Giant Sequoia

National Monument

Specialist Report

Groundwater

Signature: ______________

Date: December 9, 2011

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Introduction

Groundwater is a key component of the water resources on the Giant Sequoia National Monument (Monument). Groundwater is fundamental to sustain the health, productivity and diversity of aquatic wildlife, terrestrial wildlife and the human populations within and downstream of the Monument. Groundwater is critical to maintain groundwater dependent ecosystems and is part of the hydrologic system that moves water from the high elevation, snow regions to the lower elevation, groundwater discharge zones. The programmatic activities and management strategies proposed in the alternatives of this environmental impact statement have been evaluated for their potential impact to groundwater resources. This report documents the evaluation and establishes desired conditions, strategies and objectives to maintain and protect groundwater and groundwater dependent resources.

Current Management Direction

Laws, Regulations and Policy

The following laws apply to the management of ground water resources: In addition to the Federal land management statutes cited in Forest Service Manual (FSM) 2501, the following Federal statutes provide pertinent direction to the Forest Service for its management of groundwater resources in the National Forest System (NFS). In addition, judicial doctrine and water-rights case law provide the legal interpretations of Federal and State statutes about usage and management of groundwater (see FSM 2541.01 and Forest Service Handbook [FSH] 2509.16 for procedures to be followed for complying with Federal policy and State water-rights laws). The Forest Service national groundwater policy is intended to set out the framework in which groundwater resources are to be managed on NFS lands. As of the publication date of this document, the national policy has not yet been finalized. However, the Technical Guide for Ground Water Resource Management provides a framework for the management of groundwater resources while the national policy is completed.

Safe Drinking Water Act of 1974, as amended. (42 U.S.C. §300f et seq). The intent of the SDWA is to ensure the safety of drinking-water supplies. Its authority is used to establish drinking-water standards and to protect surface- and groundwater supplies from contamination.

Resource Conservation and Recovery Act of 1976, as amended. (42 U.S.C. §6901 et seq) The Resource Conservation and Recovery Act (RCRA) regulates the generation, transportation, treatment, storage and disposal of waste materials. It has very specific requirements for the protection and monitoring of groundwater and surface water at operating facilities that may generate solid wastes or hazardous wastes.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended. (42 U.S.C. §9601 et seq). Also known as “Superfund,” the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulates cleanup of existing environmental contamination at non-operating and abandoned sites (see also FSM 2160).

National Environmental Policy Act of January 1, 1970 (NEPA) (83 Stat. 852 as Amended; 42 U.S.C. 4321, 4331-4335, 4341-4347) (FSM 1950.2). This act directs all agencies of the Federal Government to utilize a systematic interdisciplinary approach which will ensure the integrated use of the natural and social sciences in planning and in decision making which may have an impact on man's environment. Hydrogeology is one of the applicable sciences.

Forest and Rangeland Renewable Resources Planning Act of August 17, 1974 (RPA) (88 Stat. 476; 16 U.S.C. 1600-1614) as Amended by National Forest Management Act of October 22, 1976 (90 Stat. 2949; 16 U.S.C. 1609) (FSM 1920 and FSM 2550). This act requires consideration of the geologic environment through the identification of hazardous conditions and the prevention of irreversible damages. The Secretary of Agriculture is required, in the development and maintenance of land management plans, to use a systematic interdisciplinary approach to achieve integrated consideration of physical, biological, economic, and other sciences.

Federal Water Pollution Control Act of July 9, 1956, as Amended (33 U.S.C. 1151) (FSM 2501.1); Federal Water Pollution Control Act Amendments of 1972 (86 Stat. 816) (FSM 2501.1), and Clean Water Act of 1977 (91 Stat. 1566; 33 U.S.C. 1251) (FSM 2501.1, 7440.1). These acts are intended to enhance the quality and value of the water resource and to establish a national policy for the prevention, control, and abatement of water pollution. Groundwater information, including that concerning recharge and discharge areas, and information on geologic conditions that affect groundwater quality are needed to carry out purposes of these acts.

Description of Proposal

Desired Conditions

Groundwater quality and quantity in aquifers across watersheds are sustained in all alternatives. Initiate ecological restoration of groundwater systems by preserving, maintaining and restoring physical and biological processes in groundwater systems including meadows and springs.

Strategies

1. Determine patterns of recharge and discharge and minimize disruptions to groundwater levels that are critical for wetland integrity.

2. Determine the groundwater levels, within a range of natural variability, that provide base flows to maintain and enhance the condition of groundwater dependent resources and their habitat.

3. Restore those groundwater-dependent ecosystems damaged by prior land uses, such as meadows and Giant Sequoia Groves with campgrounds.

Objectives

1. During evaluation of site-specific projects with the potential to affect groundwater (such as recreational development), determine groundwater conditions and evaluate the potential effects to groundwater levels and groundwater dependant ecosystems.

2. During the life of the Monument Plan, evaluate the effects of groundwater pumping on groundwater-dependent resources in 10 wells near giant sequoia groves, meadows, or springs. The following are a list of recommended standards applied to the management of groundwater on the Giant Sequoia National Monument for all alternatives except Alternative E.

The following are a list of recommended standards applied to the management of groundwater on the Giant Sequoia National Monument for all alternatives except Alternative E.

Standard and Guidelines

1. Establish minimum distances for well site locations adjacent to rivers, streams, wetlands or other groundwater-dependent ecosystems that are determined to be hydrologically connected to the well.

2. Establish maximum water level draw down limits for wells located adjacent to or within groundwater-dependent ecosystems.

The following standard applies to all alternatives.

3. Conduct appropriate analyses when evaluating proposals and applications for water wells or other activities that test, study, monitor, modify, remediate, withdraw or inject groundwater on NFS lands (see Technical Guide to Managing Groundwater Resources, FS-881, May 2007).

Affected Environment

Groundwater within the Monument is located within weathered, fractured bedrock and unconsolidated alluvial and glacial deposits. Carbonate (marble and meta-limestone) geology exists in the Windy Gulch Area and in Tule River Basin. The carbonate geology has components of a karst landscape and groundwater systems may be considered karst groundwater systems. Karst groundwater systems may have flat water tables, enlarged fractures from solution cavities, sink hole springs and karst springs, swallows and sinks in the middle of channels that capture surface water, and flowing subsurface streams in cave passages. Groundwater systems have not been studied in these karst landscapes and site specific groundwater conditions are unknown. Unconsolidated alluvial and glacial deposits are unconfined aquifers. Most alluvial deposits are wet meadows that often contain springs.

Three types of groundwater flow systems have been identified in the scientific literature (Toth 1962, 1963, Freeze 1969, Freeze and Witherspoon 1966, 1967, and 1968, Freeze and Cherry 1979). Local groundwater flow systems are recharged at a topographic high and discharge at the adjacent topographic low. Intermediate groundwater flow systems have a topographic high between the recharge and discharge areas. Regional groundwater flow systems are recharged at the topographic high of a groundwater basin and discharge to the hydrologic sink of the groundwater basin. Local groundwater flow systems respond immediately to a recharge event. There is generally a time lag between the response of groundwater levels to a recharge event within an intermediate groundwater flow system. Groundwater levels in a regional flow system respond more slowly to recharge events than intermediate and local groundwater flow systems. Groundwater is transported down gradient from recharge areas to discharge areas. Springs provide an exit point for a groundwater flow system. Springs and wet meadows are considered groundwater dependent ecosystems.

Several wells are located within the Monument at administrative sites, including campgrounds, fire stations, and state and private land holdings. Well sites are located at the Hot Springs Ranger District, California Hot Springs, Johnsondale, and Mountain Home State Park.

The Monument is located in three California groundwater administrative basins, including the Kings River Basin, the Upper Kern River Basin, and the Upper Tulare Basin. Groundwater within these basins originates and discharges in these basin with some unknown interaction between the basins. Several ecosystems in these basins are dependent on groundwater and include giant sequoia, springs, meadows, fens and caves.

Hydrologic processes deliver subsurface water, (or groundwater) to giant sequoia groves. The connection of groundwater to Giant Sequoia groves is not well studied or understood. Borcher, 2001 produced a manuscript entitled *An Ecological Zone of Influence for Giant Sequoia: Subsurface Water Considerations*. This manuscript summarizes current understanding of giant sequoia subsurface water relations; describing subsurface flow systems that might provide water to groves. Borchers describes the relation of giant sequoia groves to direct precipitation, soil moisture, movement of water down hillslopes, unsaturated groundwater, shallow groundwater flow systems, and deep groundwater flow systems. Borchers' assessment can be summarized with the following points:

1. Water balance studies suggest precipitation directly on groves areas may be adequate to sustain some giant sequoia ecosystems.

2. Movement of water down hill, within the unsaturated zone and as surface runoff, possibly provides soil moisture used in giant sequoia groves.

3. During periods of extended drought, recharge to shallow, seasonally-saturated, groundwater systems on hill slopes might not provide adequate water to sustain healthy giant sequoia ecosystems. Healthy giant sequoia ecosystems might persist during times of drought where groundwater moves to the root zone from perennially saturated groundwater flow systems.

4. Shallow groundwater flow systems are nested overlying, intermediate, and regional groundwater flow systems. The relationship between shallow groundwater flow systems and intermediate and regional groundwater flow systems is unclear. Shallow groundwater can move downward to deeper groundwater flow systems in recharge areas where vertical hydraulic gradients exist.

5. Detailed hydrologic and hydrogeologic characterization of giant sequoia groves does not exist and the sources and flow paths of subsurface water available to giant sequoia groves cannot currently be described quantitatively.

In a 1972 study, completed by Philip W. Rundel, high levels of soil moisture appear to be maintained within giant sequoia groves during the dry summer months through groundwater originating from summer thunderstorms in the high Sierra. Groundwater percolates down to lower elevations where it appears in the soil profile. Percolation of high elevation groundwater into groves during the dry summer months may be key to the continued existence of giant sequoia groves.

There are approximately 65 springs[(1)] known within the Monument. Spring locations are dependent upon the presence of rock layers of differing hydraulic conductivity, the groundwater flow system, the level of the water table, and local topography (Bachman 1997). Springs are distributed throughout the Monument, with most springs clustered in the southwest part of the Monument: near California Hot Springs; near Nobe Young and Dry Meadow Creeks; around Freeman Creek Grove; in the Camp Nelson and Camp Wishon areas; and in the northern Monument south of the Kings River canyon. Most springs are perennial and have little information on site specific flow rates or water quality. However an inventory of aquatic insects suggest overall water quality is excellent to very good and flow rates can be determined through the use of regional discharge relationships on Monument lands (see the hydrology report for more detailed information). Spring ecosystems are dependent on groundwater to maintain their flow rates and ecosystem function. Springs can have phreatophyte vegetation, which are deep-rooted plants that obtain their water needs from just above the water table. These species are a key component of most riparian ecosystems. There are approximately 268 meadows, including 112 wet meadows in the Monument. A wet meadow is considered a wetland and can include fens. Fens are peat-forming wetlands that receive recharge and nutrients almost exclusively from groundwater. The average size of wet meadows are approximately 5.5 acres, with the largest being 53 acres and the smallest being .5 acres. Meadows are productive and diverse ecosystems scattered throughout the Monument, except in the Kings Canyon inner gorge and between the Tule Reservation, north to the boundary of Sequoia National Park. Meadow ecosystems and phreatophyte vegetation are groundwater dependent and rely on shallow groundwater during the growing season.

Loheide and Richard (2009) concluded that meadows throughout the Sierra Nevada have experienced important changes in vegetation and hydrology since the 1850s. Because of the connection between vegetation and the groundwater systems, a lowering of the water table, resulting from changes in hydrologic patterns and processes, typically results in a shift from native wet meadow vegetation to more xeric vegetation. These changes could be associated with logging, road and railroad construction, ditching/channelization, grazing, and climate change. One of the most apparent issues in meadows today is the invasion of lodgepole pine, which is encroaching on meadows and reducing meadow vegetation around the perimeter. It is unknown how much meadows have changed in the Monument area, since the 1850's.

There are fifteen known caves and possibly as many as 100 caves, located in the Monument. Most of these caves are located in proximity to Boyden Cave. Caves are a type of groundwater dependent ecosystem and their formation and continuing formation is due to groundwater percolating through fractures and dissolving carbonate rocks located in the Monument. A comprehensive inventory of the caves has not been conducted and there is a high potential that groundwater dependent fauna and microorganisms exist within the cave systems.

There are twenty six wells located in the Monument that draw groundwater for domestic uses at campgrounds and administrative sites, including fire stations. Some of these wells are located near Giant Sequoia groves and within the groves' ecological zone of influence (see the following table). It is unknown how much water these wells draw and whether they are affecting groundwater dependent resources.

Table 1. List of Wells Within Ecological Zone of Influence

WELL NAME	Known Groundwater Dependent Ecosystem
Boulder Creek Well	Belknap Complex Sequoia Grove
Belknap Well	Belknap Complex Sequoia Grove
Coy Flat Well	Belknap Complex Sequoia Grove
Quaking Aspen Well	Belknap Complex Sequoia Grove
Jerkey Well	Small Meadow
Princess Campground Well	Indian Basin Sequoia Grove
Redwood Meadow Well	Long Meadow Sequoia Grove
Eshom Campground Well	Redwood Mtn. Sequoia Grove
Fir Cove Campground Well	3 Meadows
Mountain Home Guard State Recreation Rental Well	Mountain Home Sequoia Grove

Environmental Effects

Groundwater can vary in quantity and quality and is dependent on precipitation, geologic setting, forest management, and the number of wells located in a particular area. Groundwater could be depleted from management activities, including use of groundwater wells and vegetation management which in turn could affect groundwater discharge and dependent ecosystems such as Giant Sequoia Groves, springs and wet meadows. Groundwater could possibly be affected by an overall change in the water budget of a groundwater basin. A groundwater budget at equilibrium is defined as groundwater recharge minus evapotranspiration minus groundwater pumping equal to groundwater discharge. Environmental effects to groundwater resources from activities detailed in management alternatives vary depending on the alternative emphasis. All alternatives would include some form of recreation, vegetation management, prescribed burning, and managed wildfire. Recreation and administrative sites can lead to the need to pump groundwater. Groundwater pumping can remove groundwater from storage and lower the groundwater level. Vegetation management has the potential to affect groundwater by reducing short term (less than 5 years) evapotranspiration, which could provide short term increases in groundwater and raise the water table. These activities could affect groundwater quality, quantity and dependent ecosystems, including Giant Sequoia groves, springs, fens, wet meadows, and caves.

Legal and Regulatory Compliance

Assumptions and Methodology

A conceptual effects analysis was used to determine the potential effects to groundwater from the alternatives analyzed in the draft EIS. This analysis includes effects from mechanical treatment, prescribed fire, and managed wildfire to treat fuels and maintain and restore healthy forests. In addition, wildfire is also analyzed.

The following is a description of the conceptual model used to determine effects to groundwater resources.

Mechanical Treatment and Prescribed Fire or Managed Wildfire

For Fuel Management

↓

Reduces Vegetation Density

↓

Reduces Evapotranspiration

↓

Increases Groundwater

Several assumptions have been made in this analysis including:

1. Runoff does not increase and infiltration does not change in areas where mechanical treatments occur (Troendle et. al. 2010).

2. Runoff will not be affected with modifications to average stand densities by less than 20 percent (Troendle et. al. 2010).

3. Groundwater pumping from water wells in campgrounds and administrative sites within the Zone of Ecological Influence of Groundwater Dependent Ecosystems is less than groundwater recharge to these systems (Troendle et. al. 2010).

4. For the purpose of this analysis, Giant Sequoia Groves are considered groundwater dependent ecosystems (see Borcher, 2001).

The following are a list of recommended standards applied to the management of groundwater on the Giant Sequoia National Monument for all alternatives except Alternative E.

Standard and Guidelines

1. Establish minimum distances for well site locations adjacent to rivers, streams, wetlands or other groundwater-dependent ecosystems that are determined to be hydrologically connected to the proposed well.

2. Establish maximum water level draw down limits for wells located adjacent to or within groundwater-dependent ecosystems.

The following standard applies to all alternatives.

3. Conduct appropriate analyses when evaluating proposals and applications for water wells or other activities that test, study, monitor, modify, remediate, withdraw or inject groundwater on NFS lands (see Technical Guide to Managing Groundwater Resources, FS-881, May 2007).

The main premise of mechanical treatment, prescribed fire and managed wildfire would be a decrease in stand density. This is in turn could reduce evapotranspiration from remaining vegetation, which could increase shallow groundwater. Numerous studies have been conducted demonstrating changes in forest density can cause a changes in water yield (Troendle et. al. 2010). These changes include changes in evapotranspiration and snow pack depth. Several of the studies have concluded that a threshold of 20 percent basal area would have to be exceeded to detect a change in annual runoff. This value is supported by paired watershed studies and modeling (Troendle et al. 2006). With removal of between 10 and 20 percent basal area, flow is affected but the change is not detectable due to the natural variability. Many investigators have found that approximately 20 percent change in basal area must occur before a statistical change in flow could be detected (Troendle et al. 2006). MacDonald and Stednick (2003) state that 15 percent basal area must be removed before a change in flow can be detected in small research watersheds, and detection becomes more difficult as watershed size increases.

There are several variables to consider to determine changes in groundwater quantity from fuel management activities. These variables include annual precipitation, recharge area, discharge areas, watershed size, groundwater flow system type, vegetation types, lag time between time of treatment, and ability to detect change in groundwater. Annual precipitation ranges from 25 to 50 inches across the Monument, with most accumulation as snow in December through March. Snow accumulation averages 100 to 300 inches, dependent in part on elevation. Snow accumulates from approximately 4,000 feet elevation and above.

Watershed size and area of groundwater recharge and discharge is a significant variable in detecting effects to groundwater. Activities directly downstream or down gradient could have an effect on groundwater; however, as the watershed size increases outside of the ecological zone of influence, changes in groundwater would probably be immeasurable. Vegetation type and size is also a significant variable. Different vegetation and the age/size of this vegetation uses varying amounts of soil moisture. As forest stands are treated, the remaining vegetation has more available soil moisture and could increase its use and grow larger faster than under pre-treatment conditions. The overall effect of decreased evapotranspiration will possibly be short term (less than 5 years) and groundwater levels would return to pretreatment conditions. There would be a lag time between treatment and detectable change. Detectable change could vary depending on the distance between the measurement location and where the treatment is conducted.

There are several unknown variables in accessing the effects of the proposed activities on groundwater resources. One of these variables is the extent of high soil burn severity areas within managed wildfire areas. Fires would be allowed to burn hot enough to create openings and tolerate high mortality in fairly extensive areas of the Monument outside the wildland urban intermix (WUI). This could be interpreted to mean that areas of high soil burn severity could result from managed wildfire in some locations. In areas with high soil burn severity, soil hydrologic function can be changed resulting in less infiltration.

Indirect Effects

Alternative A

Recreation management includes management of recreation activities in the back country and at developed recreation sites. Impacts associated with recreation could include drilling new wells in the Monument at new campgrounds or administrative sites. These sites have the highest potential to affect groundwater resources in the immediate vicinity of the site. Groundwater availability varies from site to site and generally can be replenished on an annual basis from yearly precipitation. The proposed standard and guidelines for well drilling defined through national guidance provides an analysis tool to determine if proposed drilling could have an effect on resources including other wells in the area and other potentially affected resources.

Alternative A would manage recreation under the current direction. Groundwater conditions should not change from existing conditions under Alternative A. There are some campgrounds with wells in the vicinity of giant sequoia groves, meadows and springs, including Indian Basin Grove. These campgrounds and wells are within the ecological zone of influence described by Borchers (2001). It is unknown if these wells currently affect adjacent groundwater dependent resources, such as wet meadows, fens and springs.

Vegetation management, including mechanical thinning, prescribed fire, and managed wildfire, should not affect groundwater resources, as treatments would not change basal areas more than 20 percent. Wildfire could affect groundwater recharge by increasing runoff and reducing infiltration. Wildfire could result in hydrophobic soil conditions or water repellent soils and reductions in ground cover that can affect groundwater recharge. Under the existing conditions in the Monument, wildfire with high burn severity could occur. If a wildfire, similar to the McNally Fire occurred in the Monument, groundwater recharge could be reduced and would likely take less than six years to recover (Berg and Azuma 2008). Managed wildfire could result in high soil burn severity and have similar consequences. Standards and guidelines for managed wildfire should provide for minimization of high soil burn severity and retention of ground cover, therefore managed wildfire should not adversely affect groundwater recharge.

Alternatives B and F

Alternatives B and F would increase recreational opportunities at day use areas, campgrounds, and commercial sites. The commercial sites could include lodges, campgrounds, restaurants, health spas and other commercial recreation facilities. These new facilities would require potable water from new groundwater wells. These alternatives have the potential to use more groundwater than any other alternative and groundwater could be depleted at the local level. The proposed standard and guidelines for well drilling and national guidance provide for a thorough analysis of groundwater systems to determine if any proposed drilling will have an effect on other resources, including other wells in the area and groundwater dependent resources. New groundwater wells should not affect groundwater dependent resources. There is also a possibility that groundwater availability could be over-estimated if these facilities are proposed during a higher than normal precipitation cycle. If this is the case, water availability in these wells could be a problem through time. The 10 wells in the vicinity of giant sequoia groves, meadows, and springs will be evaluated to determine if groundwater pumping is affecting these groundwater dependent ecosystems. If the wells are found to be negatively affecting these groundwater dependent ecosystems, management of these facilities will be modified to eliminate this affect.

Alternatives B and F include vegetation management, prescribed burning, and managed wildfire. Alternatives B and F will manage vegetation the most, using the best available tools, and will reduce stand densities the most as compared to the other alternatives. Alternatives B and F could result in average stand densities being decreased by more than 20 percent. This could result in an overall increase in groundwater recharge. This reduction of stand density will result in less evapotranspiration of water and will increase groundwater for the short term or until basal area growth reaches pretreatment conditions. Conifers, including giant sequoia located at the edge of wet meadows, could be subjected to higher water tables. It is unknown if increased groundwater levels could affect giant sequoias. As the existing vegetation grows and stand densities increase, evapotranspiration will increase to pretreatment levels. This overall increase in shallow groundwater will balance out over 5 to 10 years. Groundwater levels should not be less than groundwater levels under current conditions.

Alternative C

Alternative C would increase recreational opportunities in developed sites. This includes constructing more picnic areas, camp grounds and other facilities. These new facilities would require potable water from new groundwater wells. More groundwater would be used in this alternative as compared to existing conditions or as compared to Alternative A, and local groundwater tables could be lowered. The proposed standard and guidelines for well drilling and national guidance provide for a thorough analysis of groundwater systems to determine if any proposed drilling will have an effect on other resources including other wells in the area and groundwater dependent resources. Therefore, new groundwater wells should not affect groundwater dependent resources. The ten wells in the vicinity of sequoia groves, meadows and springs will be evaluated to determine if groundwater pumping is affecting these groundwater dependent ecosystems. If the wells are found to be negatively affecting these groundwater dependent ecosystems, management of these facilities will be modified to eliminate this affect.

Alternative C includes vegetation management, prescribed burning, and managed wildfire. Managed wildfire will be emphasized in this alternative, except in WUIs. Fires would be allowed to burn hot enough to create openings and tolerate high mortality in fairly extensive areas of the Monument outside the WUI. The extent and the location of areas of high soil burn severity are unknown, but it is estimated to be higher than under any of the other alternatives. Soil hydrologic function will be changed, resulting in less infiltration and this could result in decreased groundwater recharge. It can take up to six years for these areas to hydrologically recovery and for groundwater conditions to be restored to pre-fire conditions.

Alternative D

Alternative D would maintain existing developed recreation sites. New developed sites would be limited to walk-in campgrounds and picnic areas. No new resorts, lodges, or organizational camps would be allowed in the Monument. The limited new developed recreation sites may require potable water and new wells. More groundwater would be used in this alternative as compared to existing conditions or as compared to Alternative A and local groundwater tables could be lowered. The proposed standard and guidelines for well drilling and national guidance provide for a thorough analysis of groundwater systems to determine if any proposed drilling will have an effect on other resources including other wells in the area and groundwater dependent resources. New groundwater wells should not affect groundwater dependent resources. The ten wells in the vicinity of giant sequoia groves, meadows and springs will be evaluated to determine if groundwater pumping is affecting these groundwater dependent ecosystems. If the wells are found to be negatively affecting these groundwater dependent ecosystems, management of these facilities will be modified to eliminate this effect.

Alternative D includes vegetation management, prescribed burning, and managed wildfire. Managed wildfire will be emphasized in this alternative, except in WUIs. Fires would be allowed to burn hot enough to create openings and tolerate high mortality in fairly extensive areas of the Monument outside the WUI. The extent and the location of high soil burn severity are unknown, but it is estimated to be higher than any of the other alternatives, except Alternative C. Soil hydrologic function will be changed, resulting in less infiltration and this could result in decreased groundwater recharge. It can take up to six years for these areas to hydrologically recovery and for groundwater conditions to be restored to pre-fire conditions.

Alternative E

Alternative E is a modification of Alternatives A and B. Some form of recreation, vegetation management, prescribed burning, and managed wildfire will occur. Recreation management will be similar to Alternative A in that recreation will not change from existing recreation management emphasis and strategies. Mechanical treatment of stands will result in less than a 20 percent basal area change. The extent and location of managed wildfire is unknown and the result would allow areas to burn hot enough to create openings and tolerate high fire mortality, outside the WUI. This could result in an overall affect of increased groundwater recharge. Recovery of these areas could take up to six years before groundwater levels are at pre-fire levels.

Cumulative Effects

The forest has a process to evaluate cumulative watershed effects (CWE) for surface water processes, including increases of peak flows and sedimentation from proposed activities. See the hydrology report for a description of this method and the expected cumulative watershed effects. The CWE Model does not directly address cumulative effects to groundwater. However, the CWE Model indirectly addresses cumulative effects to groundwater by ensuring that surface water processes are not adversely impacted. The Forest does not have a technique or model for determining the cumulative effects to groundwater. However, existing standard and guidelines and the national guidance for evaluating groundwater does provide for an assessment of cumulative effects for groundwater and groundwater dependent resources. The cumulative effects of vegetation management and local groundwater use from wells in campgrounds and administrative sites are unknown. On one hand, vegetation management by mechanical thinning and prescribed burning could increase groundwater levels by reducing evapotranspiration. On the other hand managed wildfire, could involve high soil burn severity and water repellent soils resulting in changes in soil hydrologic function. This could result in increased runoff and less infiltration. The overall effect could be less groundwater recharge. This condition could last for six years or less and groundwater levels could recover to pre-fire conditions in areas where managed wildfire is allowed to occur. Alternatives C and D have the highest potential for adverse impacts to groundwater resources because these two alternatives emphasize managed wildfire. Alternatives B and F have the lowest potential for adverse impacts to groundwater resources because these two alternatives allow for more flexibility in mechanical treatment.

Monitoring of groundwater should be conducted to validate the assumption that "Groundwater pumping from water wells in campgrounds and administrative sites within the Zone of Ecological Influence of groundwater dependent ecosystems is less than groundwater recharge to these systems". This may be particularly important in Giant Sequoia Groves where campgrounds and wells are located. Monitoring should consist of determining the extent of groundwater draw down from wells in campgrounds in the Giant Sequoia Groves. In addition, lysimeters should be installed around the groves to determine the relationship between soil moisture and groundwater withdrawal in the Giant Sequoia Groves. See Monitoring Plan in the Land Management Plan for more discussion on monitoring for surface and ground water.

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