Factors for Wildfire, Prescribed Burning, and Pile Burning

FOFEM Inputs				Emission Factors (pounds per year per acre burned)					
GGNRA Cover Type	FOFEM Surrogate	Code	Fire Type	PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Coastal Scrub	Cean	SRM 208	Prescribed	190	161	49	404	198	62
Grass	Valley Grassland	SRM 215	Prescribed	11	9	3	23	12	4
Native Forest	Pacific Douglas-fir	SAF 229	Prescribed	2863	2445	1480	32319	24	114
Coastal Scrub	Cean	SRM 208	Wild	190	161	49	404	198	62
Grass	Valley Grassland	SRM 215	Wild	11	9	3	23	12	4
Native Forest	Pacific Douglas-fir	SAF 229	Wild	3640	3085	1867	40836	31	145
Nonnative Trees	Pacific Douglas-fir	SRM 229	Pile Burning	2660	2254	1329	28606	162	145

Source: NPS Air Resources Division 2004.

Notes:

FOFEM = First Order Fire Effects Model, SRM = Society for Range Management, SAF = Society of American Foresters, PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SO_2 = sulfur dioxide

During suppression of unplanned ignitions, transport and fire vehicles such as trucks, engines, and water tenders would be onsite to patrol and stand by on alert at fires. Equipment such as chain saws and graders could be used to clear fuels, provide access, or transport firefighters. Heavy equipment, fire engines, and water tenders would be used to fight the fire. The level of emissions generated by equipment and vehicles during wildland fire suppression is considered a negligible contribution to air emissions relative to the emissions in the wildfire smoke.

The potential annual air emissions from wildland fire in GGNRA are shown in Table 4-6. Emissions generated by this level of wildland fire would have a long-term, negligible, adverse effect on levels of SO, PM_{10}, CO, and NO_x and a long-term, minor, adverse effect on ozone (represented by VOC) levels in the Bay Area Air Basin.

Smoke dispersion during a wildfire would vary depending on weather conditions, elevation of the fire, wind direction, fuel type, and accessibility of the area for firefighting equipment. A fire in blue gum eucalyptus could burn with tremendous intensity and spread extremely fast, producing local winds from rapid convection and heating. Under these conditions, drifting burning material, such as the eucalyptus bark, has great potential to ignite spot fires further spreading the fire (Boyd 1997). Active suppression can affect smoke generation and visibility as a cooling, slower fire produces more smoke than a rapidly burning fire. However, smoke management is typically a secondary concern to overall suppression and containment. Suppression actions are geared to control, containment, and confinement and, while cooling a fire, suppression may actually increase smoke generation over the short term while curtailing the

continued combustion of new fuels and additional smoke. There are too many variables for each fire and each suppression effort to make a definitive conclusion about the effect of suppression on smoke generation, regional air quality, and visibility. As the fire is the primary cause of air emissions, smoke and the pollutants generated as a result of the actual suppression efforts on the part of firefighters can be considered secondary and a minor consequence of the suppression effort. Suppression actions would generally have a short-term, moderate beneficial effect on regional air quality but would not reduce the potential for a large-scale catastrophic wildfire to occur in the future with more severe air quality impacts.

Table 4-6: Projected Annual Emissions for Wildland Fire in GGNRA

County / Cover Type	Wildland Fire Acreage	Emissions					
		PM_{10}	$PM_{2.5}$	VOC (as methane)	CO	NOx	SO2
Marin							
Coastal scrub	10	1,900	1,610	490	4,040	1,980	620
Grass	20	220	180	60	460	240	80
Native forest	2	7,280	6,170	3,734	81,672	62	290
Subtotal		**9,400**	**7,960**	**4,284**	**86,172**	**2,282**	**990**
San Francisco	**0**	**0**	**0**	**0**	**0**	**0**	**0**
San Mateo							
Coastal scrub	2	380	322	98	808	396	124
Grass	5	55	45	15	115	60	20
Native forest	0	0	0	0	0	0	0
Subtotal		**435**	**367**	**113**	**923**	**456**	**144**
Total Acreage	**39**						
Total Wildland Fire Emissions (pounds per year)		**9,835**	**8,327**	**4,397**	**87,095**	**2,738**	**1,134**
Total Wildland Fire Emissions (tons per year)		**4.9**	**4.2**	**2.2**	**43.5**	**1.4**	**0.6**

Source: GGNRA Fire Management Office and NPS Air Resources Division 2004.

Notes:

PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SO_2 = sulfur dioxide

Treatment of Muir Woods FMU

FOFEM is used to estimate the amounts of air emissions generated by the up to 50 acres of understory burning annually in the Muir Woods FMU in burn units of 0.5 to 50 acres. The fuel type used to generate emissions for understory is Pacific Douglas-fir with characteristics indicating low rate of forest canopy involved by the burning. Proposed FMP actions for this FMU also include approximately 5 acres of mechanical treatment, including providing defensible space around structures and preparing burn units for prescribed fires.

The proposed strategy for the Muir Woods FMU is the same under the three FMP alternatives. However, under each alternative, the 50 acres of prescribed burning in the understory of the redwood/Douglas-fir forest at Muir Woods differs in relative importance to the overall program for fuel reduction, in the degree of activity it represents, and the percent of total emissions it produces (see Tables 4-7 and 4-8).

Table 4-7: Relative Importance of Muir Woods Prescribed Burning (PB) Under Each Alternative

Alternative	Muir Woods PB as % of Total Acreage of PB	Muir Woods PB as % of Total Acreage of PB in Native Forest	Muir Woods PB as % of Total $PM_{2.5}$ Emissions	Muir Woods PB as % of Total VOC Emissions	Muir Woods PB as % of Total NOx Emissions
A	45%	100%	96%	98%	16%
B	42%	77%	74%	75%	16%
C	16%	71%	66%	69%	6%

Source: NPS Air Resources Division 2004.

Notes:

$PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), NOx = nitrogen oxides

Table 4-8: Projected Annual Emissions from Prescribed Burning in Douglas-Fir Forested Understory at Muir Woods FMU

Action Type	Acres	Emissions (tons per year)					
		PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Annual Emissions, Prescribed Fire	50	71.6	61.1	37.0	808.0	0.6	2.9

Source: NPS Air Resources Division 2004.

Notes:

PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SO_2 = sulfur dioxide

Table 4-8 shows the estimated levels of emissions produced by understory burning in the Muir Woods FMU at the annual maximum of 50 acres per year. Given the amount of preparation through mechanical treatment required prior to burning in a mature forest, restrictions on allowable burn days, demands for implementation of competing fire management projects elsewhere in the park, variable coastal climate, and visitation levels at Muir Woods National Monument, NPS fire staff may not be able to complete 50 acres per year or successfully schedule a prescribed burn in the redwood/Douglas-fir forest once each year. In actual practice, understory burning may be accomplished by a series of smaller burns scheduled over several consecutive years. (Estimated daily emissions under this scenario are shown in Table 4-9.) In this respect, the annual emissions estimated for Muir Woods FMU projects, which represents the largest generator of particulate matter and volatile organic compound (VOC) emissions annually for each alternative, may be overstating actual emissions produced by the three alternatives. Nonetheless, the estimate of emissions is a useful conservative estimate to compare the relative impacts for full implementation of the three alternatives.

Table 4-9: Projected Daily Emissions from Prescribed Burning in Douglas-Fir Forested Understory at Muir Woods FMU

Action Type	Total Acres	Burns per Year	Emissions per Burn (tons per day)					
Prescribed Burn Totals	**50 acres**	**3 burns total**	**PM_{10}**	**$PM_{2.5}$**	**VOC**	**CO**	**NO_x**	**SO_2**
Typical Forested Understory Prescribed Burn	16.6	3	23.7	20.3	12.3	268.2	0.2	0.9

Source: NPS Air Resources Division and GGNRA Fire Management Office 2004.
Notes:
PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NO_x = nitrogen oxides, SO_2 = sulfur dioxide

The total annual emissions of VOC, for which the air basin is in nonattainment status, is less than 50 tons per year, a level below the *de minimus* threshold and therefore not requiring a determination of conformity with the SIP. The No Action alternative would generate approximately 39.9 tons per year including the 39 acres of wildland fire annually. This level of emissions would have a long-term, moderate adverse effect on air quality, according to the methodology used when assessing those emissions with "nonattainment" status in the air basin. NOx emissions generated would be less than one ton per year and would have a long-term, negligible adverse effect.

Smoke management plans proposed by the NPS for prescribed burning in the Muir Woods FMU or other areas of the park are submitted to BAAQMD for approval at least 30 days before the planned burn day. The approval for ignition by BAAQMD is based on the objective of maintaining Bay Area Air Basin air pollutant emissions within the NAAQS shown in Table 3-4. BAAQMD's decision to permit ignition of prescribed burns is supported by the best available meteorology and forecasting at the time of ignition and allows BAAQMD to coordinate the location and amount of emissions generated simultaneously by prescribed burning in one air basin.

Generally, smoke effects from prescribed burning last only as long as the fire management action. Smoke behavior varies with the amount and type of fuel burned. In areas such as the redwood/Douglas-fir forests at Muir Woods National Monument, the fuel load consists of decades of accumulated duff. Because it tends to smolder, duff produces relatively more particulates than burning vegetation does. In grassland and coastal scrub, a higher percentage of fuels are light fuels that burn in the flaming phase, resulting in a significantly lower rate of emissions and smoke generation.

Dense smoke would likely occur in the vicinity closest to wildfire operations. Unhealthful concentrations of smoke would be most likely to affect fire personnel immediately adjacent to the fire. (See discussion under "Impacts on Human Health and Safety" below.) Most smoke plumes from fire suppression operations disperse at middle to upper elevations and, occasionally, under unfavorable wind conditions, into the more heavily populated areas of Marin County.

Under prevailing wind conditions, smoke generation would generally be confined to the interior of the Marin Headlands, Muir Woods National Monument, Muir Woods Road, and Panoramic Highway, with

short-term, minor adverse effects on the residential areas along Panoramic Highway. Ideal conditions for prescribed burning would push smoke west toward the ocean. Less ideal would be winds or drift to the southwest toward Muir Beach, Highway 1, and the Muir Beach community. However, if burn prescription conditions are met, prescribed burning could proceed under prevailing wind conditions, with potential short-term, minor-to-moderate adverse smoke effects on unincorporated areas of Mill Valley, Marin City, or Sausalito once or twice a year. Under offshore conditions, there could be a short-term, minor, adverse effect on visibility at Highway 1, Muir Beach, and the Muir Beach community

Treatment of San Francisco County Project Area

Fuel reduction projects within San Francisco parklands would involve (1) mechanical fuel reduction projects, primarily along the open space/residential interface where nonnative vegetation has created a fire hazard, and (2) research burns that are strictly limited in size and focus on resource enhancement objectives. Emissions from equipment use and from small research prescribed burn would have negligible effects on air quality. No pile burning is proposed for the San Francisco project area. Actions in the San Francisco project area would have a short-term, negligible adverse effect on regional air quality and no effect on visibility.

Public Information and Fire Education Programs

The public information and education program would be used to notify the public and visitors in advance of prescribed burning and pile burning projects. The program would also be the primary means used to explain the role of prescribed burning in promoting ecosystem health and restoration of the role of fire to the extent possible. In the immediate vicinity of proposed burning, the program would be used to identify any at-risk members of the public in advance of burning and discuss ways to protect their health if smoke drift affects the area or their neighborhood. The program would have no effect on regional air quality or visibility.

Fire Cache

The relocation of the fire cache to one facility would not affect regional air quality or visibility.

Fire Effects Monitoring

Implementation of the fire behavior monitoring program would have no effect on regional air quality or visibility.

Alternative A

Under Alternative A, the No Action alternative, a maximum of 110 acres of prescribed burning, 100 acres of mechanical treatment and limited pile burning (25 burn piles) could occur annually.

All prescribed burning at GGNRA has been, and would continue to be, planned and performed under the auspices of the BAAQMD Smoke Management Program. Prior to igniting a prescribed fire, GGNRA fire management staff must submit a smoke management plan to the BAAQMD Smoke Management Program and obtain meteorological approval to burn from that program. It is the responsibility of BAAQMD to coordinate the number of fires burning in one area. BAAQMD's objective is to ensure that

annual emissions from fire management actions implemented under the GGNRA FMP do not exceed state or federal standards.

Mechanical Fuel Reduction

As discussed earlier, emissions from mechanical treatments generated by equipment used to remove, process, or control vegetation are considered to be insignificant by the NPS Air Resources Division in relation to emissions generated by combustion, and have a negligible contribution to emission levels. For this reason, the low emission levels generated by equipment are not calculated as part of the impact assessment. Mechanical fuel reduction would have a short-term, negligible effect on regional air quality and visibility.

Pile Burning

Emission levels generated by pile burning under Alternative A are shown in Table 4-10. Burning of 25 piles would occur on one to three separate days depending on whether the woody debris was collected at one project site or at several. All pile burning would be coordinated with BAAQMD and a smoke management plan and burn plan would be submitted at least 30 days in advance for BAAQMD approval. Pile burning under Alternative A would have a short-term, negligible-to-minor adverse effect on regional air quality and visibility.

Prescribed Burning

As described earlier, FOFEM is used to estimate the amounts of air emissions that would be generated by the acreage of prescribed burning and number of pile burns proposed under Alternative A. In order to derive realistic emission totals, the inputs into FOFEM are based on the characteristics present at sites in GGNRA that could be proposed for prescribed burning in the future. The total area of the series of the burn sites modeled for each alternative is equivalent to the permissible acreage for prescribed burning annually under that alternative – for example, 110 acres under Alternative A. The vegetation type modeled is based on an estimate of the potential composition of the actual burn sites – roughly 27 percent grassland, 27 percent shrublands, and 45 percent forest understory. This estimate translates into 30 acres of grasslands, 30 acres of shrublands, and 50 acres of understory burns conducted primarily in redwood/Douglas-fir forest in Muir Woods National Monument.

All prescribed burns proposed by GGNRA must be approved for ignition by BAAQMD with the objective of maintaining Bay Area Air Basin air pollutant emissions within the NAAQS shown in Table 3-4. BAAQMD's decision to permit ignition of prescribed burns is supported by the best available meteorology and forecasting at the time of ignition and allows BAAQMD to coordinate the location and amount of emissions generated simultaneously by prescribed burning in one air basin.

Table 4-10: Projected Annual and Daily Emissions for Alternative A

ANNUAL EMISSIONS – TONS PER YEAR

Action Type	Area	Emissions (tons per year)					
		PM_{10}	$PM_{2.5}$	VOC	CO	NO_x	SO_2
Prescribed Fire: Grassland and Scrub	60 acres	3.0	2.6	0.8	6.4	3.2	1.0
Prescribed Fire: Forested Understory	50 acres	71.6	61.1	37.0	808.0	0.6	2.9
Pile Burning	25 burn piles	0.03	0.02	0.01	0.30	0.00	0.00
Annual Emissions From NPS Prescribed Fire		**74.6**	**63.7**	**37.8**	**814.7**	**3.8**	**3.9**
Estimated Annual Occurrence of Wildfire	39 acres	4.7	4.0	2.1	43.1	1.1	0.5
Total All FMP Projects – Alternative A		**79.3**	**67.7**	**39.9**	**857.8**	**4.9**	**4.4**

DAILY EMISSIONS –TONS PER DAY (per burn)

Action Type	Total Acres	Burns per Year	Emissions (tons per day)					
Prescribed Burn Totals	**110**	**7 burns total**	PM_{10}	$PM_{2.5}$	VOC	CO	NO_x	SO_2
Emissions – Typical Prescribed Burn in Grassland	30	2	0.1	0.1	0.0	0.2	0.1	0.0
Emissions – Typical Prescribed Burn in Coastal Scrub	30	2	1.4	1.2	0.4	3.0	1.5	0.5
Emissions – Typical Prescribed Burn in Forested Understory	50	3	23.9	20.4	12.3	269.3	0.2	1.0

Source: NPS Air Resources Division 2004.

Notes:

PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SO_2 = sulfur dioxide

Generally, air quality throughout GGNRA is very good due to prevailing winds and proximity to the Golden Gate and marine influences. Air quality can become degraded when the east Pacific high pressure system becomes displaced, typically in late summer and early fall when major atmospheric systems undergo a seasonal change. The result can be a general haze in the air basin, significantly impairing visibility (Sullivan et al. 2001).

The behavior of a smoke plume from a prescribed fire, including the direction and elevation of the plume and resulting concentrations at ground level, is highly dependent on elevation and dynamic meteorological conditions at the time. Higher-elevation winds tend to better dilute and disperse smoke at lower concentrations. High-level winds may transport dispersed smoke particles long distances. Complex

geography and weather patterns complicate the ability to predict exactly the quantity and destination of smoke particles in the plume. Fall and early winter generally have climatic conditions least favorable to smoke dispersion, while spring and summer generally have better conditions for dispersing smoke. Within GGNRA, prescribed burning is normally scheduled from early fall through late spring with specific meteorological requirements in the burn prescription for conditions with lower potential for loss of control of the fire and smoke dispersal. As discussed below under "Impacts on Human Health and Safety" and "Impacts on Visitor Use and Visitor Experience," care would be taken to site prescribed burns sufficiently distant from residential development and principal roads to avoid direct effects from smoke. GGNRA staff would inform park neighbors and visitors about the scope of prescribed burns and provide roadway assistance if burning results in visibility hazards on adjacent roadways.

Perceptible visibility impacts could occur during the prescribed burn but would be limited to primarily to the project site in the park and to the smoke plume following the prevailing winds; normally the smoke would disperse quickly during the course of the day. Prescribed burning under Alternative A could contribute 37.8 tons of VOC (as methane) and 3.8 tons of NOx annually to the Bay Area Air Basin. These pollutants are precursors to ozone; the air basin is currently in nonattainment for ozone though in attainment status for NOx. The level of VOCs would have a long-term, moderate adverse effect on air basin air quality; particulates (PM_{10} and $PM_{2.5}$) generated by full implementation of Alternative A would have a minor adverse effect recurring annually as additional areas of the park are treated to reduce fuels. The level of NOx and SO_2 would be considered a long-term, negligible adverse effect on air quality (see air quality methodology discussion at the beginning of this section).

Research

Impacts on air quality from the use of prescribed burning for research purposes are included in the overall assessment of effect of the full 110 acres of prescribed burning permitted annually under Alternative A. There is no effect on air quality from research burns distinct from the effect of the larger prescribed burning program. Research burns in the San Francisco project area would be of a very limited size, focusing on resource enhancement objectives in either grassland or coastal scrub and contributing negligible emissions annually.

Cumulative Impacts

Assessment of cumulative impacts for the FMP alternatives includes the effects of pile burning conducted to reduce debris from fuel reduction projects funded by the Wildland-Urban Interface Initiative occurring outside the park boundaries, and other prescribed burning occurring annually in western Marin County. Projects listed in Appendix C were considered in the cumulative impact assessment for air quality but, with the exception of the PRNS FMP, the projects listed would not generate significant emissions compared to those generated by prescribed burning and would have a relatively negligible effect.

Experience over the past three years of implementation of the Wildland-Urban Interface Initiative in the community shows that approximately 25 burn piles can be expected annually from community fuel reduction projects funded by this program. Additional projects considered in the cumulative scenario for air quality impacts (and included in Table 4-11) include the annual fuel reduction program conducted by the Marin County Fire Department, which is estimated at roughly 50 acres of prescribed burning and 50

burn piles annually (Julin 2004). These burns may be conducted on private property or on lands managed by California State Parks, the Marin County Open Space District, or the Marin Municipal Water District. Of the Marin County Fire Department prescribed burns, half of the vegetation affected would be on grasslands with nonnative broom species and half conducted in mixed evergreen forest understory.

Cumulative impacts also include prescribed burning conducted under the recently adopted PRNS FMP, which permits a total of 2,000 acres of prescribed burning annually. The amount of pile burning was not calculated for the PRNS assessment.

Table 4-11 below combines the total emissions levels for Alternative A projects from Table 4-10 with the additional emissions from Wildland-Urban Interface Initiative community projects and Marin County Fire Department burning that could cumulatively contribute to air quality impacts. Nearly all potential emissions would occur in Marin County, as compared to San Mateo County. (Under Alternative A, 91 percent of prescribed burning would occur in Marin County). The cumulative effect of GGNRA and Marin County Fire Department actions would be a long-term, moderate, adverse cumulative impact on ozone and PM_{10} levels, a minor long-term effect on $PM_{2.5}$ levels, and negligible effects on nitrogen oxide and sulfur dioxide levels in the air basin.

Table 4-11: Alternative A Annual Cumulative Air Emissions

Project Type	Acres	Fire Emissions (tons per year)					
		PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Total All FMP Projects Alternative A	110-acre PB 25 burn piles 39-acre wildland fire	**79.3**	**67.7**	**39.9**	**857.8**	**4.9**	**4.3**
Pile Burning for Community Projects Funded by Wildland-Urban Interface Initiative	25 burn piles	0.03	0.02	0.01	0.3	0	0
Total GGNRA Actions		**79.33**	**67.72**	**39.91**	**858.1**	**4.9**	**4.3**
Typical MCFD Annual Actions*	50 burn piles 50-acre PB	35.96	30.75	18.53	404.9	0.5	1.5
Total Annual Actions by GGNRA and MCFD		**115.3**	**98.5**	**58.4**	**1,263.0**	**5.4**	**5.8**
PRNS FMP Implementation	Up to 2,000-acre PB	241.3	205	101.3	1801.7	51.5	NG
Total Cumulative Annual Smoke Emissions		**356.6**	**303.5**	**159.7**	**3064.7**	**56.9**	**NG**

Source: PRNS Draft FMP 2004, NPS Air Resources Division and Kent Julin, Ph. D., County Forester, Marin County Fire Department, pers. comm.

Notes:

*Marin County Fire Department (MCFD) actions are meant to be representative of averaged estimated annual accomplishments.

PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SO_2 = sulfur dioxide, NG = not given, PB = prescribed burn

The PRNS FMP assessed the effects of prescribed burning on 2,000 acres annually and 1,500 acres of mechanical treatment. When the emission levels predicted for the selected alternative from the PRNS FMP EIS are added, impact levels of particulate matter and NOx move into the category of a long-term, major adverse cumulative effect on PM_{10}, $PM_{2.5}$, and VOC emission levels. The level of NOx emissions would have a long-term, minor effect and SO_2 emissions would remain at a negligible level of effect.

All prescribed burning at PRNS and GGNRA would continue to be planned and performed under the auspices of the BAAQMD Smoke Management Program, which in turn is incorporated into the SIP. The SIP is managed by BAAQMD staff to ensure that all ambient air quality standards and provisions of the Clean Air Act are met and public health is protected. Prior to igniting a prescribed fire, NPS fire management staff must submit a smoke management plan to BAAQMD and must obtain meteorological approval to burn from BAAQMD. It is the responsibility of BAAQMD to coordinate the numbers of fires burning in one area in relation to ambient air quality. The oversight of BAAQMD would ensure that annual emissions from fire management actions implemented under the PRNS FMP do not exceed state or federal standards. This oversight and the requirement to obtain BAAQMD approval for each individual prescribed burn, plus the availability of the mitigation measures to minimize the effects of prescribed burning, would reduce the level of effect on particulates and NOx to a long-term, moderate adverse cumulative effect.

Other projects and planning efforts listed in Appendix C would not generate nor significantly reduce emission levels on a scale that would be comparable to emissions generated by burning. Both the Comprehensive Transportation Management Plan for Parklands in Southwest Marin County and the Marin Headlands/Fort Baker Roadway Improvement and Transportation Management Plan are anticipated to include alternatives that would produce a slight reduction in vehicle emissions when fully implemented. This level of reduction in ambient air quality would not significantly reduce the effect of prescribed burning under Alternative A.

Conclusion

The largest source of air emissions is prescribed burning of understory fuels in the Douglas-fir/redwood forest in the Muir Woods FMU. This action is considered critical to the success of the FMP and is proposed as common to all alternatives. Understory burning in Muir Woods was initiated under the 1993 FMP and is the primary element held over from the original fire management plan. Under Alternative A, full implementation of prescribed burning in the Muir Woods FMU represents 96 percent of annual emissions while prescribed burning in 60 acres of grassland and coastal scrub vegetation generates the remaining 4 percent of annual emissions. Muir Woods FMU emissions would be generated in 1 to 3 prescribed burns annually depending on available opportunities for burn days, amount of pre-burn mechanical treatment needed to prepare a site for burning, competing demands on staffing and budgeting, and maintenance of prescription conditions through the burn day. (Changes in weather often result in early termination of burning or unsuccessful combustion when conditions are too wet.) The annual target of 50 acres of understory burning per year in each successive year can be considered as a worst-case scenario for air pollution generation under Alternative A with the exception of the occurrence of a catastrophic wildland fire. The intent of full implementation of Alternative A is to reduce the potential of a large-scale wildland fire and its consequent high levels of air emissions.

Alternative A would have a long-term negligible adverse effect on levels of NOx and SO_2, a long-term minor adverse effect on levels of particulates, and a long-term moderate adverse effect on levels of VOCs. Emission levels can be modified with the application of appropriate strategies from among the mitigation measures in consultation with BAAQMD.

The primary contributor to cumulative impacts in this portion of the air basin would be the full implementation of the approved PRNS FMP. Other similar actions in western Marin produce approximately half of the annual emissions estimated for GGNRA. Full implementation of the PRNS FMP and all other actions could produce more than twice the particulates generated by GGNRA and other sources annually (see Table 4-11). In comparison, a large-scale catastrophic wildland fire, such as the 1995 Vision Fire in Inverness Park in western Marin County, could produce nearly 85 times the amount of particulates (PM_{10}) as Alternative A and nearly 20 times the particulates generated by cumulative projects shown in Table 4-11 (NPS 2004a)[1].

Mitigating the cumulative impact on air quality is the regulatory authority of BAAQMD. BAAQMD has approval authority over all prescribed burns in the air basin and the authority to reduce emissions by assigning Mitigation Measures AIR-1 and AIR-2 to any prescribed burn. The oversight authority of BAAQMD to maintain air quality in conformance with the Clean Air Act would reduce the potential cumulative air quality impact to a long-term cumulative, moderate, adverse effect. By gradually lessening the potential for a large-scale wildland fire to occur with consequent high levels of air emissions, Alternative A would also have a long-term, minor, beneficial, cumulative effect on regional air quality.

Impairment

The effects of this alternative on air quality would not represent an impairment of important park resources or values.

Alternative B

Alternative B places a greater emphasis on mechanical fuel reduction, particularly in the WUI FMU. Alternative B would provide for a total of 230 acres of mechanical fuels treatment each year, primarily in Marin County. Approximately 70 acres of the 230 acres would occur as roadside fuel reduction or mowing along access roads and fire roads. Prescribed burning could occur on 120 acres of parkland each year, including the 50 acres at Muir Woods National Monument proposed for each of the alternatives. Higher permissible levels of mechanical fuel treatment under Alternative B than under Alternative A could result in a slight increase of levels of pile burning.

Mechanical Fuel Reduction

Mechanical fuel reduction would be similar to that under Alternative A and would have a short-term, negligible effect on regional air quality and visibility.

[1] FOFEM modeling for the PRNS FMP EIS estimated that a large-scale wildland fire, similar to the 1995 Vision Fire, could generate approximately 6,801 tons of PM_{10} and 3,395 tons of VOCs (NPS 2004a, page 234).

Pile Burning

Emission levels generated by pile burning under Alternative B are shown in Table 4-12. Burning of 100 piles annually could occur in Marin and San Mateo counties in either the Park Interior or the WUI FMU depending on where fuels are treated or fuel breaks are constructed. As under Alternative A, pile burning under Alternative B would have a short-term, negligible-to-minor adverse effect on regional air quality and visibility.

Table 4-12: Alternative B Annual Cumulative Emissions

Action Type	Acres	Emissions (tons per year)					
		PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Total All FMP Projects: Alternative B		**100.6**	**86**	**51**	**1,100.7**	**4.8**	**5.1**
Pile Burning for Community Projects Funded by Wildland-Urban Interface Initiative	25 burn piles	0.03	0.02	0.01	0.3	0	0
Total GGNRA Actions		**100.7**	**86.0**	**51.0**	**1,101.0**	**4.8**	**5.1**
Typical MCFD Annual Actions*	50-acre PB 50 burn piles	36.0	30.8	18.5	405	0.5	1.5
Total of Annual Actions by GGNRA and MCFD		**136.7**	**116.8**	**69.5**	**1,506.0**	**5.3**	**6.6**
PRNS FMP Implementation	Up to 2,000-acre PB	241.3	205	101.3	1,801.7	51.5	NG
Total Cumulative Annual Smoke Emissions		**378.0**	**321.8**	**170.8**	**3,307.7**	**56.8**	**NG**

Source: Kent Julin, Ph. D., County Forester, Marin County Fire Department 2004 and NPS Air Resources Division 2004.

Notes:

* Emissions for Marin County Fire Department (MCFD) actions are meant to be representative of averaged estimated annual accomplishments

PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SO_2 = sulfur dioxide, NG = not given, PB = prescribed burn

Prescribed Burning

FOFEM modeling for Alternative B is based on a mock annual work plan of prescribed fire project sites comprised of 27 acres of grasslands, 28 acres of coastal scrub, and 65 acres of forested understory. In addition to 50 acres in the Muir Woods FMU, the remaining acres of prescribed burning would occur in the Park Interior FMU in Marin County. This total of 120 acres of prescribed burning was modeled with the output of 100 burn piles modeled as nonnative wood debris. No prescribed burning, other than very small-scale research burns, are proposed for San Mateo or San Francisco counties. Table 4-13 shows projected annual and daily emissions for this alternative.

Table 4-13: Projected Annual and Daily Emissions for Alternative B

ANNUAL EMISSIONS – TONS PER YEAR

Action Type	Area	Emissions (tons per year)					
		PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Prescribed Fire: Grassland and Scrub	55 acres	2.8	2.4	0.7	6.0	2.9	0.9
Prescribed Fire: Forested Understory	65 acres	93.0	79.5	48.1	1,050.4	0.8	3.7
Pile Burning	100 burn piles	0.1	0.1	0.1	1.2	0.0	0.0
Annual Emissions From Prescribed Fire		**95.9**	**82**	**48.9**	**1,057.6**	**3.7**	**4.6**
Estimated Annual Occurrence of Wildfire	39 acres	4.7	4.0	2.1	43.1	1.1	0.5
Total All FMP Projects: Alternative B		**100.6**	**86**	**51.0**	**1,100.7**	**4.8**	**5.1**

DAILY EMISSIONS –TONS PER DAY (per burn)

Action Type	Total Acres	Burns per Year	Emissions (tons per day)					
Prescribed burn totals	**120**	**6 burns total**	PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Emissions – Typical Prescribed Burn in Grassland	27	1	0.1	0.1	0.0	0.3	0.2	0.1
Emissions – Typical Prescribed Burn in Coastal Scrub	28	2	1.3	1.1	0.3	2.8	1.4	0.4
Emissions – Typical Prescribed Burn in Forested Understory	65	3	31.0	26.5	16.0	350.1	0.3	1.2

Source: NPS Air Resources Division 2004.

Notes:

PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SOx = sulfur dioxide

Prescribed burning activity under Alternative B is nearly identical in vegetation type to Alternative A. Unlike Alternative A, all prescribed burning, with the exception of pile burning, would be restricted to the Park Interior FMU away from residential areas. The principal difference for purposes of emissions modeling is an additional 15 acres of understory burning in forested areas under Alternative B. On a per-acre basis, the increase in forested areas under Alternative B produces a higher emission rate than did Alternative A. The greater level of mechanical fuel reduction under Alternative B as compared to Alternative A, with a comparable level of prescribed burning, would allow Alternative B to reduce areas of hazardous fuels in the park more quickly and contribute to decreasing the potential risk of a catastrophic wildfire, with accompanying high levels of air emissions, originating near the parklands.

Alternative B would produce approximately 23 percent more fine particulates than Alternative A (82 tons per year of $PM_{2.5}$ compared to 63.7 tons per year of $PM_{2.5}$, respectively) and would have a long-term, minor adverse effect, as under Alternative A. Emissions could occur at the time of prescribed burning, would be visible locally within the park, and would be dispersed quickly during the course of the day. As under Alternative A, Alternative B would have a short-term, minor, adverse effect on visibility locally during prescribed or pile burning.

Alternative B could contribute higher levels of VOC (as methane) than Alternative A (48.9 tons per year compared to 37.8 tons per year for Alternative A). Contributions of NOx are essentially equivalent under the two alternatives, though slightly less under Alternative B. As in Alternative A, the level of VOCs generated by Alternative B would have a long-term, moderate adverse effect on air basin air quality. NOx emissions are roughly similar under Alternative B as compared to Alternative A and would have a long-term, minor adverse effect by adding 3.7 tons per year of this ozone precursor to the air basin.

Impacts of prescribed fire activity on the surrounding communities, such as reduced visibility and smoke nuisance effects, would be reduced under Alternative B, as prescribed burning would be restricted to more remote parts of GGNRA, with the exception of proposed burning in the Muir Woods FMU and the potential for a higher level of pile burning permitted throughout all FMUs.

Research

Impacts on air quality from the use of prescribed burning for research purposes are included in the overall assessment of effect of the full 120 acres of prescribed burning permitted annually under Alternative B. There would be no effect on air quality distinct from the effect of the larger prescribed burning program.

Cumulative Impacts

The combined emissions of FMP actions under Alternative B and other GGNRA fire-related emission sources are shown in Table 4-12. As in Alternative A, other GGNRA emission sources include pile burning through Wildland-Urban Interface Initiative grants and emissions generated by wildland fire occurring in the park. With the addition of the typical annual burn program supervised by Marin County Fire Department (MCFD) staff in the county, the emission levels would increase but remain within the moderate intensity threshold. As discussed earlier, the threshold for criteria pollutants that are in attainment in the air basin is considered moderate up to 250 tons per year. The cumulative effect of all GGNRA actions plus the annual MCFD work program would create long-term, moderate, adverse cumulative impacts on $PM_{2.5}$ levels and ozone precursors NOx and VOC.

When considered in conjunction with the level of prescribed burning assessed in the PRNS FMP FEIS, air quality impacts under Alternative B would be similar to those under Alternative A. The emission levels for PM_{10}, $PM_{2.5}$, and VOC meet and exceed the threshold for a long-term, major, adverse cumulative effect on air basin emissions. The level of NOx emissions would have a long-term, minor adverse cumulative effect on air basin air quality.

As with Alternative A, the oversight of BAAQMD, the requirement to obtain BAAQMD approval for each individual burn plan, and the implementation of Mitigation Measures AIR-1 through AIR-7 to

minimize the effects of prescribed burning would reduce the impact of particulates and NOx to a long-term, moderate adverse cumulative effect.

By gradually lessening the potential for a large-scale wildland fire to occur, Alternative B would have a long-term, minor, beneficial, cumulative effect on regional air quality.

Conclusion

Air quality impacts of Alternative B would be greater than those estimated for Alternative A, as a larger acreage could be treated annually under Alternative B. Though more emissions would be produced annually, the level of effect based on NAAQS status would be essentially the same. The effects of particulate generation would be long-term (annually occurring), minor, and adverse, as under Alternative A. Similar to Alternative A, VOC emissions would be a long-term, moderate, and adverse, and NOx and SO2 emissions would be long-term, negligible, and adverse contributions to air basin air quality. The highest amount of emissions would be produced by one to three prescribed burns in the Muir Woods FMU, which represents approximately 75 percent of the particulate and VOC emissions produced under Alternative B. The full implementation of prescribed burning in Muir Woods is the same under each alternative and, as under Alternative A, the ability to achieve the full 50 acres annually in that FMU would depend on many constraining factors, such as availability and timing of burn days and demands on staff.

The cumulative air quality effects of Alternative B would be very similar to those of Alternative A. Full implementation of the PRNS FMP and all other actions could produce more than twice the particulates generated by GGNRA and other sources annually and would be a long-term, major adverse effect.

Impairment

The effects of this alternative on air quality would not represent an impairment of important park resources or values.

Alternative C

Alternative C provides for a total of 275 acres of mechanical fuels treatment each year. Approximately 70 acres of that treatment would occur as roadside fuel reduction or mowing along access roads and fire roads. Prescribed burning could occur on 320 acres of parkland each year, including the 50 acres in the Muir Woods FMU proposed for each of the alternatives. For purposes of air quality assessment, pile burning is estimated at 100 piles of 64 cubic feet each.

Mechanical Fuel Reduction

Alternative C would allow for a greater amount of mechanical fuel treatment than under Alternatives A and B. Equipment and vehicle use during mechanical fuel reduction projects would have a negligible, short-term, adverse effect on air quality and visibility in the opinion of the NPS Air Resources Division staff.

Pile Burning

Emission levels generated by pile burning under Alternative C are shown in Table 4-14. The same estimate for pile burning is used for Alternative B and Alternative C. As under Alternative A, pile burning under Alternative C would have a short-term, negligible-to-minor adverse effect on regional air quality and visibility.

Table 4-14: Alternative C Annual Cumulative Emissions

Action Type	Acres	Emissions (tons per year)[a]					
		PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Total All FMP Projects: Alternative C		**112.8**	**96.2**	**55.7**	**1,178.6**	**11.4**	**7.4**
Pile Burning for Community Projects Funded by Wildland-Urban Interface Initiative	25 burn piles	0.1	0.1	0.1	1.2	0	0
Total GGNRA Actions		**112.9**	**96.3**	**55.8**	**1,179.8**	**11.4**	**7.4**
Typical MCFD Annual Actions*	50-acre PB 50 burn piles	36.0	30.7	18.5	404	0.4	1.5
Total of Annual Actions by GGNRA and MCFD		**148.9**	**127.0**	**74.3**	**1,583.8**	**11.8**	**8.9**
PRNS FMP Implementation	Up to 2,000-acre PB	241.3	205	101.3	1,801.7	51.5	NG
Total Annual Smoke Emissions		**390.2**	**332.0**	**175.6**	**3,385.5**	**63.3**	**NG**

Source: Kent Julin, Ph. D., County Forester, Marin County Fire Department 2004 and NPS Air Resources Division 2004.

Notes:

* Emissions for Marin County Fire Department (MCFD) actions are meant to be representative of averaged estimated annual accomplishments.

PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SO2 = sulfur dioxide, NG = not given, PB = prescribed burns.

Prescribed Burning

Alternative C is based on a representative annual work plan totaling 320 acres of prescribed burning each year, divided among 86 acres of coastal scrub (27 percent of the total), 165 acres of grassland (52 percent), and 69 acres of understory burning in redwood/Douglas-fir forest (22 percent). Understory burning produces very high emission levels compared to prescribed burns in grass or coastal scrub. Table 4-15 shows projected annual and daily emissions for this alternative. Emission levels for fine particulates would be 92.2 tons per year under Alternative C, compared to 63.7 tons per year under Alternative A. Alternative C would therefore produce more fine particulate emissions than Alternative A. Though it could result in more frequent prescribed fires and pile burning, Alternative C would still have a short-term, minor adverse effect on visibility in the local region. VOC emissions would be higher under Alternative C, compared to Alternative A. The increase in the estimated level of NOx would be 10.3 tons per year under Alternative C, compared to 3.8 tons per year under Alternative A. This would be an

increase of 63 percent over Alternative A. The increase represented by emissions produced under Alternative C would have a long-term, moderate adverse effect on levels of these ozone precursors and on air basin air quality.

Table 4-15: Projected Annual and Daily Emissions for Alternative C

ANNUAL EMISSIONS – TONS PER YEAR

Action Type	Area	Emissions (tons per year)					
		PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Prescribed Fire: Grassland and Scrub	251 acres	9.1	7.7	2.4	19.3	9.5	3.0
Prescribed Fire: Forested Understory	69 acres	98.9	84.4	51.1	1,115.0	0.8	3.9
Pile Burning	100 burn piles	0.1	0.1	0.1	1.2	0.0	0.0
Annual Emissions From Prescribed Fire		**108.1**	**92.2**	**53.6**	**1,135.5**	**10.3**	**6.9**
Estimated Annual Occurrence of Wildfire	39 acres	4.7	4.0	2.1	43.1	1.1	0.5
Total All FMP Projects: Alternative C		**112.8**	**96.2**	**55.7**	**1,178.6**	**11.4**	**7.4**

DAILY EMISSIONS – TONS PER DAY (per burn)

Action Type	Total Acres	Burns Per Year	Emissions (tons per day)					
Prescribed Burn Totals	**320 acres**	**6 burns total**	PM_{10}	$PM_{2.5}$	VOC	CO	NOx	SO_2
Emissions – Typical Grass Prescribed Burn	165	4	0.2	0.2	0.1	0.5	0.2	0.1
Emissions – Typical Scrub Prescribed Burn	86	4	2.0	1.7	0.5	4.3	2.1	0.7
Emissions – Typical Forested Understory Prescribed Burn	69	4	24.7	21.1	12.8	278.8	0.2	1.0

Source: NPS Air Resources Division 2004.

Notes:

PM_{10} = suspended particulate, $PM_{2.5}$ = fine particulate matter, VOC = volatile organic compounds (methane), CO = carbon monoxide, NOx = nitrogen oxides, SOx = sulfur dioxide

Impacts of prescribed fire activity on the surrounding communities could be more widespread under Alternative C and have greater potential for smoke to drift to nearly residential areas, as prescribed burning would be allowed in the WUI FMUs to some degree in both San Mateo and Marin counties. Only 5 acres of prescribed burning would take place in the WUI FMU in San Mateo County.

Research

Impacts on air quality from the use of prescribed burning for research purposes are included in the overall assessment of effect of the full 320 acres of prescribed burning permitted annually under Alternative C. There would be no effect on air quality distinct from the effect of the larger prescribed burning program.

Cumulative Impacts

Cumulative impacts from just the GGNRA fire-related actions under Alternative C (NPS projects, Wildland-Urban Interface Initiative community projects, suppression of wildland fires) would have a long-term, cumulative, moderate, adverse effect on PM_{10} and VOC emissions generation and a long-term moderate, adverse cumulative effect on emissions of ozone precursors, NOx and VOC. This is the same outcome as was determined for Alternatives A and B.

As in Alternatives A and B, when MCFD's annual program is added to GGNRA fire-related actions, the level of cumulative effect on particulate matter is raised to a long-term, moderate and adverse effect, as more than 100 tons per year of $PM_{2.5}$ would be generated from the combined actions. Levels of NOx and VOC would also represent long-term moderate and adverse cumulative effects.

And finally, with the addition of emissions from the PRNS maximum annual program, threshold levels for particulates and NOx would exceed the threshold for a long-term major adverse effect. This impact could be minimized to a level of long-term, moderate adverse effect, as in Alternatives A and B. Mitigation Measures AIR-1 through AIR-7 could be applied and BAAQMD's authority and oversight would ensure that emission levels and the attainment status in the air basin are not compromised by excessive production of emissions through prescribed burning.

Alternative C follows a more accelerated regimen to reduce high fuel loading as compared to Alternatives A and B. Alternative C would result in a long-term, moderate, beneficial effect on cumulative air quality.

Conclusion

On an annual basis, Alternative C would generate the highest levels of particulate emissions among the three alternatives. This is a result of the greater number of acres treated each year by prescribed burning and the higher percentage of understory burning represented in Alternative C. Depending on the size of the prescribed burn in the forested area, levels of fine particulates generated per burn day would range from approximately 21 to 26.5 tons per burn with roughly three to four understory burns per year. On an annual basis, Alternatives A and B would result in a long-term, minor adverse effect on regional visibility. The impact is considered long-term as the effect would recur annually during the life of the FMP. The Bay Area Air Basin is in attainment for federal standards for particulate matter. Alternatives A and B would contribute between 50 and 100 tons of additional PM_{10} annually. Alternative C would contribute approximately 110 tons per year of PM_{10}, a level of effect that is considered long-term, moderate, and adverse.

Emissions of NOx and SO_2 generated under the three alternatives would have a long-term, negligible effect.

Alternative C would annually produce the highest amount of the ozone precursor VOC at levels representing a long-term, moderate adverse effect on air basin air quality, as would Alternatives A and B. The effect is determined to be long-term due to the continued annual contribution of the FMP over the life of the planning effort (approximately 15 years). The effect is judged as moderate because the additional emissions of 53.6 tons per year are more than 5 tons per year and less than the conformity *de minimus* levels of 100 tons per year for VOC .

The annual acreage treatment under Alternative A would not appreciably reduce the potential size or severity of a catastrophic wildfire even after a decade of implementation. Under Alternative B, and more so under Alternative C, fuel reduction efforts would begin to reduce the potential for a catastrophic wildfire to occur near GGNRA lands with resultant high levels of air pollutant emissions. All alternatives would have a long-term, beneficial effect on air quality by reducing this potential for a large fire. Under Alternatives A and B, the effect would be long-term, minor and beneficial; under Alternative C, it would be long-term, moderate and beneficial.

Other FMP actions are considered to have minor or negligible effects or no effect on air quality.

Impairment

The effects of this alternative on air quality would not represent an impairment of important park resources or values.

Impacts on the Biological Environment

Impacts on Vegetation

Analysis

Numerous activities associated with wildland fire, prescribed fire, wildland fire suppression, and mechanical treatments can have either adverse or beneficial impacts on vegetation. Impacts can be sustained by individual plants or by plant communities. Examples of impacts on individual plants include direct mortality or physical damage resulting from burning, or from mowing or cutting vegetation for fire line. A plant community-level impact would occur if cutting fire line or prescribed burning led to the establishment or spread of nonnative plants, which could alter plant community species diversity and function. Mitigation such as monitoring and the removal of nonnative plants would limit these effects. This analysis is intended to reflect NPS Management Policies 2001, which states that "All cultural resource and natural resource values will be considered in defining specific treatment and management goals (NPS 2000a).

The impacts of fire on vegetation are a function of the severity of the fire itself and characteristics of the plants on the site. The ultimate response of a plant or a plant community to fire is related to the type of fire (e.g., surface vs. crown), fire behavior, fire duration, fire intensity, the season in which the fire burns, and how recently the area burned in the past. Fuel quantity and arrangement, fuel moisture content, topography (e.g., slope and aspect), wind speed, and the structure of the plant community itself cause the lethal heat zone to vary significantly in time and space (Miller 2000). This means fire effects on plants can vary not only widely among fires, but also among different areas of the same fire.

Species and individual plants respond uniquely to fire based on plant age, vigor, morphology, reproductive strategies (e.g., seeders vs. sprouters), germination requirements, and phenological state at the time of the fire. Trees, shrubs, and herbaceous species all respond differently to fire and exhibit numerous strategies for post-fire colonization, including sprouting and seeding. The amount of subsurface heating that occurs, as well as the amount of organic matter removed from the soil surface, affects plants and regeneration. Post-fire weather also influences post-fire species establishment (e.g., which species will recolonize the site and how quickly) and affects the success of newly established plants.

Post-fire plant communities, at least for the first few years following the fire, are comprised of species that have the following regeneration strategies: plants that survived the fire, plants that produced sprouts or suckers from the base or from protected aerial reproductive structures, or plants that established from seed. Seedlings that establish on a burned site are derived from seeds that were dispersed from plants that survived the fire (usually trees), were dispersed onto the site from adjacent unburned areas, were in the soil seed bank that were stimulated to germinate by the fire, or came from plants within the fire that resprouted following the fire (Miller 2000).

Types of Effects from Prescribed Burning

Prescribed fire can result in direct mortality, can damage plants or seeds, and can change plant community structure and species composition. The primary difference, however, between unplanned wildland fire and prescribed fire is that prescribed fires are conducted under a rigid set of prescriptive parameters, including air temperature, fuel moisture, and wind speed. Prescribed fire planners and managers, therefore, exercise careful control over when and where the burns occur, and site-specific prescriptions are developed to meet set objectives relative to vegetation.

The impacts associated with line construction, holding, monitoring, and mop-up of prescribed fires would be similar to those described in the following section addressing suppression of unplanned wildland fire. These impacts, however, would be less substantial with prescribed fire because fire would be carefully planned to minimize impacts and would be implemented under controlled conditions.

Types of Effects from Wildland Fires and Suppression

The direct effects of unplanned wildland fires on vegetation can be substantial, including long-term, possibly permanent changes in plant species composition or percent cover, and the introduction or spread of nonnative plant species. However, in burned areas where a high percentage of trees survive and native understory vegetation resprouts, it can be difficult to determine that a fire has recently occurred.

Actions Common to All Alternatives

Wildland-Urban Interface Initiative

The emphasis of the Wildland-Urban Interface Initiative at GGNRA is to reduce the density of hazardous fuels that create a risk to lives or property on parklands adjacent to the park boundary. Most projects would continue to focus upon the mechanical removal of nonnative and highly flammable eucalyptus and acacia trees and nonnative shrubs (cotoneaster, brooms) from areas where parklands are adjacent to neighboring properties. The removal of these nonnative species would have two primary long-term benefits: reducing the chances for large, high-intensity burns, and promoting or allowing for the

reestablishment of more compatible native vegetation close to developments. For example, native species of oak and California bay laurel, which typically inhabit sites where eucalypts have invaded, provide key habitat for wildlife species and patchy year-round shade for the development of diverse and less flammable native plant assemblages, including coastal scrubland and hardwood forests. Mechanical removal activities would remove vegetation, disturb soil and forest litter, and change shade and moisture characteristics through loss of overstory cover. With mitigations, including development and implementation of revegetation and weed efforts in conjunction with Wildland-Urban Interface Initiative projects, these short-term adverse impacts would result in minor long-term beneficial impacts on vegetation.

Defensible Space/Vegetation Clearing Around Structures

The creation of defensible spaces around structures would remove vegetation and disturb soil and litter, with the possibility of increasing cover of nonnative plant species following soil disturbance. However, these species could easily be removed due to their proximity to frequently used areas of the park, and new invasions would be detected early enough to avoid spread into adjacent wildlands. Impacts would be minor to negligible, adverse, and long-term because treatments would need to be repeated.

Roadside Fuel Reduction

Fire road maintenance would remove vegetation adjacent to road edges, creating open and available habitat for the invasion of nonnative plant species. Efforts already underway in the park to mitigate these effects (e.g., minimizing soil and ground litter disturbance by increasing the height of mower blades) have seen some reduction in this predictable incursion of nonnative plant species. A number of studies have shown that roads serve as vectors for intrusion of new nonnative plants, which can "hitch a ride" on passing vehicles, pedestrians, and other fire road users. Therefore, identification of needed fire roads is critical, and downgrading of unnecessary fire roads to trails or complete road obliteration should be a priority for fire management personnel. Annual roadside surveys, an action common to all alternatives, can help detect and stop the spread of new nonnative species. Maintaining fire roads would have greater impacts on vegetation than clearing defensible space around buildings because some portions of fire roads run through interior, relatively intact vegetation communities in the park. Impacts would be minor to moderate, depending on the integrity of the surrounding vegetation; adverse; and long-term because treatments would be repeated.

Suppression

Activities associated with suppression of wildland fire can kill or damage native vegetation. Adverse effects on vegetation can result from fire suppression activities such as construction and use of staging areas, helispots, or spike camps; construction of fire lines using hand tools or bulldozers; cutting of snags; and mop-up. Maintaining control of prescribed fires can also involve hand line construction, snag removal, water drops, and other actions, but such efforts are likely to be much less intense and have less impact than they would during wildland fire suppression. The impacts of hand line construction in association with managed wildland fire, in conjunction with mitigation measures, would be adverse, short-term, and negligible given the present limited amount of wildland fire that occurs and the relatively limited use of prescribed fire called for in the GGNRA FMP alternatives.

Individual plants and plant communities can be damaged or destroyed when vehicles are traveling to sites or staging areas or when bulldozers are constructing fire lines, creating avenues for nonnative plant establishment through soil disturbance, loss of native vegetation cover, and changes in light and moisture conditions. It is anticipated that in most cases these impacts would occur infrequently. Similar effects could result from removal or trampling of vegetation in temporary staging areas and helispots used for suppression activities. Spills of fuel, oil, hydraulic fluid, antifreeze, and other toxic chemicals at staging areas and helispots could adversely affect vegetation though changes in soil chemistry, hydrophobicity, and water uptake properties, especially if spills occur in wetter environments such as riparian forest and scrub and herbaceous wetland communities. All landing areas will meet the standards outlined in the Interagency Helicopter Operations Guide, and safe landing spots identified in the GGNRA Aviation Management Plan mitigations would be used. These mitigations, in addition to limiting helispot construction and locating helispots away from sensitive resources, would reduce these impacts.

Use of water or retardant drops during suppression activities can have both a direct adverse impact – from the sheer force of the physical impact – and a longer-term chemical impact due to the chemical composition of the materials used. Most fire retardants contain fertilizer-type compounds, including ammonia, nitrogen, and phosphorous, that can change vegetation, especially in areas low in nitrate/ammonia-type nutrients. Added nutrients can decrease growth of native vegetation and increase the establishment of nonnative species that favor higher nutrient levels, or can stimulate unnatural growth spurts during drought-stressed periods of the year (when fires are most common), causing longer-term stress to individual plants. Impacts can be mitigated by avoiding use of retardant or by using "clear" retardant that has minimal active nutrients within the mix. Retardants can cause short-term impacts on the overall health and reproductive ability of some species, although fall and winter rains leach these chemicals out of the system and long-term effects are not detectable.

The proximity of saltwater to most areas of GGNRA means there is a high likelihood for the use of saltwater or brackish bay water during suppression actions. Short-term die-back in annual species can result if salts are concentrated in drainages and swales. Again, these impacts are generally short-term as the annual rains flush salts out of the system. In addition, most vegetation communities in the park are adapted to some salt deposition from fog cover, so overall impacts are negligible from the chemical standpoint, and minor to negligible from the direct impact (force of water/retardant falls) on plants. The advantage of water and retardant drops is that in some circumstances they can take the place of hand lines ("wet-lining") to control fire movement. This tactic results in less physical impact on soils, forest litter, and vegetation than hand line construction.

Personnel at fire camps or on suppression crews have the potential to transport weed seeds with their equipment and tools, which may have long-term adverse impacts on vegetation composition. They also cause trampling and loss of vegetation cover, which could have short- to long-term, negligible, adverse impacts. However, locating spike camps away from sensitive resources such as shrub lands and riparian/wetlands areas would help minimize these impacts.

Hand line construction would remove vegetation and disturb soil and forest litter, leading to soil erosion and loss of native seedbanks and soil structure. In all cases, minimum impact suppression tactics (MIST)

would be used to minimize ground disturbance, including use of wet lines and construction of minimal hand lines through the use of mowers to break up fuel continuity and retain vegetation stems on the ground surface (see Appendix G).

Mop-up, or the churning of soil and forest litter to extinguish residual hot spots along the periphery of a fire, would cause additional impacts on soil integrity and the soil seedbank, creating an increased potential for introduction and establishment of nonnative plant species within native plant stands. These actions could also stimulate sprouting of hard-coated seeds including French broom, Scotch broom, cotoneaster, and other species typically found in grasslands, coastal scrub, and the understory of nonnative evergreen forests. Although "flushes" of weedy species would occur after ground-disturbing activities, these actions would also speed up the removal of weed seed in the seedbank, which, in conjunction with ongoing vegetation management of post-fire areas (to prevent sprouted seeds from reaching maturity and gong to seed again), would gradually eliminate these species from the burn area.

The use of a flexible suppression strategy wherever possible can help mitigate potential adverse impacts, as discussed above. Use of indirect fire lines to take advantage of either natural firebreaks (rock outcrops, bodies of water) or roads or otherwise devegetated areas would have a substantial beneficial effect on natural vegetation areas by minimizing ground disturbance through the construction of direct fire lines with hand tools and machinery. This flexible strategy would allow fire personnel to direct wildland fires toward areas of lower fuel loads, such as previously thinned or cleared WUI sites, such that suppression fire lines could be smaller and less intrusive on the landscape. (This is because line width and extent change based on the fuel that the line is being cut through; lines through grass are minimal, whereas control lines through forested areas can be substantial, with large areas of ground disturbance and vegetation loss.) Using this strategy would reduce the level of effect to a negligible-to-minor adverse impact on vegetation, with long-term effects.

Treatment of Muir Woods FMU

Fire actions for Muir Woods FMU would include a mix of prescribed fire, mechanical fuel reduction, and understory thinning projects. Prescribed burning would be conducted to reduce fuel loading and restore vegetation structure and composition to areas with high nonnative plant components, as well as to restore the disturbance role fire plays within the coastal scrub and chaparral, grassland, and redwood/Douglas-fir ecosystem. Burns would range in size from 0.5 to 50 acres annually in a variety of vegetation communities. Research burns would be conducted to investigate how fire affects the spread and control of the Sudden Oak Death (SOD) pathogen, *Phytophthora ramorum.*

Adverse impacts on vegetation from fire management actions would largely be associated with undesired changes in vegetation composition and structure. This could include introductions or increases in existing nonnative plant species and cover, alterations of vegetation communities to conditions that will not sustain the native species components (such as removal of overstory trees in riparian corridors), and substantially increased fuel loads that could support higher-intensity wildland or prescribed fires. Careful consideration of fire management activities, including adherence to sound prescribed burn prescriptions, review of burn objectives with natural resources staff, and adequate planning and implementation of pre- and post-burn weed treatments, would mitigate these impacts. Fire actions in forest and woodland areas

typically produce an initial increase in fuel loads (due to understory mortality), but should not adversely affect long-term vegetation characteristics. The adverse impacts of fire management actions in most cases would be minor and short-term due to the limited areas that would be affected, and negligible with inclusion of all mitigation measures. Long-term beneficial impacts would result from fire actions that restore and enhance native plant communities and vegetation structure.

Fire management activities in nonforested areas (grassland, coastal scrub, and chaparral) would have similar long-term beneficial effects by restoring native plant communities and vegetation structure. Adherence to specific mitigation measures, such as minimizing ground disturbance activities during implementation of fire actions, using carefully designed prescriptions and adhering to those prescriptions, and developing and evaluating specific project objectives, would result in minor-to-major beneficial effects, depending on the condition of the site prior to the action. For example, a prescribed burn implemented in an area with a dominant nonnative grass cover, such as Harding grass, that was converted to native grassland through careful burn implementation would have a major beneficial effect on the park's grassland community. Sites with little to no nonnative component that were maintained at those same levels through fire actions, such as burning in hardwood forest understory areas, would have a minor beneficial effect. Actions that enhance the opportunity for coast redwoods within Muir Woods National Monument to out-compete encroaching Douglas-fir saplings, either through removal of encroaching trees or improved redwood regeneration, would have a moderate beneficial impact with long-term effects.

Fire management actions would have many long-term benefits in Muir Woods National Monument. Reducing the chances for catastrophic fire would prevent the loss of the last contiguous stand of old-growth coast redwood forest in the region, as well as protect portions of the Redwood Creek watershed. Research on fire effects on SOD may lead to ways to control the pathogen and prevent excessive loss of the tan oak understory, which provides cover and acorns for wildlife. Removal of nonnative plants and restoration of natural stand structures and ground litter load would foster the reestablishment of native plant species.

Treatment of San Francisco County Project Area

The fuel reduction strategy for San Francisco lands focuses upon maintaining defensible spaces around buildings (see discussion above) and removing nonnative trees, with small research burns in association with listed threatened and endangered plant species. These actions would remove vegetation and could disturb soil and litter, possibly increasing the potential for establishment of nonnative plant species. Adverse effects would be long-term and minor.

Public Information and Fire Education Programs

Impacts associated with public information and education would largely be indirect and beneficial, although highly dependent on the nature of the fire management action. Pre-planned events such as prescribed fires and mechanical treatment provide the opportunity to demonstrate the effectiveness of natural resource management to local communities and the interested public. During unplanned events, such as wildfires, time for effective communication is often more limited and education efforts can be more controversial since resources are often damaged. However, public information and education could

have an indirect positive effect on vegetation. For example, education can be used to enforce a closure of an area to ensure quick habitat recovery or to increase recruitment of stewardship volunteers for revegetation or weeding projects associated with fire management activities.

Fire Cache

Centrally locating the fire cache and management personnel within GGNRA allows for faster response time to wildfires, implying less potential for higher-intensity and larger fires, as well as less intensive suppression activities. The use of existing buildings for the fire cache would avoid impacts on vegetation from construction activities. Fire cache relocation would have indirect, beneficial, long-term effects on vegetation.

Fire Effects Monitoring

There would be some trampling and disturbance effects associated with onsite monitoring of vegetation and fuels, although these would be relatively minor. The timing of monitoring would influence the intensity of these effects. For example, conducting field work during early spring growth when herbaceous species are easily crushed and soils are wet and erodible would have a very localized minor adverse effect. The knowledge gained, however, through monitoring and subsequent data analysis would be beneficial to vegetation. By gaining a better understanding of how fire behaves in different vegetation communities and in different weather and climatic conditions, park fire specialists would be better able to avoid catastrophic fire events and use fire management actions to enhance vegetation structure and composition. Overall, the impacts associates with monitoring fire effects would be minor to moderate, long-term, and beneficial.

Alternative A

Mechanical Fuel Reduction

Approximately 100 acres of vegetation would be mechanically treated under this alternative, reflecting the current level of park practices. Work would continue to be focused on the removal of nonnative, highly flammable vegetation in Marin, San Francisco, and San Mateo counties; the second-growth redwood/Douglas-fir at Muir Woods National Monument; and the grassland and coastal scrub in all three counties, with an emphasis on Marin County. The focus of treatment would be removal of eucalyptus, Monterey pine and cypress, acacia, and other flammable trees along the urban interface, with some removal of Scotch and French broom to reduce fire hazards and limit the potential spread of these nonnative species through reduction of mature plants. Some mechanical fuel reduction work would take place under this alternative in the second-growth redwood/Douglas-fir FMU to reduce fire hazards and facilitate implementation of prescribed burns. Some soil disturbance would occur during this work due to the use of chipping and hauling equipment, with associated potential for nonnative plant species establishment or spread. Follow-up nonnative plant monitoring and removal would be conducted to remove new recruits that come into the site in years following mechanical treatments.

Coastal Scrub and Chaparral. Under Alternative A, mechanical treatments would be used to remove individual trees and tree patches, and stands of broom. Access to these sites would be along maintained fire roads. Most actions would be done in conjunction with follow-up pile or prescribed burn treatments. Short-term adverse negligible-to-minor impacts could result from these actions due to immediate

trampling and soil disturbance impacts. Long-term effects of mechanical treatments on this community would be beneficial because the continuity and ecological integrity of scrub and chaparral would be improved through management of nonnative shrubs and Douglas-fir trees that have encroached into both communities, but the overall effect would be negligible to minor due to the very limited nature of this type of action under Alternative A.

Grasslands. Where Scotch and French broom occur in grasslands, mechanical treatment with hand tools would be used to help control the spread of these species and reduce fire hazards. Overall impacts would be similar to those for the coastal scrub and chaparral vegetation community; short-term adverse negligible-to-minor impacts could result from these actions due to immediate trampling and soil disturbance impacts. Long-term effects of mechanical treatments on this community would be beneficial, but negligible to minor due to the very limited nature of this type of action under Alternative A.

Herbaceous Wetlands. No mechanical treatment would occur within herbaceous wetlands under this alternative, aside from nonnative nonhistoric tree and shrub removal to restore wetland integrity. With mitigations listed in Chapter 2, the effects of these actions would be long-term, minor, and beneficial

Riparian Forest and Scrub. No mechanical treatment would occur within riparian woodland under this alternative, aside from nonnative nonhistoric tree and shrub removal to restore riparian forest and scrub integrity. With mitigations listed in Chapter 2, the effects of these actions would be long-term, minor, and beneficial.

Native Hardwood Forest. No mechanical treatment would occur within native hardwood forests under this alternative, aside from nonnative nonhistoric tree and shrub removal. With mitigations listed in Chapter 2, the effects of these actions would be long-term, minor, and beneficial.

Douglas-Fir and Coast Redwood. Mechanical treatments in this community would focus on removal of understory fuel accumulations, including dead and down trees and shrubs and nonnative shrubs (cotoneaster, brooms). These actions would help reduce the possibility of high-intensity fires facilitated by ample ladder fuels, and would also prepare areas for future prescribed burns. Most mechanical fuel efforts would have follow-up pile burns. Since these actions would potentially occur over larger areas within this community (as opposed to isolated stands in grassland and coastal scrub/chaparral), short-term impacts would be more obvious, with increased impacts on soils and understory herbaceous vegetation having minor adverse effects. There would be a decrease in nonnative species abundance, with an increased potential for the establishment of native understory plant species more characteristic of these stands, a decreased potential for unnaturally high-intensity burns, and an increased likelihood of restoration of these stands to a more sustainable condition. Long-term impacts would be beneficial and minor.

Nonnative Evergreen Forest. Mechanical treatments under Alternative A would be focused on this plant community throughout the park. Short-term impacts would be adverse due to ground and soil disturbance, but long-term impacts would be beneficial and minor to moderate, depending on the extent of work on an annual basis. Current park operations in this community are focusing on lands in Marin County, and this area would receive the greatest benefit from mechanical treatments for the reasons mentioned above.

Follow-up removal of nonnative species would be a necessary mitigation to ensure that these initial efforts are successful in reducing fire hazards, changing overall vegetation structure to less flammable conditions, and restoring sites to appropriate vegetation communities (including coastal scrub, native hardwood forests, and grasslands). Any existing cultural, as well as natural, resource values would be considered in defining specific treatment and management goals for this vegetation type.

Pile Burning

Piles of cut vegetation could be burned following mechanical treatments as a means to reduce fuel loading in an area. These piles would be constructed away from sensitive resources, such as wet areas and sensitive species habitat, to prevent impacts from heat intensity that occur when piles are burned. Piles would be limited in size, and would be burned during seasons when the potential for fire spread and impacts on adjacent native vegetation would be minimal, such as during the fall after the first rains. This timing means live fuel moistures would be increased and rain-induced seed germination or resprouting of senescent perennial plant species would not yet have begun, so impacts would be minimal. Timing as a mitigation to reduce impacts from pile burning can thus ameliorate the direct-burning impacts on soils and vegetation. Pile burns under this alternative would focus only on those plant communities mentioned above in association with mechanical treatments: coastal scrub and chaparral, grasslands, Douglas-fir and coast redwood, and nonnative evergreen forests. Pile burning, with associate applicable mitigations, would result in short-term direct impacts on the underlying soils, with negligible effects. Long-term impacts would be minor and beneficial in that overall vegetation structure and composition would be improved through the removal of nonnative species and the restoration of native species habitat.

Prescribed Burning

The FMUs or plant communities that could be treated with prescribed fire under this alternative are the grassland and coastal scrub, broadleaf evergreen forest, old-growth redwood forest, and second-growth redwood and Douglas-fir. The chaparral FMU would not be treated with prescribed fire under this alternative. As noted in Chapter 2, Alternatives, of this EIS, the primary focus of treatment would be to manage hazardous fuels in strategic locations such as along the wildland urban interface, to mimic the effects of natural fires, and to aid in controlling nonnative plant species including Scotch broom, French broom, eucalyptus, and cotoneaster.

Coastal Scrub and Chaparral. Prescribed fire would be used to continue efforts to reduce the extent and density of nonnative plant species including Scotch broom and French broom, which are common inhabitants of the GNNRA coastal scrub community. Burning would also be used as a follow-up to mechanical treatments for these species and nonnative trees such as eucalyptus and pine within the coastal scrub community.

Control of broom species through fire has been achieved by meeting specific temperatures to kill broom seeds. Heat greater than 150 degrees Celsius (C) for more than two minutes kills the majority of the Scotch broom seeds, and heat greater than 100 degrees C for one minute increases susceptibility of this species to fungal pathogens. Cooler burns have resulted in significantly increased Scotch broom seed germination. French broom seeds are killed when soil temperatures reach 125 degrees C for one minute. Effective control of both species, as proven by multiyear efforts at Point Reyes National Seashore and at

Redwood national and state parks in northern California, involves a combination of cutting at the end of the dry season to decrease the rate of resprouting (the plants are stressed due to summer drought conditions), and a later fall burn repeated every other year for several years. This combination of actions removes reproducing broom plants and either kills the seeds or induces seed germination. Follow-up burns (or mechanical removal) kill the newly sprouted plants, preventing new additions of seed into the seedbank. Over time, seeds are either killed or flushed from the soil and adult plants are removed, leading to a gradual shift in species cover to native perennial grasses and forbs.

Repeated burning to manage broom also prevents coastal scrub species such as *Artemisia* and ceanothus from surviving, since the mechanism for removal of broom works equally well on native shrubs. Current practices with prescribed burning in the coastal scrub community are extremely limited, and generally occur in areas that have recently transitioned from grassland to coastal scrub. Therefore, these treatments would have a long-term, minor-to-negligible, adverse impact on coastal scrub, since the scrub extent would be reduced, but the nonnative species component within the grassland-scrub transition would be eliminated over time.

Low-intensity prescribed burns in scrub or chaparral may include isolated, single, nonnative trees or small stands of nonnatives. If the trees are historically significant, they may be limbed up to prevent the spread of fire into the canopy and maintained in the burn unit where a low-intensity fire is anticipated. If nonnative trees are not historically significant, they would be cut before the burn and, if necessary, the stump would be treated with herbicide. Repeat applications of fire would not be needed with subsequent survival of the coastal scrub component. These actions would have long-term minor beneficial effects on the coastal scrub community due to the increase in available habitat for coastal scrub vegetation.

Lack of burning within the chaparral community could have short-term adverse impacts on the fire-adapted plant species within the chaparral, some of which are locally rare. Fire stimulates regeneration, and impedes the continued encroachment of Douglas-fir trees into the chaparral. The continually increasing fuel load in the chaparral along Bolinas Ridge and near Muir Woods National Monument would eventually support a planned or unplanned ignition, and the vegetation within these stands would recover in accordance with their species-specific adaptations. Therefore, the chaparral communities would incur negligible, adverse effects under Alternative A.

Grasslands. Prescribed burns could occur in both Marin and San Mateo county grasslands under Alternative A. In keeping with NPS and GGNRA objectives to reduce the overall extent of nonnative plant species and encourage native plant species under prescribed fire would be used in combination with mechanical treatments and/or herbicides. Dominant nonnative plant species in grasslands include velvet grass, annual wild rye, perennial ryegrass, small fescue, foxtail fescue, erharta grass, and Harding grass. Dominant native grass species include California purple needlegrass, tufted hairgrass, California brome, Pacific reedgrass, California oatgrass, and meadow barley. Many of the native species are either undamaged by prescribed fire or appear to be stimulated by it, either because seeds are buried and remain unaffected by all but very hot fires, or the plant sprouts from buried structures, such as rhizomes or root crown, in the growing season following the burn. The nonnative species may or may not be negatively affected by burning. Harding grass, for example, appears to be stimulated by fall burns, but is effectively

killed by early spring burning. A recent analysis of monitoring data from the PRNS prescribed burning program did not identify any one strategy that consistently favored native species relative to nonnative species (Twedt 2003). Rather, the outcomes were very case- and site-specific. For example, while a combination of prescribed fire and mowing has been successful in removing Scotch broom from some grassland communities, prescribed burning of the highly invasive purple velvet grass may be increasing its abundance.

Efforts to study the effects of prescribed burns on specific species and grassland communities would continue under this alternative. The effects of prescribed burning on grasslands would be carefully monitored to assess post-burn plant species cover and composition. If monitoring shows undesirable effects, such as an increase in nonnative plant cover or distribution, either the prescription would be changed (e.g., burn during different seasons) or combined with other treatments (such as seeding of native plant species), or other strategies would be tried. All applicable mitigation measures would be applied to these burns, including continued monitoring, adherence to site-specific prescriptions, development and analysis of specific burn objectives, and alteration of prescriptions based on those monitoring results. Prescribed burns in the grassland and coastal scrub communities would result in a long-term negligible-to-minor beneficial impact on the grassland community because of the expected increased extent of grassland species and control of specific nonnative species. Continued studies and adjustment of burn prescriptions could result in moderate beneficial impacts on this community over time.

Herbaceous Wetlands. Herbaceous wetland vegetation grows alongside rivers, streams, and creeks. In GGNRA, herbaceous wetlands would not be treated with prescribed fire, and a suitable buffer would be maintained if fire management activities were to occur in the vicinity of wetlands supporting special status species. The buffer would be created through use of a wet line or other means to avoid use of a scraped hand line, so that impacts on herbaceous wetland species would be avoided.

Riparian Forest and Scrub. Riparian vegetation grows alongside rivers, streams, and creeks. In GGNRA, riparian woodlands and shrublands would not be treated with prescribed fire, and a suitable buffer would be maintained if fire management activities were to occur in the vicinity of riparian areas supporting special status species. The buffer would be created through use of a wet line or other means that avoid use of a scraped hand line, so that direct impacts on riparian species would be avoided.

Native Hardwood Forest. Hardwood forests occur in the broadleaf evergreen forest FMU under Alternative A. Limited prescribed burning could be conducted in small areas supporting hardwood forests, but only where such forest borders grasslands or stands of Scotch or French broom, or where specific research plots are located. Under current park practices (as represented by Alternative A) specific burns within the hardwood forest community are not projected to occur except where these actions would reduce fuel loads or help control nonnative plant species. Mitigations applicable to this vegetation type would include follow-up nonnative plant monitoring and removal, and development of stabilization plans to prevent new recruits following prescribed burning. Therefore, prescribed fire effects on species dominant in hardwood forests would have negligible beneficial long-term impacts on these forests, resulting in improved forest health.

Douglas-Fir and Coast Redwood. This vegetation type occurs in both Marin and San Mateo counties, within the old-growth redwood and second-growth redwood and Douglas-fir FMUs. Numerous prescribed burns have taken place within this vegetation type in Marin County, but none has occurred under the 1993 FMP in San Mateo County. As described in Chapter 3, Affected Environment, of this document, fire can have both beneficial and adverse impacts on this vegetation type depending on season, mitigation measures applied, and follow-up treatments to control invading nonnative plant species. The primary objectives of past burn efforts have been to reduce fuel loads where hazardous accumulations have occurred, and to reintroduce fire as a disturbance process into the redwood forest ecosystem. These general objectives have been successfully met, and actions under Alternative A would continue to improve the overall condition of these forests. The encroachment of Douglas-fir trees into coast redwood-dominated stands would be impeded through prescribed burns, and the overall extent of the coast redwood stands would either remain stable or slightly increase as competition from Douglas-fir trees is reduced.

The only stands of this vegetation type on GGNRA lands in San Mateo County are at the Phleger Estate. These second-growth forests are a mix of both Douglas-fir and coast redwood, with a sub-overstory of old hardwood trees that became established following logging of the site in the late 1800s. This area has never been treated with prescribed burning under the current FMP. Research burns within second-growth stands would contribute to the body of knowledge regarding the effectiveness of using prescribed fire to restore old-growth stand characteristics to second-growth coast redwood forests. Some work has been done in this regard at Big Sur State Park south of Monterey, and park staff would work closely with state park personnel if research actions were proposed for this area.

Prescribed burning would have positive effects on coast redwood forest with the inclusion of applicable mitigations, including adherence to specific prescriptions, development of specific burn objectives and post-fire analysis to determine achievement of objectives, and minimization of ground-disturbing activities during burn site preparation, implementation, and clean-up. Prescribed burning within this vegetation type under Alternative A would have long-term negligible-to-minor beneficial effects due to the limited acreage allotted to burning in San Mateo County and the limited annual burn window.

Research

Research projects would examine the role of fire in enhancing natural resources and the effects of fire on specific natural resources to determine the effectiveness of various treatment strategies. For example, research would continue on Harding grass and Scotch and French broom to help ecologists refine burning prescription parameters to control these species. This could have substantial benefits to the coastal scrub and grassland communities both within the park and regionally where these vegetation-based species continue to expand. Alternative A would allow for additional research or test plots in each of the six FMUs, and specific research questions would be formulated for these other areas. Research into the effects of fire on SOD would potentially help manage this pathogen and reduce its impacts on the native hardwood Douglas-fir and coast redwood forests of the park. The overall impact of research on vegetation communities under Alternative A would be a long-term, negligible benefit.

Cumulative Impacts

Primary among the past actions that have influenced vegetation at GGNRA are fire suppression (especially in areas that were sustained by fire), urban development and loss of habitat continuity, and the establishment and overall dominance of many areas by nonnative plant species.

Suppression of periodic fires has favored fire-intolerant species and nonnative species, and allowed the unnatural buildup of both dead and live fuels. Shrub and grassland habitats are experiencing encroachment by fire-intolerant conifers and nonnative trees. The buildup of fuels, or change in fuel density from grasses- and forbs-dominated communities to tree- and shrub-dominated communities, generally increase the risk of a high-intensity wildfire.

Urban development has also contributed to changes in composition and density of key species. For example, redwood forest is estimated to have covered 1,976, 000 acres 200 years ago. Today, approximately 85,000 acres are left. Four percent of the original old-growth forest remains. In 1986, aerial photo interpretation estimated 1.26 million acres of second growth redwood forest covering 63 percent of the former range. At that time, old-growth redwood was confined to 208,000 acres, of which 54 percent was in public ownership. Nearly 60 percent (53,000 acres) of the old-growth forest in private ownership was harvested in the next 10 years (1986-1996). So in the decade of 1986-1996, 25 percent of the remaining old-growth coast redwood forest was cut. Muir Woods National Monument contains 300 acres of old growth forest (Fox 1996). Analysis of pollen from coast live oak (the dominant tree of the park's hardwood forests) shows that oak woodlands were stable for up to four centuries before major European-American settlement. Fire suppression efforts beginning in 1870 and extending into recent years resulted in a two-fold increase in oak pollen and oak density, perhaps facilitating the spread and effect of the nonnative Sudden Oak Death pathogen. Monterey pine, Monterey cypress, and eucalyptus have all been imported by European-American settlers for lumber or other purposes. Eucalyptus in particular has been a prolific "weed tree" over much of California. Coastal sage scrub is present in about 15 percent of its former habitat, primarily because of agricultural, industrial, and residential development. Grasslands in California have been invaded by nonnative species in part because of the displacement of native tule elk by domestic livestock, the introduction of nonnative plant species adapted to livestock grazing, and the clearing and plowing of land for agriculture. Scotch and French broom are escaped ornamental shrubs brought from Europe, and most of the park's nonnative grasses are imported from Eurasia. All are highly invasive species that occur in grasslands and coastal scrub in the park, and all are adapted to the area's Mediterranean climate.

Current and reasonably foreseeable future actions positively affecting vegetation in the park are activities such as the Big Lagoon, Redwood Creek, and mission blue butterfly habitat restoration projects. These projects take into account the natural processes of the site and incorporate nonnative plant removal and establishment of native plant communities (through planting and weed removal) into their efforts. Potentially adverse impacts could occur with development projects both within the park and adjacent to park boundaries, including the various transportation plans and trails plans. These efforts will involve ground disturbance activities that could add to or exacerbate existing nonnative plant problems along road and trial corridors. However, ongoing efforts to identify mitigations for these projects, such as pre-project weed control, post-project planting and weeding, and use of weed-free products (soils, fill material, and

clean equipment), would reduce the potential for these type of impacts. These projects would have an overall long-term negligible-to-minor beneficial impact on vegetation as a whole.

Conclusion

Limited prescribed burning and mechanical fuel treatments would have negligible-to-minor beneficial long-term impacts on coastal scrub and chaparral communities due to continued work to control nonnative species with increased available habitat for native scrub species. Prescribed burning and research within the native hardwood forests would create a minor beneficial impact in these stands, resulting in improved forest health. Removal of individual nonnative trees would have a localized minor-to-moderate long-term beneficial impact on native vegetation, but these beneficial impacts would only persist if follow-up activities to remove new recruits were carried out after prescribed burning or mechanical treatments. Adverse, minor, short-term impacts could occur as a result of application of fire management activities if other nonnative plant species invade or spread into treated sites. Prescribed burns in grasslands could have negligible-to-beneficial impacts, and more study is necessary to determine the overall effects if this treatment is to be used on a large-scale basis in the park.

The average annual occurrences of wildfires and their suppression could have minor, short-term adverse or beneficial impacts on vegetation. Benefits may result from stimulation of fire-adapted native species, or from the destruction of nonnative plants. Adverse impacts may come from the loss of native species with subsequent establishment of nonnative plant species in newly available habitat, as well as from crushing, removal, or other physical impacts of suppression actions.

Mechanical fuel reduction in Douglas-fir and hardwood forests would result in negligible-to-minor short-term adverse impacts. Minor-to-moderate benefits to coastal scrub and grasslands from the continued removal of Scotch broom and French broom would result from the combination of mechanical and prescribed burning techniques. The continuation of research and wide application of its results would increase these benefits over a wider geographic area. Riparian and wetland areas would be minimally affected under this alternative due to the use of buffers and appropriate mitigation measures.

Overall, the cumulative effects of past, present, and reasonably foreseeable future actions in conjunction with actions called for in this alternative would have long-term negligible-to-minor and adverse effects on vegetation, due to the extent of nonnative plant species dominance in many areas of the park, the lack of current fire management actions in many areas of the park, and lack of actions focused on nonurban interface areas.

Impairment

Overall, Alternative A would have a short term, minor, adverse effect on vegetation. As the level of intensity of impacts would not exceed moderate, no impairment of vegetation resources would result.

Alternative B

Mechanical Fuel Reduction

Under this alternative, up to 230 acres of vegetation would be mechanically treated on an annual basis. Work would focus on the WUI FMU in Marin, San Francisco, and San Mateo counties, the Muir Woods

FMU in Marin County, and the Park Interior FMU. Hazardous fuel reduction treatments would include removal of eucalyptus, Monterey pine and cypress, acacia, and other flammable trees along the urban interface. Scotch and French broom and other nonnative plant species would be removed where they pose a fire hazard. Some soil disturbance would occur during this work due to the use of chipping and hauling equipment, with associated potential for nonnative plant species establishment or spread. Follow-up nonnative plant monitoring and removal would be conducted to remove new recruits that come into the site in years following mechanical treatments.

Coastal Scrub and Chaparral. Treatment of coastal scrub and chaparral areas under Alternative B would focus primarily on those areas where fuel buildups pose a threat to developments, such as adjacent to developments at Sweeney Ridge, Tam Valley, and Stinson Beach. These treatments would generally be within the WUI FMU, although some lower priority sites within the Park Interior FMU could be treated. The overall number of acres to be treated would be more than double the area treated in Alternative A, but the distribution of those treatment actions would be more confined along the wildland urban interface. Access would continue to be via maintained fire roads. Most actions would be done in conjunction with follow-up pile burns. Due to the expanded number of acres that could be treated under this alternative, short-term adverse impacts would increase to minor due to more concentrated trampling and soil disturbance impacts. There would be minimal to no increases in overall habitat continuity and ecological integrity of scrub and chaparral stands due to the focus on interface lands, and an increased likelihood of invasion of nonnative plants into the treated strips along the boundary and road edges, further affecting the overall integrity of these stands. Long-term effects of mechanical treatments on the coastal scrub and chaparral community would be negligible and adverse due to the focus on strips of habitat adjacent to development.

Grasslands. In contrast to Alternative A, the purpose of mechanical treatments under Alternative B would be twofold. A priority would be placed on reducing fire hazards and secondarily on restoring integrity to grassland communities through elimination of nonnative species and management of native encroaching coastal scrub and tree species in some sites. Positive effects resulting from this secondary priority would be limited, since Alternative B would (1) focus on the developed area/urban interface with minimal to no increases in overall habitat continuity and ecological integrity of grasslands, and (2) increase the likelihood of nonnative plant invasions into the treated strips, further affecting the overall integrity of these stands. Therefore, the overall impacts would be similar to that for the coastal scrub and chaparral vegetation community; short-term adverse minor impacts could result from these actions due to immediate trampling and soil disturbance impacts. Long-term effects of mechanical treatments on grasslands would be negligible and adverse due to the primary focus on the strips of habitat adjacent to development.

Herbaceous Wetlands. Impacts under Alternative B would be the same as under Alternative A.

Riparian Forest and Scrub. Impacts under Alternative B would be the same as under Alternative A.

Native Hardwood Forest. Impacts under Alternative B would be the same as under Alternative A.

Douglas-Fir and Coast Redwood. Mechanical treatments in this community within the WUI and Park Interior FMUs in San Mateo and Marin counties would double from the acreage in Alternative A. (Actions in the Muir Woods FMU are described in the "Actions Common to All Alternatives" discussion above.) There would be an increased focus on removal of understory fuel accumulations including dead and down trees and shrubs and nonnative shrubs (cotoneaster, brooms). These treatments would further reduce the possibility of high-intensity fires facilitated by existing ladder fuel conditions, and most of these mechanical fuel efforts would have follow-up pile burn treatments, further reducing hazards to adjacent developments and to the vegetation itself. Under Alternative B, no prescribed burning would occur in San Mateo County, and mechanical treatments would be the sole means by which vegetation structure within this community is restored and maintained over time. Short-term impacts would be more obvious than within the grassland and coastal scrub/chaparral communities due to the size of equipment used to remove the cut fuel and litter, with increased impacts on soils and understory herbaceous vegetation, resulting in minor adverse effects. Over the long term, the proportion of nonnative species would remain the same due to ongoing mechanical disturbances. There would be a decreased potential for high-intensity burns, and a low but slightly increased potential for restoration of these stands to a more sustainable condition when done in conjunction with mitigation measures. Long-term impacts would be beneficial and negligible to minor.

Nonnative Evergreen Forest. As with Alternative A, mechanical treatments under Alternative B would be focused on this plant community throughout the park, although priority staffing and funding would be in stands adjacent to developed areas, with a lower priority placed on stands isolated within the Park Interior FMU. As a result, restoration of these sites to native vegetation communities (including coastal scrub, native hardwood forests, and grasslands) would be less likely under this alternative, since the native communities could harbor undesirable fuel loads that would have to be managed as well. The use of a phased implementation plan to piece together restored patches could, however, eventually create long-term benefits. Short-term impacts would be minor to moderate and adverse due to ground and soil disturbance, but long-term impacts would be beneficial and negligible to minor, depending on the extent of work on an annual basis, use of mitigation measures, and adherence to an overall phased implementation and site stabilization plan.

Pile Burning

Piles of cut vegetation could be burned following mechanical treatments, and the overall strategy, implementation, mitigations, and effects would be the same as in Alternative A. These piles would be constructed away from sensitive resources – wet areas, sensitive species habitat, etc. – to prevent impacts from the concentrated heat effects that occur when piles are burned. Piles would be limited in size, and would be burned during seasons when the potential for fire spread and impacts on adjacent native vegetation would be minimal, such as during the fall after the first rains. Pile burns under Alternative B would increase substantially from the number called for under Alternative A, in association with increased mechanical treatments under Alternative B. Pile burning, with applicable mitigations, would result in short-term direct impacts on the underlying soils, with negligible effects. Long-term impacts would be minor and beneficial (same as Alternative A) in that overall vegetation structure and composition would be improved through the removal of nonnative species and the restoration of native species habitat.

Prescribed Burning

The areas that could be treated with prescribed fire under Alternative B are limited to the Park Interior and Muir Woods FMUs in Marin County. The Muir Woods FMU treatments and impacts are described above in the "Actions Common to All Alternatives" section above. Compared to Alternative A estimates (see Table 2-4 in Chapter 2), prescribed burn acres within the Park Interior FMU would increase slightly, with potential actions in the coastal scrub and chaparral, grasslands, native hardwood forest, and Douglas-fir and coast redwood communities. As noted above, the primary focus of prescribed burn treatments would be to manage hazardous fuels in strategic locations closer to the WUI FMU, and adjacent to developments within the park interior areas.

Coastal Scrub and Chaparral. Prescribed fire would be used to reduce fuel buildups and restore and maintain the integrity and continuity of the coastal scrub and chaparral communities in Marin County. There would be a continued effort to reduce the extent and density of nonnative plant species through follow-up to mechanical treatments for Scotch and French broom and nonnative trees, using strategies and mitigations similar to those outlined in Alternative A. Burning would be conducted to manage broom buildup and control the rapid spread of native shrub species into adjacent grasslands. The scrub extent and the nonnative species component within the grassland-scrub transition would be reduced over time. Individual nonnative, historically significant trees or small groves may be included in the burn unit though limbed up to protect the canopy and prevent tree mortality. Alternative B, unlike Alternative A, would allow burning within the limited chaparral community in Marin County. This could have short-term moderate-to-major beneficial impacts on the fire-adapted species within the chaparral if burns were implemented to best meet the regeneration requirements of these species. Since the continually increasing fuel load within the chaparral stands along Bolinas Ridge and near Muir Woods would eventually support a planned or unplanned ignition, and the vegetation within these stands would recover according to their species-specific adaptations, the long-term impacts of allowing prescribed burns would have a minor beneficial impact on chaparral. Overall, the actions proposed under Alternative B would have long-term minor beneficial effects on coastal scrub and chaparral communities in Marin County, but restrictions on prescribed burning in San Mateo County under Alternative B would result in long-term negligible benefits parkwide.

Grasslands. Prescribed burns could occur only in the Marin County grasslands in Alternative B. Therefore, isolated stands of native perennial grasses – such as purple needlegrass – in San Mateo County would continue to be affected by encroaching native coastal scrub species and nonnative shrubs, forbs, and grasses. Nonnative patches of Harding and African rice grasses would either remain untreated or would require treatment with mechanical or chemical methods, with associated impacts on soils and adjacent native species. Efforts to study the effects of prescribed burns on specific species and grassland communities in Marin County would continue, however, and would ideally be applied to future planning efforts more inclusive of the park's grassland ecosystems at Sweeney and Milagra Ridges. All applicable mitigation measures would be applied to these burns, including continued monitoring, adherence to site-specific prescriptions, development and analysis of specific burn objectives, and alteration of prescriptions based on those monitoring results. Prescribed burn actions in the grassland community would result in a long-term negligible beneficial impact because of the increased extent of grassland

species and control of specific nonnative species in Marin County. Continued studies and adjustment of burn prescriptions could result in moderate beneficial long-term impacts on this community in later years.

Herbaceous Wetlands. Impacts under Alternative B would be the same as under Alternative A.

Riparian Forest and Scrub. Impacts under Alternative B would be the same as under Alternative A.

Native Hardwood Forest. Hardwood forests in the Marin County Park Interior FMU would receive limited prescribed burning under Alternative B. These actions would occur only where such forests border developed or wildland urban interface areas and where these actions would reduce fuel loads or help control nonnative plant species, or within the Muir Woods FMU discussed above. Prescribed fire effects on the native hardwood forests under Alternative B would have negligible beneficial long-term impacts on these forests due to the limited potential extent of area to be treated.

Douglas-fir and Coast Redwood. Although this vegetation type occurs in both Marin and San Mateo counties, only stands in Marin County would be treated under Alternative B. Extant stands at the Phleger Estate would continue to grow without the benefits of understory clearing and forest litter recycling that occurs with prescribed fires. Prescribed burn implementation in the Muir Woods FMU is described in the "Actions Common to All Alternatives" section above. Remaining stands in Marin County outside of Muir Woods would experience long-term negligible-to-minor beneficial effects due to the limited nature of the areas available for burning, their relative isolation and lack of overall habitat continuity, and lower priority for treatment based on the development focus of this alternative. Overall, the impacts would be minor and adverse for this community parkwide, due to the exclusion of stands in San Mateo County.

Research

As under Alternative A, research projects would examine the role of fire in enhancing natural resources and the effects of fire on key natural resources to determine the effectiveness of various treatments. For example, research burns on Harding grass and Scotch and French broom would continue helping ecologists refine burning prescription parameters to control these species and creating the potential for substantial benefits to the park's native coastal scrub and grassland communities. Research into the effects of fire on SOD could potentially help manage this nonnative pathogen and reduce its impacts on bays and tan oaks in the native hardwood Douglas-fir and coast redwood forests of the park. Alternative B only allows for burning within Marin County in the Park Interior and Muir Woods FMUs, and in San Francisco for specific objectives of recovery plans for listed threatened or endangered plant species, limiting applicable research questions. The overall impacts of research on vegetation communities under Alternative B would be long-term and minor benefits.

Cumulative Impacts

Vegetation at GGNRA has been affected by past fire suppression actions, urban development and loss of habitat continuity, and the establishment and overall dominance of many areas by nonnative plant species. Current and reasonably foreseeable future actions positively affecting vegetation in the park are activities such as the Big Lagoon, Redwood Creek, and mission blue butterfly habitat restoration projects. These projects take into account the natural processes of these sites and are incorporating nonnative plant removal and reestablishment of native plant communities into the project objectives. Potentially adverse

impacts could occur with development projects both within the park and adjacent to park boundaries, since they involve ground disturbance activities that could add to or exacerbate existing nonnative plant problems along road and trial corridors. However, ongoing efforts to mitigate these impacts through pre-project weed control, post-project planting and weeding, and use of weed-free products (soils, fill material, and clean equipment) would reduce negative impacts.

Conclusion

As with Alternative A, unplanned wildfires and their suppression could have minor, short-term adverse or beneficial impacts on vegetation. Benefits may result from stimulation of fire-adapted native species or from the destruction of nonnatives. Adverse impacts would result from the loss of native species with subsequent invasion by nonnative species, as well as from crushing, removal, or other physical impacts of suppression actions.

The increased mechanical fuel treatments (and associated pile burning) that would occur with Alternative B would have negligible-to-minor beneficial long-term impacts on the affected vegetation communities overall, as compared to Alternative A. Beneficial effects would be minimized due to the focus of this alternative on developed and wildland urban interface areas, with the potential for creating "strips" of treated vegetation rather than larger, continuous, ecologically sustainable stands, particularly within the coastal scrub and grassland communities. In the forest communities, the long-term proportion of nonnative species would remain the same due to ongoing mechanical disturbances. There would be a decreased potential for unnaturally high-intensity wildland fire, and a low but slightly increased potential for restoration of these stands to more sustainable conditions. Long-term impacts would be beneficial and negligible to minor.

The prescribed burn actions proposed under Alternative B would have long-term minor beneficial effects on coastal scrub, chaparral, and grassland communities in Marin County. Prescribed fire effects on the native hardwood forests under Alternative B would have negligible beneficial long-term impacts on these forests due to the limited potential extent of area to be treated. Continued studies and research, along with adjustment of burn prescriptions, could result in moderate beneficial long-term impacts in later years and would increase these benefits over a wider geographic area. Riparian and wetland areas would be minimally affected under this alternative due to the use of buffers and appropriate mitigation measures. However, the restrictions on using prescribed fire within the WUI FMU or in San Mateo County under this alternative would minimize long-term benefits, since larger-scale restoration of continuous stands of native vegetation would not be achieved.

Overall, the cumulative effects of past, present, and reasonably foreseeable future actions in conjunction with actions called for under Alternative B would have long-term negligible-to-minor and adverse effects on vegetation, due to the extent of nonnative plant species dominance in many areas of the park, restrictions on fire management actions in many areas of the park (San Mateo County and the WUI FMU for prescribed burning), and more limited geographic extent as compared to Alternative A, with the primary focus on areas with the highest fire risk and limited integration of natural and cultural resource objectives.

Impairment

Overall impacts of Alternative B on vegetation would be slightly adverse. No impairment of vegetation would result.

Alternative C

Mechanical Fuel Reduction

Under this alternative, up to 275 acres of vegetation would be mechanically treated annually. Work would continue, as with Alternative B, in the WUI FMU in Marin, San Francisco, and San Mateo counties, in the Muir Woods FMU in Marin County, and in Marin and San Mateo counties within the Park Interior FMU. Work in the Park Interior FMU would be nearly double that allowed under Alternative B. Hazardous fuel reduction treatments would again include removal of eucalyptus, Monterey pine and cypress, acacia, and other potentially flammable trees along the urban interface, as well as removal of fuel loads threatening the integrity of vegetation or landscapes in more remote areas of the park. Scotch and French broom and other nonnative plant species would be removed. Some soil disturbance would occur during this work due to the use of chipping and hauling equipment, with associated potential for nonnative plant species establishment or spread. Follow-up nonnative plant monitoring would occur on a regular basis with removal of new recruits that come into the site in years following mechanical treatments.

Coastal Scrub and Chaparral. Treatment of coastal scrub and chaparral areas under Alternative C would spread the work effort out to areas where fuel buildups pose both a threat to developments and to the vegetation character of the site (such as from catastrophic fire events or crowding out of native species). The overall number of acres to be treated would be more than double the area treated in Alternative A, and the distribution of those treatment actions would be roughly two-thirds in the WUI FMU and one-third in the Park Interior FMU. Access would continue to be via maintained fire roads. Most actions would be done in conjunction with follow-up pile burns. Under Alternative C, short-term adverse impacts would remain minor (same as Alternative B) due to concentrated trampling and soil disturbance. In setting priorities for and carrying out treatment efforts, however, emphasis would be more on ecosystem health than simply fire hazard abatement, with a focus away from the development strip treatments of Alternative B. This increased opportunity for mechanical treatment (by increasing the number of acres that could be treated annually) and subsequent restoration of habitat continuity and integrity would result in long-term minor beneficial impacts on larger scrub and chaparral stands.

Grasslands. As with Alternative B, mechanical treatments in grassland would be focused on both reducing fire hazards and restoring grassland integrity through the removal of nonnative plant species including Scotch and French broom. The increased opportunities for treating large patches of vegetation under Alternative C would result in short-term adverse negligible to minor impacts from trampling and soil disturbance, with long-term minor-to-moderate beneficial effects.

Herbaceous Wetlands. Impacts under Alternative C would be the same as under Alternative A.

Riparian Forest and Scrub. Impacts under Alternative C would be the same as under Alternative A.

Native Hardwood Forest. Impacts under Alternative C would be the same as under Alternative A.

Douglas-Fir and Coast Redwood. As with Alternative B, mechanical fuel treatments would occur within the Douglas-fir and coast redwood stands with a continued focus on removal of understory fuel accumulations, including dead and down trees and shrubs and nonnative shrubs (cotoneaster, brooms). These treatments, paired with follow-up pile burns and the potential implementation of prescribed burns in both Marin and San Mateo counties, would increase the potential for (1) restoration of sustainable forest structure and integrity, (2) minimal nonnative plant species components, and (3) establishment of native understory plant species more characteristic of these stands. Short-term adverse impacts would be negligible to minor due to site disturbance and soil impacts. Long-term impacts on these stands parkwide, however, would be beneficial and minor to moderate, due to the increased availability of all treatment options.

Nonnative Evergreen Forest. As with Alternative A, mechanical treatments under Alternative C would occur in this plant community throughout the park. The focus of efforts under this alternative, however, would be spread out to cover both those stands adjacent to developed areas as well as treatments within isolated stands in the Park Interior FMU. As a result, restoration of these sites to appropriate self-sustaining native vegetation communities (including coastal scrub, native hardwood forests, and grasslands) would be more likely under this alternative than under either Alternatives A or B. The larger number of acres of allowable treatment under this alternative would speed up overall restoration efforts, which would result in greater short-term minor-to-moderate adverse impacts due to ground and soil disturbance. Long-term impacts would be beneficial and minor to moderate since this alternative would allow for consistent treatment of these nonnative stands over the lifetime of the FMP, taking into consideration both natural and cultural resource values.

Pile Burning

Piles of cut vegetation could be burned following mechanical treatments, and the overall strategy, implementation, mitigations, and effects would be the same as in Alternative A. These piles would be constructed away from sensitive resources – wet areas, sensitive species habitat, etc. – to prevent impacts from the concentrated heat effects that occur when piles are burned.

Piles would be limited in size, and would be burned during seasons when the potential for fire spread and impacts on adjacent native vegetation would be minimal, such as during the fall after the first rains. Due to increased mechanical treatments, pile burns under Alternative C would increase substantially from the number called for under Alternatives A or B. Pile burning, with applicable mitigations, would result in short-term direct impacts on the underlying soils, with negligible effects. Long-term impacts would be minor-to-moderate and beneficial in that larger vegetated areas would be improved through the removal of nonnative species and the restoration of vegetation continuity and native species habitat.

Prescribed Burning

The areas that could be treated with prescribed fire under Alternative C would include all areas and FMUs of the park except San Francisco, and the number of potential acres that could be treated annually would be substantially higher than under the other alternatives. (The Muir Woods FMU treatments and impacts

are described above in the "Actions Common to All Alternatives" section.) The opportunity for conducting small-scale research burns and studies within the WUI FMU, in conjunction with larger broadcast burns in the Park Interior FMU, would help create a more seamless blend of management strategies across vegetation types rather than along management zone boundaries. Potential prescribed burn actions would occur in the coastal scrub and chaparral, grassland, native hardwood forest, and Douglas-fir and coast redwood communities.

Coastal Scrub and Chaparral. Prescribed fire would be used to manage coastal scrub and chaparral communities within both Marin and San Mateo counties. There would be an increased effort to reduce the extent and density of nonnative plant species, where possible, through a combination of management actions including burning. For example, mechanical treatments for Scotch and French broom and nonnative tree removal could be followed up with broadcast burns, where appropriate, using strategies and mitigations similar to those outlined for Alternatives A and B. Alternative C would also allow burning within the park's small chaparral stands, with short-term moderate-to-major beneficial impacts on the fire-dependent species. The broader flexibility of treatment options (size, location, and extent), and the dual focus of treatment rationale under Alternative C would result in long-term moderate beneficial effects within the coastal scrub and chaparral communities parkwide.

Grasslands. Prescribed burns could occur on grasslands in both Marin and San Mateo counties under Alternative C, and the actions and approaches would be similar to the actions described for Alternative A. The larger number of total acres of annual burning under Alternative C would translate to the potential for increased acres of grassland treatments under this alternative, as compared to Alternative A, with the potential for larger gains in nonnative plant species control and eradication, removal of encroaching scrub species, retention of larger intact stands of grassland unconfined by the FMU boundary restrictions of Alternative B, and an opportunity to conduct additional research to answer species-specific or habitat-specific restoration questions. The overall effects of Alternative C on grasslands within the park would therefore be long-term, beneficial, and moderate to major.

Herbaceous Wetlands. Impacts would be the same as under Alternative A.

Riparian Forest and Scrub. Impacts would be the same as under Alternative A.

Native Hardwood Forest. The park's native hardwood forests, which are found throughout the park in the WUI, Park Interior, and Muir Woods FMUs, could be treated through a combination of actions under Alternative C. Specific burns could occur with objectives to restore forest structure and integrity through the removal of nonnative species, unnaturally high fuel loads, and restoration of fire as a process within the forest understory. In contrast to Alternative A, these actions would not be restricted to areas of hardwood forest adjacent to broom stands or grasslands, and would therefore offer the potential to create a richer mosaic of vegetation communities transitioning from Douglas-fir and redwood forests at more mesic sites to coastal scrub and grassland ecotones at drier sites. The opportunity to use a broader range of management actions within this community and apply those actions to more areas of the park would have long-term minor-to-moderate beneficial impacts on these forests.

Douglas-fir and Coast Redwood. The inclusion of prescribed burning as an option for treatment and management of the Douglas-fir and coast redwood stands in San Mateo County, in addition to those in Marin County, would increase the ecological integrity of this limited community in the park. (Prescribed burn implementation in the Muir Woods FMU is described in the "Actions Common to All Alternatives" section above.) Extant stands at the Phleger Estate would benefit from phased implementation of burns to clear understory fuels, recycle forest litter, and restore or create natural stand structure. The overall impacts of Alternative C would be long-term, minor to moderate, and beneficial.

Research

As with Alternatives A and B, research burns would examine the role of fire in enhancing natural resources and the effects of fire on key natural resources to determine the effectiveness of various treatments. Research on a variety of nonnative species would continue, helping ecologists refine burning prescription parameters that could help control these species. Research could also be conducted throughout the park to investigate the effects of fire treatments on the SOD pathogen, with possible reductions in SOD's impacts on the native hardwood, Douglas-fir, and coast redwood forests of the park. Research opportunities under this alternative would include the WUI FMU, with the potential for investigation, for example, into the effects of buildup (and control of) native soil pathogens on special status species that occur within this management unit, and small research burns in San Francisco in support of federally listed threatened and endangered species. The overall impacts of research on vegetation communities under Alternative C would be long-term, beneficial, and minor.

Cumulative Impacts

The vegetation at GGNRA has been affected by past fire suppression actions, urban development and loss of habitat continuity, and the establishment and overall dominance in many areas by nonnative plant species. Current and reasonably foreseeable future actions positively affecting vegetation in the park are activities such as the Big Lagoon, Redwood Creek, and mission blue butterfly habitat restoration projects, as well as ongoing park operations of the Habitat Restoration Team and Site Stewardship Program. These projects and programs take into account the natural processes of treated sites and incorporate nonnative plant removal and reestablishment of native plant communities into site objectives. Potentially adverse impacts could occur with development projects both within the park and adjacent to park boundaries, since they involve ground disturbance activities that could add to or exacerbate existing nonnative plant problems along road and trial corridors. However, ongoing efforts to mitigate these impacts through pre-project weed control, post-project planting and weeding, and use of weed-free products (soils, fill material, and clean equipment) would reduce negative impacts. The overall cumulative impact on vegetation with past, present, and reasonably foreseeable future actions both in and adjacent to the park would be minor, long-term, and beneficial.

Conclusion

Unplanned wildfires and associated suppression activities would have minor, short-term adverse or beneficial impacts on vegetation, depending on the vegetation community in which the fire occurred, the timing of the event, and the immediate and long-term impact mitigation measures applied to the site.

The substantially increased potential for mechanical fuel treatments (and associated pile burning) that would occur with Alternative C (as compared to Alternatives A or B) would have minor beneficial long-term impacts on the affected vegetation communities overall. These beneficial effects would be applied to all areas of the park as appropriate, and would integrate both natural and cultural resource values into management of the vegetation, rather than focusing simply on the developed and wildland urban interface areas of the park. In the forest communities, there would be a decreased potential for unnaturally high-intensity burns, and a moderately increased potential for restoration of these stands to more sustainable conditions. Long-term impacts would be beneficial and minor.

The prescribed burn actions proposed in Alternative C, in conjunction with mechanical and pile burn treatments, would have long-term minor-to-moderate beneficial effects on the coastal scrub, chaparral, and grassland communities. There would be a greater potential for creation and maintenance of continuous ecologically sustainable stands, and an increased opportunity for larger-scale restoration of continuous stands of native vegetation. Prescribed fire actions on the native hardwood forests in Alternative C would increase the potential to create a richer mosaic of vegetation communities. The opportunity to use a broader range of management actions within this community, and apply those actions to more areas of the park would have long-term minor-to-moderate beneficial impacts on these forests. Continued studies and research, along with adjustment of burn prescriptions, would result in moderate beneficial long-term impacts throughout the park in all affected vegetation communities. As in Alternatives A and B, riparian and wetland areas would be minimally affected under this alternative due to the use of buffers and appropriate mitigation measures.

Overall, the cumulative effects of past, present, and reasonably foreseeable future actions in conjunction with actions called for under Alternative C would have long-term minor-to-moderate beneficial effects on vegetation.

Impairment

The overall impacts of Alternative C on vegetation would be beneficial and would not result in impairment of vegetation.

Impacts on Wetlands

Analysis

The major adverse impacts of fire management activities on wetlands include sedimentation, hydrological alteration, soil compaction, disturbance of vegetation, and contamination by saltwater, herbicides, or fire retardant. Beneficial impacts of fire on wetlands include the continuation of natural processes as well as the eradication of nonnative species.

Sedimentation can occur when fire activities upslope of the wetland result in erosion. Excess sediment levels in a wetland can adversely affect the wetland by altering the hydrology and in turn the vegetation composition. These effects could be major and permanent depending on the percentage of the wetland that is affected.

Increased runoff from compacted or hydrophobic soils upstream could affect wetland hydrology by causing scour or forming new drainage channels that deplete the site of water. This may lead to a change in the hydrology, soils, and vegetation of the site that could be both major and permanent.

Soil compaction requires special consideration in wetlands, since wetlands have wetter soils year-round. Fire management activities such as cutting hand line or dozer line in wetlands can be very destructive if conducted when soils are wet. Soil compaction could lead to a change in the hydrology of the site, but would likely affect only a portion of the site and thus be considered moderate in intensity.

Wetland vegetation can be affected by burning or vegetation removal activities. A certain degree of burning through a wetland could be beneficial, since wetlands are included in a landscape that has evolved with fire. Research described by the Point Reyes National Seashore (PRNS) FMP (2004) suggests that, if burned areas retain seed of native species in the soil, or if burns create a mosaic pattern with some surviving native vegetation or resprouting native vegetation, within a few years it can be difficult to determine that a fire recently occurred. However, high-intensity impacts such as an uncontrolled fire or disruptive fire lines through a wetland could make the area more susceptible to invasion by nonnative plants.

Impacts from fire management actions could also occur during fire suppression from aerial drops of saltwater into freshwater wetlands or the use of foam or wetting agents. These could have the effect of killing salt-intolerant plants or smothering vegetation with fire retardant. These effects would likely be short-term and minor, except if the area is subsequently invaded by nonnative species that present a long-term threat to native vegetation.

Actions Common to All Alternatives

Wildland-Urban Interface Initiative

The cooperative Wildland-Urban Interface Initiative would continue under all the alternatives, and would consist of reducing fuels along the park boundary. Mechanical removal of trees and brush in the upper reaches of the watersheds could create soil compaction and erosion that increase surface flow and sedimentation in the lower-lying wetlands. These effects would be localized and minor, and with the applicable mitigation measures listed in Chapter 2 would be negligible.

Defensible Space/Vegetation Clearing Around Structures

Mechanical removal of trees and brush throughout the watersheds could create soil compaction and erosion that increase surface flow and sedimentation in the lower-lying wetlands. These effects would be localized and minor, and with the applicable mitigation measures listed in Chapter 2 would be negligible.

Roadside Fuel Reduction

Maintenance or upgrading of fire roads could create ground disturbance and runoff and cause a sedimentation problem in wetlands. However, many fire roads in the park are currently in substandard condition, and maintenance activities and drainage improvements could actually correct a current problem. With current best management practices (BMPs) for the maintenance of fire roads and trails incorporated, these activities would have a beneficial, long-term, and minor effect on wetlands.

Suppression

The potential impacts of wildland fire suppression on wetlands are similar to potential impacts of wildland fire suppression on other vegetation classes as described in the previous section (see discussion under "Impacts on Vegetation" above). Due to increased moisture levels often present in wetlands, however, such impacts can be more severe.

GGNRA has had an average of 8 unplanned fires annually, with each fire generally burning less than 5 acres. The impacts on wetlands associated with these small unplanned wildfires and their suppression are expected to be both adverse and beneficial. Adverse impacts are expected to be minor and short-term. It is possible that small invasions of nonnative plants would result from these fires, which could result in a longer-term impact, but the impact would be localized. Small unplanned wildland fires in the project area may have some beneficial impact on wetlands in localized areas if nonnative plants are killed and native plants establish on the site following the fire.

Suppression activities would also have direct but localized impacts. Fire control lines can involve clearing all vegetation within an 18- to 24-inch-wide swath down to bare mineral soil. In emergency situations, bulldozers can be used to create fuel breaks to stop wildfire. Vegetation clearing can disturb wetland soils as well as create conditions that are favorable for the establishment of nonnative plant species.

Aerial drops of water or retardant are means of releasing liquids onto burning or unburned areas. Although the chemical components of retardant only remain for a few months at most, and long-term, chemical alteration of the soil would not occur, there could be localized long-term impacts on areas if nonnative plants become established or spread.

These effects on wetlands would be minor, short-term, and adverse. However, if the applicable mitigation measures listed in Chapter 2 are applied during or following suppression, the wetland could receive a beneficial, long-term, and minor effect from the wildland fire.

Treatment of Muir Woods FMU

Prescribed fire, mechanical thinning, and understory thinning would occur in Muir Woods FMU in all the alternatives. These projects could affect wetlands adjacent to Redwood Creek through sedimentation, compaction, and disturbance of vegetation. This would create an adverse, short-term minor effect. However, prescribed burning could have a beneficial impact on wetlands by maintaining the natural processes of the watershed. Likewise, mechanical removal of nonnative species such as French broom would prevent encroachment of these species into wetlands.

If the applicable mitigation measures listed in Chapter 2 are followed for actions at Muir Woods FMU, there would be beneficial, long-term, minor impacts on the wetlands.

Treatment of San Francisco County Project Area

Fire management activities in San Francisco lands would consist only of mechanical treatment and small research burns for implementation of Recovery Plan objectives for federally listed plant species. Mechanical treatments would avoid wetland areas to the greatest extent possible. If such treatments in wetlands were deemed necessary to ensure fire safety around structures or roads or to remove nonnative

vegetation, a buffer would be maintained around wetland areas where fire management activities would be restricted. Staging and vehicle use would occur outside of the buffer area, and nonnative vegetation removal would occur under tightly controlled conditions. Any impacts that occur in the buffer area must be correctable by site-specific actions, and must be confined to short-term, minor (or less), adverse effects. In many cases, clearing of dense nonnative vegetation could result in increased growth or establishment of native wetland species by creating gaps or openings in canopy cover. These impacts would be considered beneficial, minor, and long-term.

Unplanned fires in San Francisco would be suppressed immediately. Fire suppression activities, as described above, could have adverse, short-term, minor effects on wetlands.

With the applicable mitigation measures listed in Chapter 2, fuel reduction measures in San Francisco lands would result in beneficial, minor, and long-term effects on wetlands.

Public Information and Fire Education Programs

The public information and education program would have no beneficial or adverse effects on wetlands.

Fire Cache

Fire cache relocation would have no beneficial or adverse effects on wetlands.

Fire Effects Monitoring

The fire effects monitoring program excludes wetlands from analysis since these habitats are not targeted for treatment with prescribed fire. Therefore, negligible impacts on wetlands would occur with continued implementation of this program.

Alternative A

Mechanical Fuel Reduction

Alternative A allows for a maximum of 100 acres of mechanical treatments throughout the park. Mechanical treatment would be focused near structures or high-value areas, largely through the Wildland-Urban Interface Initiative. Mechanical treatments would avoid wetland areas to the greatest extent possible to minimize adverse impacts on soils, hydrology, and vegetation. If such treatments in wetlands were deemed necessary to ensure fire safety around structures or roads or to remove nonnative vegetation, a buffer would be maintained around wetland areas where fire management activities would be restricted. Staging and vehicle use would occur outside of the buffer area, and nonnative vegetation removal would occur under tightly controlled conditions. Any impacts on wetland soils, hydrology, or vegetation that occur in the buffer area must be correctable by site-specific actions, and must be confined to short-term, minor (or less), adverse effects. In many cases, clearing of dense nonnative vegetation could result in increased growth or establishment of native wetland species by creating gaps or openings in canopy cover. These impacts would be considered beneficial, minor, and long-term.

With the applicable mitigation measures listed in Chapter 2, the impacts on wetlands from mechanical treatments under Alternative A would be beneficial, long-term, and minor.

Pile Burning

Most mechanical removal projects would include pile burning. The piles would be small in size and create very localized compaction and hydrophobic soil. The piles would not be located in wetlands, and would otherwise have a negligible impact on the park's wetlands.

Prescribed Fire

This alternative focuses on prescribed burning for resource management, but does not specify wetlands as a target resource. Seasonal wetlands are often located adjacent to grasslands and scrub communities throughout the park, and therefore could be affected by prescribed burns in these plant communities. These would be low- to moderate-intensity burns, which generally burn near or around moist wetland soils rather than in the wetlands themselves. If burns are prescribed in the summer or fall, when seasonal wetlands are dry, some impact from the loss of vegetation is possible. In dry years, prescribed fire may burn into perennial wetlands as well.

In general, a buffer would be maintained around wetland areas where fire management activities would be restricted. Staging, fire line construction, and vehicle use would occur outside of the buffer area, and prescribed burning inside the buffer area would occur under tightly controlled conditions. Any impacts on wetland soils, hydrology, or vegetation that occur in the buffer area must be correctable by site-specific actions, and must be confined to short-term, minor (or less), adverse effects. The sites will be monitored after prescribed burning to ensure that the species composition favors native wetland species and does not promote the growth of nonnative species.

Under these circumstances, the prescribed burns would have minor-to-moderate long-term beneficial impacts on wetland vegetation by stimulating growth and reproduction of native wetland species. Even if the wetland vegetation was too wet to burn, the wetland would benefit from native plant stimulation in the surrounding buffer area. One benefit would be a reduced chance of encroachment by nonnative plants into the wetland area.

By following the applicable mitigation measures listed in Chapter 2 during prescribed burning, the impacts on wetlands from Alternative A would be beneficial, long-term, and moderate.

Research

Alternative A could include elements of research into the effects of fire on vegetation, hydrology, soils, and other features. It is possible that some research could focus on the effects of fire on wetlands. If this is the case, there is a chance that the research could show that fire has an adverse effect on wetlands. These effects, however, would likely be short-term and minor. Research would more likely show that fire has a beneficial effect on wetlands by maintaining the natural processes in the wetlands.

The applicable mitigation measures listed in Chapter 2 would ensure that only short-term, minor effects occur as a result of fire effects research.

Cumulative Impacts

As previously described in this chapter, cumulative impacts are those that would occur not only as a direct result of this planning effort or actions proposed under the alternative, but in conjunction with other activities within the same project areas. These projects should be considered when developing fire management plans for the various project areas. The combined impacts of unrelated projects and fire management activities within a project area should not exceed the threshold for minor impacts on wetlands (i.e., changes in the areal extent, or in wetland vegetation, soils, or hydrology, would be measurable but would affect less than 5 percent of the total extent of the wetland type in the project area). For example, the Big Lagoon restoration in the Redwood Creek watershed is a large-scale restoration that could temporarily disrupt wetland function in the area while natural processes are restored. Fire management planning for the upper reaches of the watershed should create only minor impacts such as erosion and sedimentation so that the wetland restoration is successful. Similar consideration should be given to any transportation, trail improvement, maintenance, habitat restoration, or other project that creates sedimentation or other impacts on wetlands.

Conclusion

Fire management activities would avoid wetland areas to the greatest extent possible to minimize adverse impacts on soils, hydrology, and vegetation. If such treatments in wetlands were deemed necessary to ensure fire safety around structures or roads or to remove nonnative vegetation, an appropriate buffer would be maintained around wetland areas where fire management activities would be restricted. Staging and vehicle use would occur outside of the buffer area, and nonnative vegetation removal would occur under tightly controlled conditions. Any impacts on wetland soils, hydrology, or vegetation that occur in the buffer area must be correctable by site-specific actions, and must be confined to short-term, minor (or less), adverse effects.

Mechanical treatments and prescribed fire could have adverse, short-term, minor impacts on wetland soils, hydrology, and vegetation. Overall, the fire management activities would have minor-to-moderate long-term benefits to wetland communities through reduction of nonnative plant species and stimulation of growth in native species. Furthermore, the minor adverse impacts could be offset by the beneficial effect of preventing a large-scale wildfire. An unplanned, excessively hot fire could have major, long-term, adverse impacts on wetlands by destroying vegetation and allowing invasion by nonnative species, creating hydrophobic soils, and increasing runoff.

Impairment

No impairment of wetlands would result from this alternative.

Alternative B

Mechanical Fuel Reduction

Alternative B relies largely on mechanical fuel reduction throughout the park, particularly in the WUI FMU. Although the total acreage of projects per year would be greater than under Alternative A, the impacts would not be significantly different. With the implementation of the mitigation measures

described for Alternative A, and in Chapter 2, the impacts on wetlands from mechanical removal under Alternative B would be beneficial, long-term, and minor.

Pile Burning

Impacts would be the same as under Alternative A.

Prescribed Fire

Under Alternative B, prescribed burning would occur in the Park Interior FMU, and Muir Woods FMU, covering a maximum of 120 acres per year throughout the park. This would be a level of impact similar to Alternative A. With the implementation of the mitigation measures described for Alternative A, the effects of prescribed fire on wetlands under Alternative B would be beneficial, short-term, and minor.

Research

Impacts would be the same as under Alternative A.

Cumulative Impacts

Impacts would be the same as under Alternative A.

Conclusion

Impacts would be the same as under Alternative A. Mechanical treatments would avoid wetland areas to the greatest extent possible. If such treatments in wetlands were deemed necessary to ensure fire safety around structures or along roads, these treatments would have negligible-to-minor adverse impacts on wetland vegetation, hydrology, and soils. Clearing vegetation also could have minor benefits to wetland species if native species establishment is enhanced.

Minor adverse impacts are possible from prescribed fires burning near and into wetlands in dry years. If fire intensity is low to moderate, minor-to-moderate benefits on wetland vegetation are possible due to reduction of nonnative plant species or stimulation of germination and resprouting in native species.

These minor adverse impacts could be offset by the beneficial effect of preventing a large-scale wildfire. An unplanned, excessively hot fire could have major, long-term, adverse impacts on wetlands by destroying vegetation and allowing invasion by nonnative species, creating hydrophobic soils, and increasing runoff.

Impairment

No impairment of wetlands would result from this alternative.

Alternative C

Mechanical Fuel Reduction

Alternative C would involve more mechanical fuel reduction in Marin County, with the same acreages in San Francisco and San Mateo counties as Alternative B. The increased acreage in Marin would occur in the park interior areas. Although the total acreage of projects per year would be greater than under Alternatives A and B, the impacts would not be significantly different. With the implementation of the

mitigation measures described for Alternative A and in Chapter 2, impacts on wetlands under Alternative C would be beneficial, long-term, and minor.

Pile Burning

Impacts would be the same as under Alternative A.

Prescribed Fire

Under Alternative C, prescribed burning would occur mainly in the Park Interior FMU, with a limited amount in the WUI FMU and Muir Woods FMU. A maximum of 320 acres per year would be burned throughout the park. While this is an increase in acreage from Alternatives A and B, the intensity of impact would not exceed minor. With the implementation of the mitigation measures described for Alternative A, the effects of prescribed fire on wetlands under Alternative C would be adverse-to-beneficial, long-term, and minor.

Research

The adverse impacts of this alternative would be similar to those of Alternatives A and B. However, the beneficial impacts could be increased due to the opportunity for more research burns.

Cumulative Impacts

Impacts would be the same as under Alternative A.

Conclusion

Impacts would be the same as under Alternative A. Mechanical treatments would avoid wetland areas to the greatest extent possible. If such treatments in wetlands were deemed necessary to ensure fire safety around structures or along roads, these treatments would have negligible-to-minor adverse impacts on wetland vegetation, hydrology, and soils. Clearing vegetation also could have minor benefits to wetland species if native species establishment is enhanced.

Minor adverse impacts are possible from prescribed fires burning near and into wetlands in dry years. If fire intensity is low to moderate, minor-to-moderate benefits on wetland vegetation are possible due to reduction of nonnative plant species or stimulation of germination and resprouting in native species.

These minor adverse impacts could be offset by the beneficial effect of preventing a large-scale wildfire. An unplanned, excessively hot fire could have major, long-term, adverse impacts on wetlands by destroying vegetation and allowing invasion by nonnative species, creating hydrophobic soils, and increasing runoff.

Impairment

No impairment of wetlands would result from this alternative.