APPENDIX J

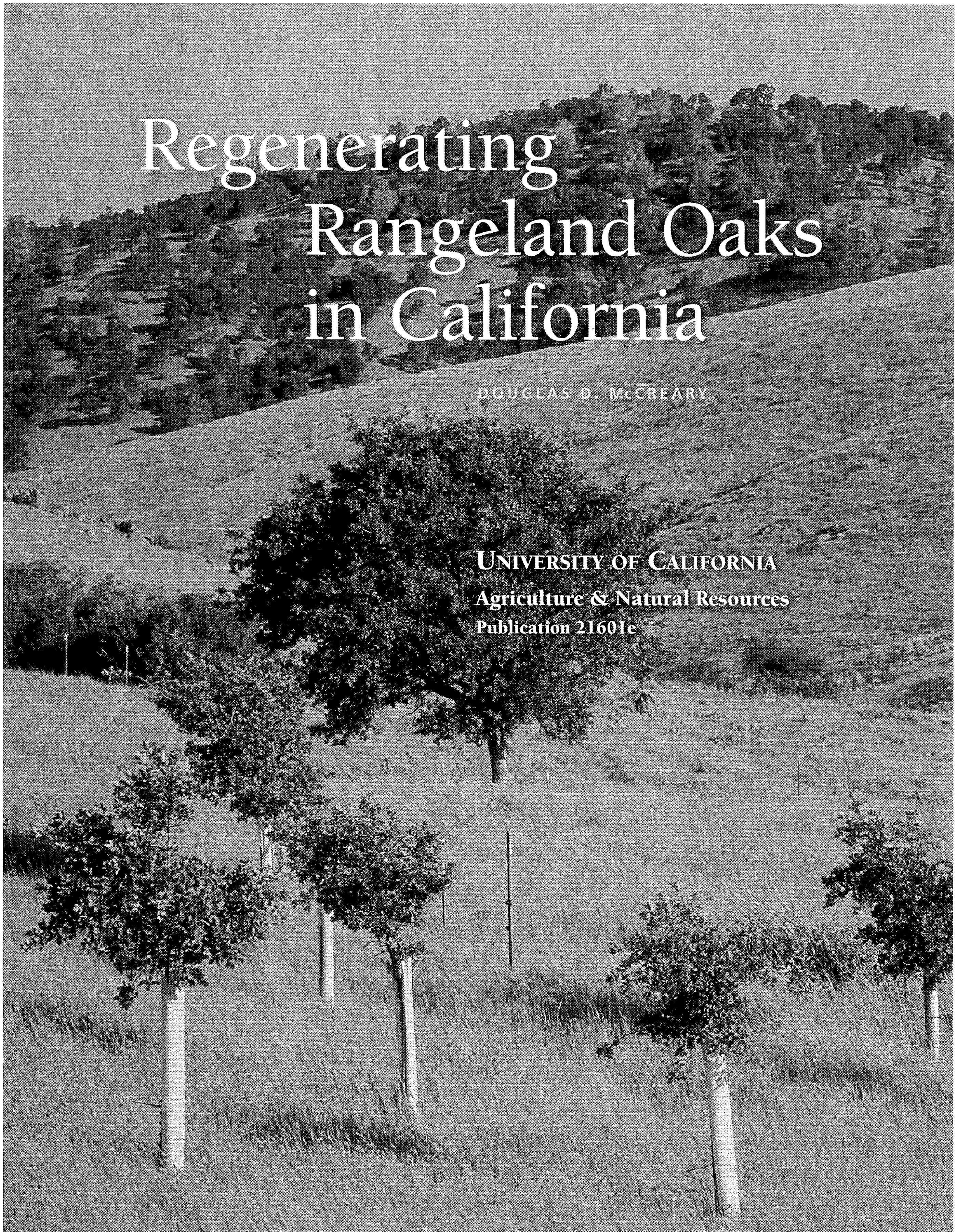
LETTER B34 ATTACHMENTS

Attachment #1

Regenerating Rangeland Oaks in California

DOUGLAS D. McCREARY

UNIVERSITY OF CALIFORNIA
Agriculture & Natural Resources
Publication 21601e



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Regenerating Rangeland Oaks in California

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An electronic version of this publication is available on the ANR Communication Services Web site at http://anrcatalog.ucdavis.edu.

Publication 21601e
ISBN-13: 978-1-60107-669-4

UC PEER REVIEWED This publication has been anonymously peer reviews for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by the ANR Associate Editor for Natural Resources.

web-09/09-AS/WJC/CR

Contents

Acknowledgments

I wrote most of this manual while I was on sabbatical in southern England at the British Forestry Commission Research Station at Alice Holt Lodge. I want to express my deep gratitude to all of the people there who made me feel at home and provided an environment conducive to learning, writing, and enjoyment. My primary host was Gary Kerr, a silviculturalist who not only provided general assistance and support during my stay but also reviewed early drafts of this document and offered many valuable comments and suggestions. Other scientists at the Research Station, including Peter Gosling, Richard Jinks, and Ralph Harmer, also reviewed individual chapters and helped make early versions of the manuscript much more readable and scientifically sound.

Another person who deserves special mention is Jerry Tecklin, a colleague of mine with the University of California Integrated Hardwood Range Management Program and collaborator on most of the oak regeneration research I have been involved with. Generally, when the term "we" is used in this document, it refers to work that Jerry and I have done together at the Sierra Foothill Research and Extension Center. Jerry has not only been instrumental in helping to design and carry out many of the studies cited in the text, but he also reviewed this whole manuscript at least twice and offered numerous helpful suggestions and editing comments.

There were also several anonymous reviewers recruited by Mel George, the Associate Editor for Natural Resources at the University of California Division of Agriculture and Natural Resources Communication Services, whose suggestions were very helpful and contributed to a more concise and readable document. My thanks to them and to Mel for their help. Thanks also to Laurie Lippitt, Mike Evans, and Julie Hooper for providing the information necessary to write the nursery case histories. Finally, I would like to thank the staff of Communication Services for putting this manual together, including design, layout, photography, and copyediting.

Introduction

For millennia, oaks have graced the valleys, hills, and mountains of California. The state has a rich and diverse assortment of *Quercus* species, which range in appearance from majestic solitary valley oaks (*Quercus lobata* Nee), with enormous trunks and massive canopies, to small, shrublike, huckleberry oaks (*Quercus vaccinifolia* Kellogg) that never grow more than a few feet tall. For many residents and nonresidents alike, golden-brown hills dotted with gnarled oak trees epitomize the California landscape, and native oaks symbolize values we hold dear—strength, beauty, adaptability, and longevity. The deep and endearing value of oaks in the psyche of the early settlers is clearly seen by a glimpse at any state map, where so many city and landmark names include *oak* or the Spanish equivalents *encina* and *roble*. To California's native peoples, oaks were even more revered and figured prominently in their world view and spiritual beliefs. Among other things, oaks were the source of *acorn*, a staple food source of many tribes.

The value of oaks goes well beyond their stature and beauty and how people view them. Oaks and oak woodlands are home to a rich and diverse assortment of wildlife. More than half of the 662 species of terrestrial vertebrates in California utilize oak woodlands at some time during the year, and the food and shelter provided are essential to their survival. Oaks are also critical in protecting watersheds and ensuring the quality of water resources. The majority of the state's water is stored as snowpack in high-elevation mountains before flowing through oak woodlands in rivers that support fisheries, farms, and cities. Oak trees anchor the soil, preventing erosion and sedimentation.

But not all is well with California's oaks and oak woodlands. In addition to adverse impacts from firewood harvesting, agricultural conversions, intensive grazing, and residential and commercial development, there has been concern for a number of years that several oak species are not regenerating well in portions of the state. These species grow primarily in the foothills of the Sierra, Coastal, and Transverse mountain ranges, regions that are commonly referred to as hardwood rangelands. As a result of concern about poor regeneration, there has been a concerted effort to develop successful techniques for the artificial regeneration of the rangeland oak species. Research has addressed a wide array of subjects, including acorn collection, storage, and handling; seedling propagation methods; and techniques for planting, protecting, and maintaining seedlings in the field. There has been a great deal of research on this subject in the last decade, and we have come a long way in understanding how to grow and plant rangeland oaks. Nevertheless, the results of this research have been largely fragmented and dispersed in a wide range of documents, including homeowner brochures, internal reports, and scientific publications in rather obscure journals.

This manual attempts to bring together the information available on artificially regenerating rangeland oaks in California. The manual's primary purpose is to provide a resource for restorationists, hardwood rangeland managers, and others involved in oak propagation and planting projects so that their efforts are based on the latest scientific information available and are, ultimately, more successful. I also hope that this document will be of interest to others not directly involved in regenerating oaks but who maintain a deep, personal interest in the ecology and management of *Quercus* species.

This manual is divided into four chapters. The first chapter deals with the subject of poor natural regeneration of native California oaks and identifies the oak species that appear to be regenerating poorly and the conditions under which this problem seems most acute. It also describes a number of theories that have been proposed to explain why regeneration appears to be less successful today than in the past.

Organization of this Manual

The second chapter focuses on acorns and provides an overview of acorn physiology, as well as a discussion of the suspected causes for the large variability in the size of acorn crops from year to year. This chapter also describes how to collect and store acorns and the recommended procedures for sorting and testing them. There is a brief discussion of genetic variability and the importance of maintaining local seed sources. Finally, information is presented on how, when, and where to sow acorns and the pros and cons of directly planting acorns in the field versus planting seedlings that have been raised in nurseries.

The third chapter discusses oak seedling propagation. Some of the more common methods of growing seedlings are presented, including case studies of three nurseries that have been producing California oaks in containers for well over a decade. The possibility of vegetatively propagating oaks is also discussed, as are the potential benefits of inoculating oak seedlings with mycorrhizae. This chapter is designed to provide a broad overview of production techniques; readers contemplating growing oaks on any large scale are advised to obtain further information from other sources, including those nurseries listed in the appendixes.

The fourth and longest chapter addresses the general subject of planting, protecting, and maintaining oak seedlings in the field. This encompasses how to select planting sites and actually plant seedlings, as well as how to overcome the two main obstacles to successfully establishing oaks: controlling competing vegetation and preventing damage to acorns and young plants by animals. A considerable amount of discussion is devoted to treeshelters since studies at the University of California Sierra Foothill Research and Extension Center (SFREC) show that these devices are particularly useful for artificially regenerating oaks, both in terms of stimulating seedling growth and preventing damage from a wide range of animals. This chapter concludes with a discussion of other practices that may enhance regeneration success, including augering planting holes, fertilizing, irrigating and shading seedlings, and top pruning.

Each of the last three chapters also contains side bars that are intended to summarize the important points covered and provide practical guides for artificially regenerating California's rangeland oaks. Following a brief conclusion are the appendixes, which are included to provide additional resources and information to assist in better understanding oak regeneration and embarking on programs to grow or plant oaks.

Finally, there is a list of all of the references cited in this manual. The main focus of the references has been to identify research conducted in California on native oak species, and most specifically, on blue oak (*Quercus douglasii* Hook. & Arn.) and valley oak. In several instances, however, relevant research from other parts of the United States and the world is also identified. It is important to point out here that the problem of poor oak regeneration, and efforts to overcome it, is not unique to California. Concerns about oak management in the Middle Ages led to forest ordinances in France—including planting programs—designed to ensure the establishment of oaks. And in the Eastern United States, concerns about oak regeneration go back to the early 1800s. There is, therefore, a large amount of literature and information on this general subject from outside of California. For those who are interested, several general references about oaks and oak regeneration both inside and outside of California are listed in the bibliography, including conference proceedings, books, and software. These references provide readers with a starting point for delving deeper into topics of interest.

It is also important to mention here that, while this manual attempts to be comprehensive and include information from throughout the state, and even from other parts of the world, much of it is based on research conducted over the past 12 years at the University of California Sierra Foothill Research and Extension Center (SFREC), located 15 miles northeast of Marysville, California. I have been very fortunate to be housed at the SFREC and, since it is located in a fairly typical oak woodland, it has proved an ideal location to carry out oak regeneration research. However, while the SFREC is representative of large areas of oak woodlands in the state, it is clearly unlike many other places where oaks grow. Consequently, the results and recommendations contained within this manual should certainly be applied to other situations cautiously. The principal characteristics of the SFREC are listed in table 1. As can be seen, the average annual rainfall is 28 inches (71 cm), which is considerably more than many areas farther south. Supplemental irrigation was not necessary in the studies described, but this may not be the case in areas of lower rainfall. Also, we report on results of trials where we have planted oaks in pastures grazed by cattle. Again, our planting areas are only moderately grazed, and in places where grazing intensity is greater, some of the procedures we recommend may be much less effective.

In spite of these limitations, it is hoped that this manual will be helpful and will, ultimately, promote the long-term conservation of oaks in California. That is the basic goal of the University of California Integrated Hardwood Range Management Program, as well as the goal of all our oak regeneration research and of this document.

Table 1. Characteristics of the University of California Sierra Foothill Research and Extension Center

Location	15 miles (24 km) northeast of Marysville, California, in rolling to steep foothills
Elevation	220–2,020 ft (67–616 m); most oak regeneration research plots are at approximately 600 ft (183 m)
Primary vegetation	oak woodlands and annual grass rangelands; primary woody species: blue oak, interior live oak (*Quercus wislizeni* A. DC.), valley oak, foothill pine (*Pinus sabiniana*)
Soils	generally rocky clay loams; primary series: Auburn, Argonaut, Las Posas, Wyman, Sobrante
Climate	Mediterranean climate zone with hot, dry summers and mild, rainy winters
Average annual rainfall	28 in (71 cm); range: 9–44 in (23–112 cm)
Temperatures	average year-round: 60°F (16°C); summer maximum mean: 90°F (32°C); winter monthly minimum: 40°F (4°C)
Historical use	cattle grazing

1

The Natural Regeneration of California Oaks

Since the turn of the century, there have been reports that certain species of hardwoods in California, including oaks, were not regenerating adequately (Jepson 1910). More recent assessments have also reported that several oak species do not seem to have sufficient recruitment to sustain populations. Describing the oaks in the foothill woodland of Carmel Valley, White (1966) stated that "a prevailing characteristic…is the lack of reproduction…with very few seedlings." Bartolome, Muick, and McClaran (1987) also concluded that "current establishment [throughout California] appears insufficient to maintain current stand structure for some sites." And Swiecki and Bernhardt (1998) reported that, at 13 of 15 blue oak locations evaluated throughout the state, "...sapling recruitment is inadequate to offset recent losses in blue oak density and canopy cover."

These regeneration assessments have relied on inventories of the size-class distribution of oaks, generally classifying the plants into three broad categories: seedlings, saplings, and mature trees. While the definitions of these classes have varied, there has been a consistent trend of finding fewer saplings or intermediate-sized trees than seedlings or mature trees (fig. 1). For instance, Phillips et al. (1997) assessed numbers of four size classes of blue oaks in different rainfall zones and reported fewer sapling- and pole-sized trees than seedlings or mature trees in all rainfall zones. It is important to note, however, that the trend of poor regeneration has only been observed in 4 of California's 22 native oak species, and patterns have varied greatly from place to place.

For these species, a general pattern of inadequate sapling recruitment has emerged in some locations. Since saplings are the trees that must be recruited into the mature size class when the older trees die, there is worry that, if these trends continue, current population densities will decline. Some areas that have historically been oak woodlands may therefore convert to other vegetation types, such as brushfields or grasslands. Generally, this regeneration problem is further exacerbated by land management practices that directly remove trees (firewood harvesting, clearing associated with construction, agricultural conversions, etc.), as well as by activities, such as intensive year-round grazing, heavy vehicle use, or yearly burning, that may create conditions in which it is much more difficult for oak seedlings to become established or grow.

However, not all assessments of existing oak stand structures have concluded that oaks are declining.

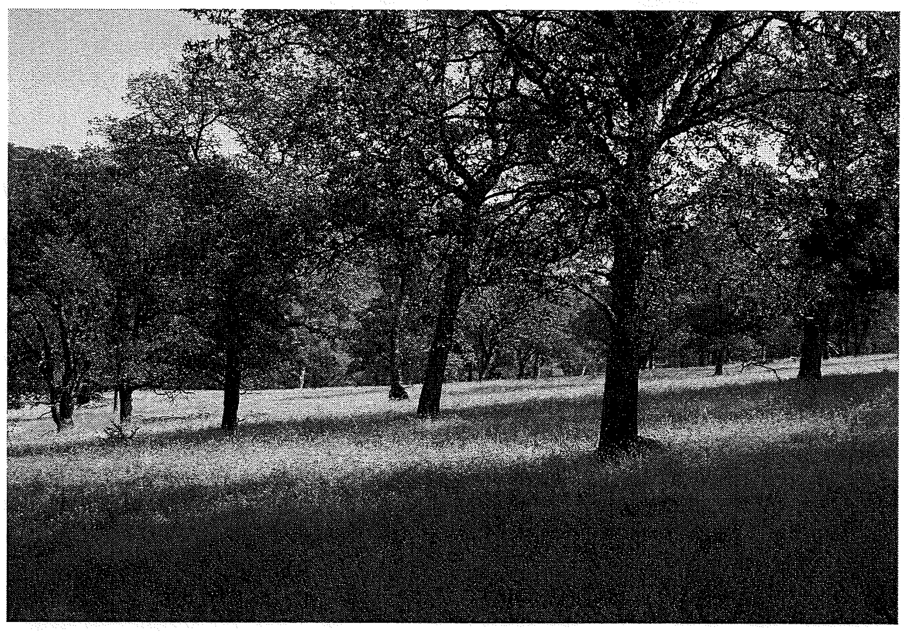

Figure 1. This mature oak stand at the SFREC has few oak saplings.

Holtzman and Allen-Diaz (1991) conducted a study that revisited vegetation plots charted in the 1920s and 1930s as part of a statewide effort to map vegetation (Wieslander 1935). They found that, in most plots originally containing blue oaks, there was an increase in the basal area of blue oaks, as well as an increase in the number of trees present. There was a decrease in the largest size class of trees, but this was offset by increases in other size classes. Davis, Brown, and Buyan (1995) also conducted an assessment of the cover and density of blue oak woodlands throughout the blue oak's current range to determine changes between 1940 and 1988. While they found many sites where woody cover had decreased, these were more than offset by sites where cover had increased. They concluded that there was little evidence of landscape-level or large-scale patterns of change. Both of these studies suggest that, in the time periods evaluated, the stands examined were sustaining themselves with sufficient recruitment to replace mortality.

Another approach to evaluating whether there are fewer or more oaks today than there were in the past utilizes pollen analysis. Pollen from oak flowers can be identified hundreds or even thousands of years after dispersal. The amount of pollen produced by a given species or genus is thought to correlate positively with the density of those plants present at the time of dispersal. In some lake beds, a pollen record can be determined by examining extracted layers of sediment. Deeper levels of this layer correspond to periods further in the past. By sampling varying depths of these lake beds and analyzing the pollen present, it is possible to estimate the abundance of oaks in different eras. Byrne, Edlund, and Mensing (1991) and Mensing (1998) evaluated sediment cores from lake beds in California and developed pollen diagrams for various species, including oaks. They concluded that, 5,000 to 10,000 years ago, the number of oaks in the Sierra Nevada Mountains increased, most likely as a result of climatic warming. In the last 500 years, however, the density of oaks has been fairly constant, except for the last 120 years. During this recent period, the density of oaks (primarily *Quercus agrifolia* Nee in the Santa Barbara coastal region studied) again increased and the authors of the studies hypothesize that this may have resulted from reduced burning by Native Americans and changes in grazing and woodcutting practices associated with intensified land use during the mid-nineteenth century.

There is obviously some disagreement about the severity of the regeneration problem and whether inventory assessments reflect real changes in population dynamics or merely natural fluctuations in the levels of recruitment that are normal. It also seems that recruitment levels can vary widely among oak species, from location to location within the state, and even over small distances within stands. As will be pointed out below, there appears to be no single cause for poor regeneration at all locations but rather many different factors that can affect recruitment success at different locations.

Oak Species with Poor Regeneration Rates

The three California oak species that are commonly reported to have regeneration problems are blue oak, valley oak, and Engelmann oak (*Quercus engelmannii* Greene) (Muick and Bartolome 1987; Bolsinger 1988), which are all deciduous white oaks. Blue and valley oaks are widely distributed and endemic to the state, while Engelmann oak has a narrower distribution range, growing only in the southern part of California and extending into Baja California, Mexico (Griffin and Critchfield 1972). In addition to these three species, coast live oak may also have insufficient recruitment to maintain existing stand structures in certain areas (Muick and Bartolome 1986; Bolsinger 1988).

It is common in stands of all of these species to find adequate numbers of seedlings and mature trees but a shortage of saplings or intermediate-sized trees. And while there are locations in the ranges of each of these species where regeneration is insufficient to sustain populations, there are also areas where regeneration appears to be adequate (fig. 2). As a result of this wide range in apparent ability to regenerate successfully, there have been efforts to correlate regeneration with both site and climatic factors, as well as with management history, to determine what is causing success and failure (Davis, Brown, and Buyan 1995; Muick and Bartolome 1987; Swiecki, Bernhardt, and Drake 1997a, 1997b; Lang 1988). While no universal reason for poor regeneration has been identified, several possible causes have been proposed.

Causes of Poor Regeneration

Introduction of Mediterranean Annuals

One widespread theory about why oaks are having more trouble regenerating today than 200 to 300 years ago claims that the change in vegetation, from predominantly perennial bunch grasses to introduced Mediterranean annual grasses and taprooted annual forbs, has created environmental conditions that make it much more difficult for oaks to establish successfully (Welker and Menke 1987). Mediterranean annuals, including bromes, ryes, oats, and filaree, are believed to have spread widely in California during the eighteenth and nineteenth centuries with the advent of widespread grazing (Heady 1977). A detailed study of the flora at the University of California Hastings Natural History Reservation in Carmel Valley reports that introduced annual grasses are now the dominant species in grasslands and in the understory of oak foothill woodlands (Knops, Griffin, and Royalty 1995). This spread of Mediterranean annuals seems to coincide roughly with the decline in oak regeneration, suggesting a possible cause and effect relationship.

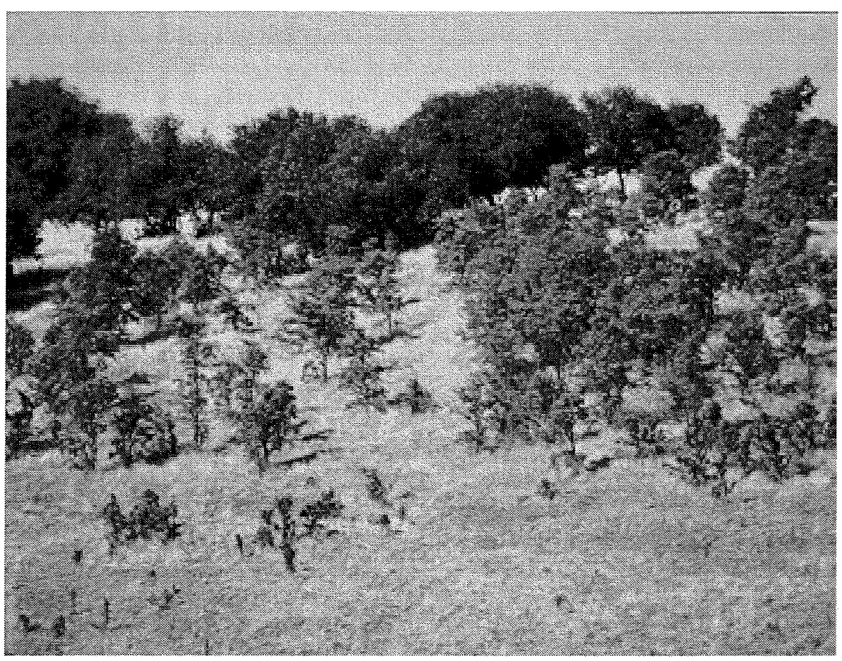

Figure 2. This hillside has good blue oak regeneration and a wide range of size classes.

Competition for Soil Moisture. The probable reason why rangeland oaks may have more difficulty regenerating in an environment dominated by annuals is that annuals often deplete soil moisture at more rapid rates than perennials, especially in the early spring when acorns are sending down their roots. Danielson and

Halvorson (1991) compared the growth of valley oaks in proximity to either an alien annual grass or a native perennial and found that seedlings near the annuals grew slower. They concluded that "the introduction of alien annual grasses has reduced valley oak seedling growth and survivorship by limiting soil moisture availability." Gordon et al. (1989) also evaluated competition between blue oak seedlings and several introduced annuals and stated that "competition for soil water with introduced annual species contributes to the increased rate of blue oak seedling mortality observed in woodland systems in California." In contrast, a study that evaluated the competition for soil water between blue oak seedlings and a native perennial bunch grass concluded that "densities of *Elymus glaucus* lower than 50 plants per square meter [5/ft^2]could allow survival and successful establishment of blue oak in understories, and are of relevance to patterns of natural regeneration" (Koukoura and Menke 1995). Finally, Welker and Menke (1990) found that the ability of blue oak seedlings to survive was related to the rate at which water stress developed. Rapid soil moisture depletion rates, which would be expected in oak-annual grass communities, were much more damaging than the gradual depletion rates expected for seedlings growing among perennial grasses.

Livestock Grazing

Livestock grazing is also believed to be a cause of poor rangeland oak regeneration. This theory is supported by the rough coincidence of changing patterns of oak regeneration and widespread introduction and spread of livestock into the state during the Mission Period (Pavlik et al. 1991), beginning in the late seventeenth century. The direct evidence that livestock contribute to reduced regeneration is that both cattle and sheep browse oak seedlings, as well as consume acorns. At the University of California Sierra Foothill Research and Extension Center (SFREC), for instance, it is easy to find small oak seedlings that have been heavily browsed or trampled by cattle. A study there found that saplings were much more likely to occur in nongrazed plots than in currently grazed plots (Swiecki, Bernhardt, and Drake 1997a). Heavy grazing, especially over many years, can also indirectly affect oak recruitment because it increases soil compaction and reduces organic matter, both of which can make it more difficult for oak roots to penetrate downward and obtain moisture (Welker and Menke 1987).

There may be other factors inhibiting oak regeneration, as well, so that livestock removal alone may have little impact. In a statewide oak regeneration assessment, Muick and Bartolome (1986) reported that the presence or absence of livestock was not sufficient to explain the pattern of oak regeneration. And Griffin (1973) stated that "experiences in nongrazing areas, such as the Hastings Natural History Reservation, suggest that even without cows, sapling valley oaks may be scarce."

Increased Rodent Populations

A consequence of the change in range vegetation from predominantly perennials to annuals is a change in the number and types of seeds present. It is possible that this change in flora has been accompanied by changes in certain rodent populations that feed primarily on the seeds of the introduced annuals. Since several species of rodents eat acorns and oak roots, higher populations of these animals could cause sufficient damage (see **Animals that Damage Acorns and Seedlings** in chapter 4) to inhibit regeneration in certain locations. Unfortunately, no one was counting gophers, squirrels, or voles two centuries ago, so it is hard to know whether their populations and impacts on oak regeneration have dramatically changed since then.

Changing Fire Frequencies

Another theory for poor regeneration concerns fire. Historical fire frequency rates in foothill woodlands are different today than they were in presettlement times when there was little effort to put out naturally occurring fires (Lewis 1993). In addition, Native Americans regularly burned oak woodlands to keep areas open for hunting, stimulate the sprouting of plants used for various products, facilitate acorn collection, and reduce populations of several insects that damage acorns (McCarthy 1993).

While there was a period of even higher fire frequency around the middle of the nineteenth century (Mensing 1991), and burning by ranchers was relatively common up until the early part of the twentieth century, fire frequencies in the last 60 years have greatly decreased as a result of intensive fire suppression activities (McClaran and Bartolome 1989). This has caused an increase in brush and a buildup of fuels in some understories, especially in the denser woodlands of the Sierra Foothills. Since foothill oaks evolved with, and are adapted to, fire, the change in fire regimes may have adversely affected oak regeneration. Because postfire sprout growth can be rapid, fires in the past may have contributed to oak establishment and continuation (Plumb and McDonald 1981; McClaran and Bartolome

1989). Also, fuel buildup as a result of fire suppression may have created conditions unfavorable for recruitment (Mensing 1992).

There is little evidence to support the theory that changes in fire frequencies have influenced oak regeneration. White (1966) concluded that fire probably played hardly any role in modifying the structure or composition of foothill woodlands in a study area in the Carmel Valley since stands unburned for at least 25 years showed no greater or lesser density of oak seedlings than in recently burned stands. Allen-Diaz and Bartolome (1992) also reported that prescribed burning at the University of California Hopland Field Station in Mendocino County did not affect blue oak seedling recruitment. And Swiecki and Bernhardt (1999), examining the effects of a wildfire on blue and valley oak seedlings, could find no growth or survival advantage associated with burning.

Changing Climate

Global climate change, and specifically a warming trend in California, has also been hypothesized as a factor influencing regeneration success. According to this hypothesis, populations at the edge of some oak species distribution ranges may no longer be able to regenerate and survive because they have not adapted to changed climatic conditions (Bayer, Schrom, and Schwan 1999). Thus, blue oak in the hotter and drier portions of its range may have more difficulty regenerating than in areas where conditions are less harsh. To date, there has been no research to verify this hypothesis.

The Pulse Theory of Regeneration

Finally, it is possible that the apparent shortage of oak saplings may not really signal a regeneration problem but only a lull in natural recruitment levels that happen in spurts or pulses. These pulses may only happen when a rare combination of events, such as low grazing and browsing pressures, good acorn years, and wet winters, occur simultaneously (Griffin 1973). Good regeneration may only take place once or twice a century because the necessary events occur simultaneously so rarely. For very long-lived species, such as oaks, however, these infrequent pulses may be perfectly adequate to sustain populations.

At present, there is not much evidence to support this theory, since studies evaluating the ages of blue oak (Kertis et al. 1993; McClaran 1986; Mensing 1991; White 1966) tend to indicate that seedling recruitment occurs irregularly, but continuously, over long intervals, rather than during short, distinct periods of simultaneous establishment. A significant exception to this pattern, however, is in stands where most of the trees have originated at the same time following fire or cutting (see **Stump Sprouting as a Mechanism of Natural Regeneration,** below).

Is There a Regeneration Problem?

Regardless of the cause of the problem, owners and managers of hardwood rangelands need to evaluate their oak stands to determine if there is adequate recruitment for maintaining stand density or if steps need to be taken to establish new trees. Figure 3 shows a decision key (Lang 1988) to assess oak regeneration. Regeneration is not a problem if there are enough seedlings and saplings present to replace the trees that are expected to die. Neither is there a problem (at least for 20 to 30 years) if the canopy is at the desired level, all overstory trees are healthy, and existing management practices do not adversely affect them. There is a problem, however, if seedlings and saplings are scarce or if a higher stand density is desired.

A Model for Oak Regeneration

Recently, Swiecki and Bernhardt (1998) have argued that blue oak recruitment is often naturally dependent on advanced regeneration and commonly occurs when gaps are created in stands, allowing sufficient light to reach the ground. Advanced regeneration consists of seedlings originating from acorns that are able to survive under the shade of mature trees, but remain small and stunted because of competition and environmental limitations, forming a "seedling bank" for future growth. When a tree falls down, for instance, and suddenly opens up the area in which the seedlings are growing, they receive much more light and have access to greater amounts of moisture and nutrients. They are then able to grow more rapidly and become saplings. However, grazing by livestock or wildlife can reduce the reproductive potential of blue oak by damaging or killing advanced regeneration through repeated browsing that depletes or eliminates the seedling bank over time. Grazing can also suppress the vertical height growth of released seedlings that are shorter than the browse line. Under current grazing management, even when gaps are created, there may simply not be enough seedlings in many locations to respond to new openings.

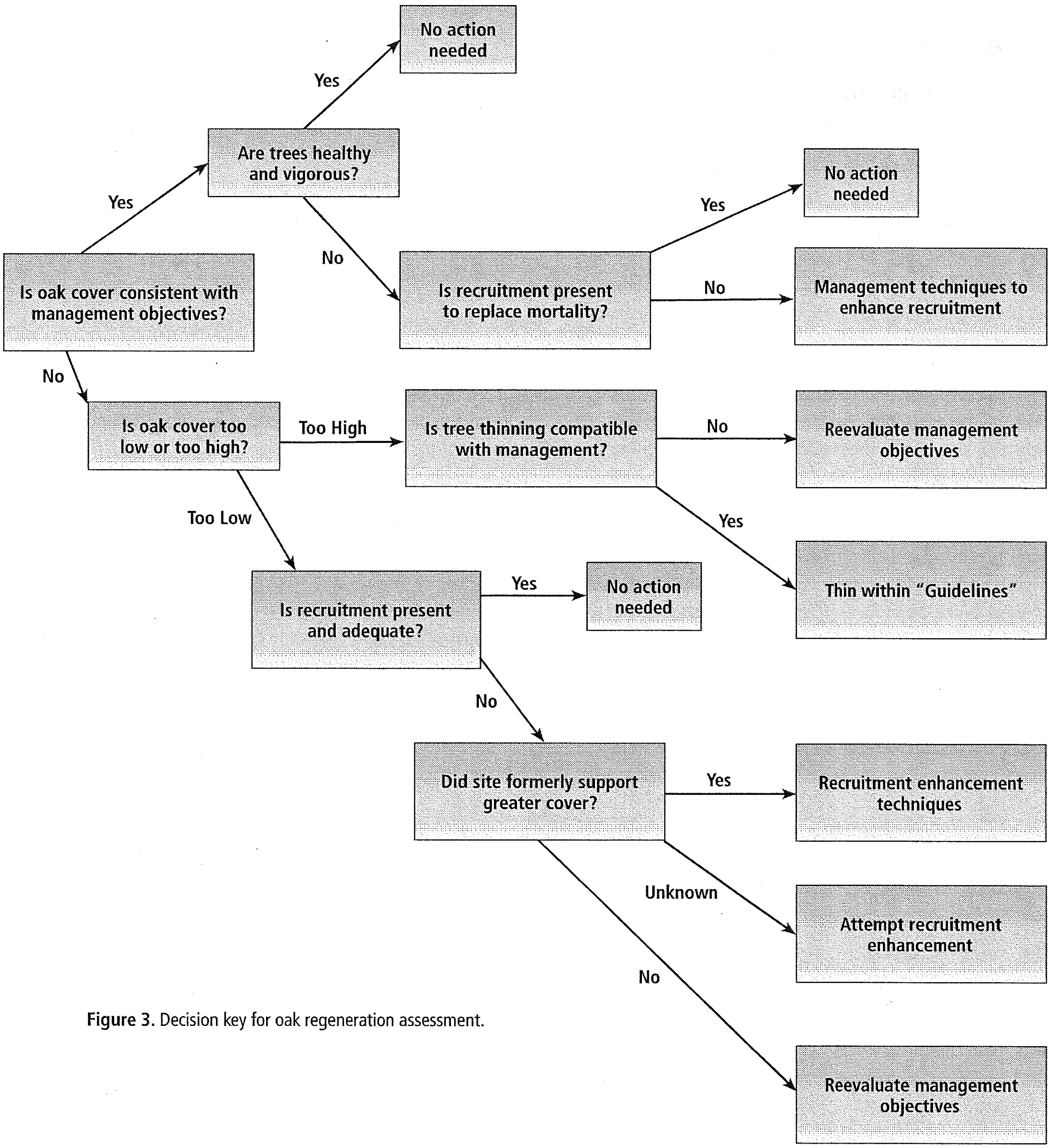

Figure 3. Decision key for oak regeneration assessment.

Stump Sprouting as a Mechanism of Natural Regeneration

There is no doubt that many of the oak trees that are alive today originated from sprouts that grew from a stump after the top was killed by fire or felling. Most stump-origin trees are easily recognized because they have multiple stems. The number of stems tends to decline with age, and older trees often have two or three main trunks. In areas where fire destroyed the stand, or where all of the oaks were cut down at the same time, most of the trees have several stems, and tree-ring studies reveal that many originated simultaneously (McClaran and Bartolome 1989; Mensing 1988).

The ability of oaks to sprout from their base following death of the aboveground portion of the tree varies by species, size of the individual tree, and environmental conditions at the site. Generally, sprouting is greater for evergreen or live oaks than for deciduous oaks; for smaller diameter stumps; and for trees growing in moister environments. While blue oak is commonly thought of as a weak sprouter compared to tan oak and California black oak (McDonald 1990), Standiford et al. (1996) found that 54 percent of blue oaks sampled in a study in the northern Sacramento Valley sprouted, even though many stumps had originally been treated with herbicides to prevent regrowth. In another large blue oak sprouting study at five sites throughout the state, almost two-thirds of the harvested trees sprouted within 2 years of harvest (McCreary et al. 1991). In general, the smaller stumps tended to sprout more, but this study detected no differences in sprouting among the four seasons of harvest, in contrast to Longhurst (1956) who reported higher sprouting for blue oaks harvested in winter.

The 1991 sprouting study also compared stumps that were protected from livestock and deer browsing to unprotected stumps. We recently assessed all trees in this study 10 years after harvest and found that protection had a tremendous effect. While the number of protected stumps that had at least one living sprout was initially higher than it was for unprotected stumps, these differences increased greatly over time. Between 1989 and 1997 the percent of protected stumps with living sprouts went down from 67 to 54 percent. Over the same interval, the percent for unprotected stumps diminished from 59 to 14 percent. Clearly the ability of sprouts to survive over time was greatly influenced by browsing.

It is not clear how many times oak stumps can sprout—several perhaps, but certainly not indefinitely. Therefore, even if sprouting is vigorous and nearly 100 percent, it will eventually be necessary for at least a portion of replacement trees to come from acorns if the stand is to be sustained over the long run.

2

Acorn Collection, Storage, and Planting

Acorns, the fruit of oak trees, contain a single seed. Compared to the seeds of most woody plants, acorns are large and contain a considerable amount of stored food. This helps ensure that they have sufficient energy to grow a large root system before producing shoots, leaves, and the photosynthetic apparatus necessary to manufacture food and become self-sufficient. This can be a great advantage in Mediterranean climates where early root development can be vital since it allows plants to more quickly reach deeper soil horizons where more moisture is available. However, there are also disadvantages of acorns compared to the seeds of some other woody plants. They are recalcitrant and cannot be dried or frozen to prolong storage. This creates problems because it means that acorns deteriorate rapidly and generally cannot be stored for more than one season. Because acorn crops tend to fluctuate from year to year, the inability to store acorns for very long periods means that planting efforts are largely dependent on current crops, which cannot be predicted with accuracy.

The *Quercus* genus can be divided into two main subgenera: the white oaks (section *Quercus*, formerly called *Lepidobalanus*) and the red or black oaks (section *Lobatae*, often known as *Erythrobalanus*) (Sternberg 1996). While there is also an intermediate group in California (section *Protobalanous*), it will not be discussed here. These subgenera have basic differences in wood structure, leaf morphology, and bark characteristics, as well as in acorn physiology. The length of time it takes from pollination and fertilization to acorn maturity is different for white and black oaks. Acorns from white oaks usually require only one year to mature, while those from black oaks (coast live oak is an exception) generally need 2 years.

Flowers on California oaks become visible in the spring, about the time the deciduous oaks are producing a new crop of leaves; both male and female flowers occur on the same tree. The male flowers, or catkins, produce clouds of pollen that are carried by wind to the female flowers, which are small and inconspicuously located in the angle between a new leaf and twig (Keator 1998). The appearance of abundant flowers, however, does not guarantee a large acorn crop (Cecich 1993). For most oak species, acorns mature and fall to the ground in the late summer and early fall. At higher elevations, this can be delayed, and weather conditions can also influence the ripening and falling dates.

Variable Acorn Crops

It has long been known that acorn production varies significantly from year to year (Sudworth 1908; Jepson 1910). In years with good acorn crops, large individual trees can have many thousands of acorns, while, in bad years, it can be difficult to find a single acorn on the same tree, or even on most of the trees in a stand or in a region. Masting cycles have been reported to vary greatly among the California oaks species examined, with good mast years occurring every 2 to 6 years.

There have been several inventories of acorn production on native California oaks. In 1977, the California Department of Fish and Game began assessing annual acorn production from 360 blue oak trees at the Dye Creek Ranch in Tehama County (McKibben and Graves 1987). They found that, in addition to highly variable annual acorn production patterns, there were certain trees in stands that were consistently better or worse producers than others. Even in heavy acorn years, about a quarter of the sampled trees had few or no acorns.

Weather As a Factor

For nearly two decades, Walt Koenig and others at the University of California Hastings Natural History Reservation in Carmel Valley have also evaluated the acorn production of several species of native California oaks, including blue and valley oak (Koenig et al. 1991; Koenig et al. 1996; Koenig et al. 1999; Koenig and Knops 1995; Koenig and Knops 1997). They have been particularly interested in finding trends in production patterns in California that are related to environmental variables that may explain why acorn crops are much larger in some years. The closest correlation they have found is related to weather at the time of flowering. When conditions are dry and warm at flowering, crop sizes for blue and valley oak tend to be larger compared to years when it is cold and wet during the same period (Koenig et al. 1996). Since acorns are wind pollinated, dry and warm conditions seem to favor pollination and subsequent acorn production. Interestingly, because some oak species, such as California black oak (*Quercus kelloggii* Newb.) and interior live oak (*Quercus wislizeni* A. DC.), require 2 years from flowering to acorn production and others, such as blue oak and valley oak, require only 1 year, it follows that production patterns between 1- and 2-year species could be very different, while trends within these groups should be similar. To date, these studies have found high synchrony throughout California within the 1-year species, but less for those requiring 2 years (Koenig et al. 1999).

Geographic Synchrony

This research has also evaluated whether or not there is geographic synchrony within individual species, that is, when acorn crops are good for blue oaks in the northern Sacramento Valley, are they also likely to be good along the central California coast or even farther south? Preliminary evidence suggests that there is widespread geographic synchrony, possibly on a statewide scale, among some of the 1-year species (especially blue oak), but much less synchrony among the 2-year species (Koenig et al. 1999).

Collecting Acorns

Timing

Acorns should be collected shortly after they are physiologically mature. While there are various indicators, such as moisture content, levels of carbohydrate, and acorn color, that have been used to predict ripeness for oak species in other parts of the country (Bonner and Vozzo 1987), the easiest and best characteristic we have found for blue and valley species is the ease with which acorns can be dislodged from the acorn cupule or cap. When acorns are ripe, they can be easily removed from the cap by gentle twisting. If they are not ripe, the caps are difficult to remove and some of the fleshy meat may be torn off the acorn and stay attached to the cap when separated. Because immature acorns cannot be ripened artificially after picking (Bonner 1979), acorns should not be collected until they are ripe. For blue oak, McCreary and Koukoura (1990) found that viable acorns could be collected over a fairly wide interval, extending from late August until mid October. Generally, acorns should be collected a few weeks after the first ones begin to drop. The early fallers often contain a large percent that are diseased or damaged by insects (Swiecki, Bernhardt, and Arnold 1991) and should be avoided.

Sensitivity to Drying

After collection, acorns are especially sensitive to drying, and their ability to germinate can decrease rapidly with even small losses in moisture content. McCreary and Koukoura (1990) found that even a 10 percent reduction in fresh weight of mature acorns resulted in nearly a 50 percent decrease in germination, and all acorns that lost 25 percent or more of their moisture

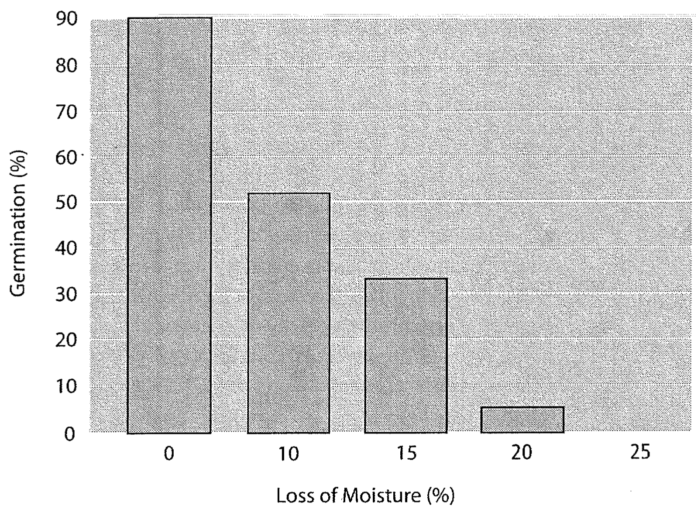

Figure 4. Acorn germination decreases with moisture loss.

failed to germinate (fig. 4). Because acorns can dry rapidly in the late summer and early fall when they drop to the ground, it is better to collect them directly from tree branches. Other researchers have reported that tree-collected acorns (fig. 5) have better germination than those collected from the ground (Teclaw and Isebrands 1986) and that damage ratings for ground-collected acorns are higher (Swiecki, Bernhardt, and Arnold 1991). On the ground, acorns can be rapidly consumed by animals. Sometimes, however, it can be impossible to collect directly from branches that are too high to reach. In these instances it is best to come back to collect acorns from the ground several times so that none remains exposed for long periods. If acorns have partially dried out, it may be possible to improve their quality by rehydrating them. Gosling (1989) found that the germination capacity of English oak (*Quercus robur* L.) acorns that had lost moisture could be improved by resoaking them for 48 hours prior to storage. However, it is best not to allow acorns to dry out in the first place.

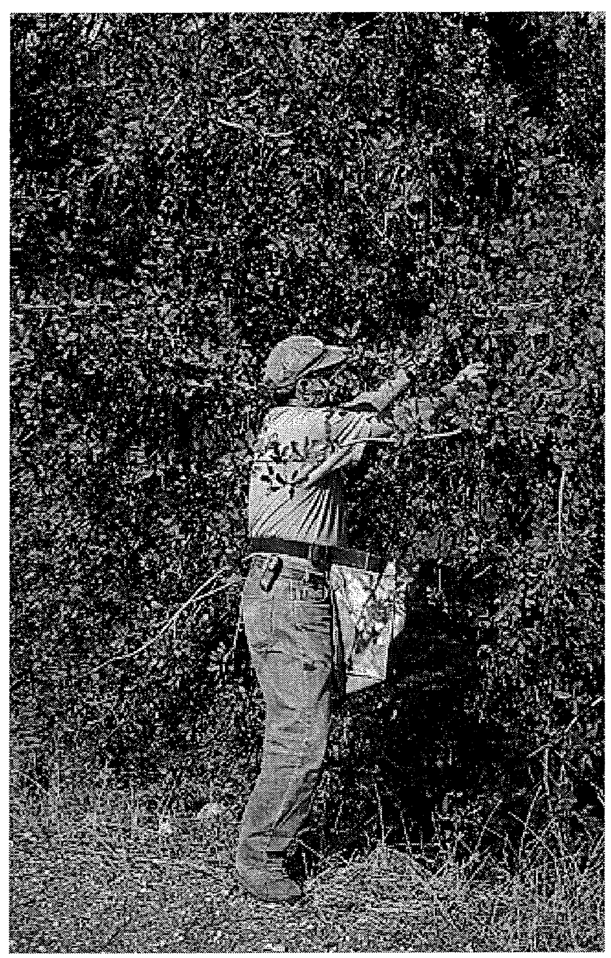

Figure 5. Using a waist bag frees both hands to collect acorns from branches.

Acorns can also be knocked to the ground from tree branches using long plastic or bamboo poles. However, it is essential to do this when the acorns are ripe. If done too early, acorns do not dislodge from the caps and remain on the tree. If too late, acorns have already fallen and may have deteriorated or been lost to animals. We have gathered acorns this way for blue oaks using tarps placed under the limbs to collect acorns as they fall (fig. 6). But many acorns knocked from the tree this way still have their caps, which must be removed prior to storage. Care should be taken not to beat the branches too forcefully so that tender new growth and even older shoots do not fall.

Sorting Acorns

Any collection of acorns contains individuals of varying quality and potential to germinate. If acorns are collected directly from the tree branches and obviously hollow or damaged acorns are discarded as they are picked, the percentage of viable acorns collected is very high, and it is generally not necessary to sort them further. But acorns collected from the ground usually have a much higher incidence of damage, and the quality of the seed lot can be improved considerably by sorting. The easiest, least expensive, and fastest sorting method is the float test. Acorns are dumped into a sufficiently large container filled with water. They are then stirred and left for several hours to either settle to the bottom, or float to the top. "Floaters" are discarded, and "sinkers" are retained. Studies have evaluated the float test for various collections of northern red oak (*Quercus rubra* L.) and found that it works reasonably well for culling damaged or insect-infested acorns (Gribko and Jones 1997; Teclaw and Isebrands 1986). The float test identifies those acorns that are hollow or damaged inside. For example, if an acorn has been infested by weevils, and a large part of the cotyledons (the white, fleshy material that provides energy and nutrition for early seedling growth) has been consumed, it will likely float.

Similarly, if acorns have been exposed on the ground for some time before collection and have desiccated and shrunk, there might be an internal air pocket that causes them to float. Finally, some acorns drop from the tree before becoming fully developed. These will also float. While the float test is inexpensive and easy, it is not 100 percent foolproof. In large seed lots, there are always some floaters that will germinate, and some sinkers that do not. Gribko and Jones (1997) reported that the float method was much better at identifying damaged, rather than sound, northern red oak acorns. That is, most of the damaged acorns floated, but many sound acorns failed to sink. However, in heavy production years, acorns are plentiful and discarding some sound acorns is probably not important. But when acorns are very scarce, it is important to retain each acorn that might germinate, so the float test may not be helpful.

Another method of sorting acorns is to select them according to size. This is fairly easy to do, and there have been reports for some oak species that larger acorns perform better (Korstian 1927) or produce larger seedlings (Matsuda and McBride 1986). A trial to evaluate the effect of acorn size on blue oak seedling performance was conducted at the Sierra Foothill Research and Extension

Figure 6. Long poles can be used to knock ripe acorns onto tarps.

Center between 1987 and 1989 (Tecklin and McCreary 1991). Results indicated that larger acorns did, in fact, produce larger seedlings, including both larger roots and larger shoots. However, after 2 years there were no significant differences in field survival between seedlings grown from acorns of different sizes.

Stratification

Dormancy in seeds can be defined as a state that prevents germination under environmental conditions that would otherwise be favorable for growth (Olson 1974). To overcome or break dormancy and stimulate subsequent germination, some seeds need a period of cold, wet conditions. Plants have evolved this delaying tactic to ensure that they do not germinate before seasonal changes make survival of the plant likely. Thus, even though there may be a week of spring-like weather in late January, these seeds will not germinate because they have not yet been naturally exposed to the necessary period of winter-like conditions. Over the long run, this is advantageous in environments where frosts following unseasonable warm spells are likely because early germination could prove lethal to the new shoot.

White Oaks

As noted previously, the *Quercus* genus can be divided into two main subgenera: white and black oaks. White oaks in California have little or no embryo dormancy. This means that they do not have to be exposed to any special environmental conditions and are ready to germinate soon after they have been gathered. Anyone who has collected valley or blue oak acorns and stored them in the refrigerator for any length of time can testify to the fact that these acorns begin germinating within a few weeks or months, even in such a cold environment. If left long enough, the acorns can form a tangled mass of elongated radicles. It can be difficult to plant (and sometimes even to separate) such acorns, but research in the southern United States suggests that it is not essential to keep the radicles intact. Bonner (1982) found that breaking radicles prior to sowing in a nursery did not adversely affect seedling production for any of the three oak species he tested. At the University of California Sierra Foothill Research and Extension Center (SFREC), we also found that when long radicles of blue oak were cut back to a .4-inch (1-cm) length, they grew as well as acorns with intact radicles (McCreary 1996). However, when the radicles were cut all the way back to the acorn, the acorns failed to produce shoots.

Black Oaks

Acorns from this group generally have embryo dormancy although it is variable, and there can be differences in dormancy even within species (Bonner and Vozzo 1987). After collection, black oak acorns need stratification, a period of artificial, winter-like conditions that helps break dormancy and allows the acorns to germinate. According to Olson (1974), stratification for oaks "should be in moist, well-drained sand, sand and peat, or similar material for 30 to 90 days at a temperature of 32° to 41°F [0° to 5°C]." We have found that it is also possible to provide stratification for black oak acorns in California by soaking the acorns for 24 hours and then putting them in a refrigerator (but not a freezer) for 30 to 90 days, though precautions must be taken to ensure that acorns do not dry out.

Our experience with black oaks in California has been limited to California black oak (*Quercus kelloggii* Newb.), interior live oak (*Quercus wislizeni* A. DC.), and coast live oak. All of these species have germinated in storage without stratification, indicating that they do not have particularly strong dormancy or stratification requirements. Matsuda and McBride (1989b) evaluated germination of seven California oak species and found that there were fast and slow germinators, with white oaks generally in the former, and black oaks in the latter group. Longer stratification periods increased the rapidity of germination after sowing for all of these species. However, even some black oak acorns not receiving stratification eventually germinated. For tree seeds in general, stratification tends to make germination more even, reducing the interval between early and late germinators. It also widens the range of conditions over which seeds can subsequently germinate. Both of these effects can be helpful when sowing acorns in a greenhouse or nursery where it is desirable to produce seedlings of uniform size.

Storing Acorns

After collection, acorns should be stored in a refrigerator or cooler preferably at a temperature just above freezing (between 33.8° and 37.4°F [1° and 3°C]). They should be placed in plastic bags that act as moisture barriers but allow some gaseous exchange. Prior to storage, the acorn caps should be removed. Because acorns continue to respire during storage, some gas exchange with the atmosphere is necessary and airtight storage containers should be avoided. It is therefore recommended that plastic bags be kept partially open at the top so that the moisture that tends to condense on the insides of the bags can evaporate and does not accumulate. Nevertheless, it is important to regularly check acorns to make sure they are not drying out.

Keeping acorns cool during storage serves several functions. First, it tends to slow respiration, which utilizes energy and can deplete carbohydrate reserves. Second, it slows the tendency for sprouting which is especially common for white oaks. And third, refrigeration tends to reduce the incidence of harmful microorganisms that can damage or kill acorns. To further retard molds, some restorationists suggest treating acorns before storage or placing fungicides inside storage bags. Bush and Thompson (1990) recommend rinsing acorns in a solution of ½ cup (118 mL) household bleach per 1 gallon (3.8 L) of cool water to kill harmful fungi. To prevent disease problems, Adams et al. (1991) dusted acorns with the fungicide Captan prior to storage. We have generally found that treating acorns prior to storage is not necessary as long as acorns are stored at the temperatures and conditions described above, and as long as they are not stored for extended periods of time. However, if molds on acorns during storage become so extensive that the radicles become discolored and slimy, it is best to discard them.

There are also several insects that can damage acorns (see **Animals that Damage Acorns and Seedlings** in chapter 4), but most damage occurs before collection. Moreover, it is difficult to kill these insects once they are inside the acorns without damaging the acorns themselves.

White oaks cannot generally be stored for more than a single season, but some researchers have reported that acorns from certain black oak species can be stored for at least 3 years (Bonner 1973). However, little research on prolonged storage has been conducted for California species. We have kept both California black oak and interior live oak acorns in a refrigerator for more than a single season but have observed that the number that subsequently germinate drops dramatically, such that only a few acorns remained viable into the second year.

Testing Acorn Quality

There may be instances when it is important to accurately determine acorn quality. Such information may be valuable before proceeding with a large-scale collection, or to assess whether temporary storage or handling procedures have been detrimental. Seed tests are also important for nurseries that need to calculate sowing densities. The most accurate measure of potential acorn performance is to incubate a representative sample of intact acorns under environmental conditions that bring about germination. Standard conditions recommended by the Association of Official Seed Analysts (AOSA 1993) for conducting germination tests on acorns are a day temperature of 86°F (30°C) and a night temperature of 68°F (20°C), with an 8-hour photoperiod (length of daily light interval). It is also critical that the acorns be placed on a moist medium, such as sand, sand and peat, or vermiculite, and not be allowed to dry during the test. These tests provide an estimate of germination percentage. Unfortunately, germination tests on the intact acorns of many oak species can take 2 months or more to complete, and this is often too long to wait. One way to speed tests is to partially dissect the acorns before sowing them. Cutting acorns in half (discarding the cap end) and peeling away the pericarp (acorn skin) can reduce the germination time to about 3 to 4 weeks. However, even this is frequently too long. Consequently, a number of more rapid viability tests have been developed and may be of use in special situations.

Recommended Acorn Collection and Storage Procedures

- Collect acorns in the fall, several weeks after the first ones have started to drop and when those remaining on the tree can be easily dislodged from the acorn cap by gentle twisting.
- If possible, collect acorns directly from the branches of trees, rather than from the ground.
- If acorns are collected from the ground, place them in a bucket of water for several hours, and discard floaters.
- Stratify acorns from the black oak group by soaking them in water for 24 hours and then storing them in a cooler or refrigerator (33.8° to 37.4°F [1° to 3°C]) for 30 to 90 days before sowing.
- Store acorns in a cooler or refrigerator in loosely sealed plastic bags, but do not store acorns from the white oak group for more than 1 or 2 months before planting to ensure greatest viability.
- If acorns start to germinate during storage, remove and plant them as soon as possible.
- If mold develops during storage, and acorns and radicles are discolored and slimy, discard acorns.

A viability test identifies those seeds that are alive, but that does not necessarily mean that they are capable of germinating. Bonner and Vozzo (1987) describe three options for quick viability tests. The first, simplest, oldest, crudest, and probably best technique is a cutting test. In this test, a sample of acorns are cut in half and those with clean, firm, and healthy-looking cotyledons are considered viable. Those that are entirely empty or in which the embryo appears undeveloped, shriveled, moldy, or insect-damaged are not viable.

Another method of testing is X-radiography. This is a quick and nondestructive technique for identifying empty and damaged fruits and seeds of most species. Unfortunately, for acorns it can be difficult to interpret because the high moisture content of live acorns renders the X-ray images opaque.

Finally, there is the tetrazolium test. This relies on the premise that only living cells have the enzymes capable of converting a colorless solution of tetrazolium salt into a colored precipitate. Although this test has been widely applied to the seeds of a large number of species, it is only moderately successful for acorns (Bonner 1984). This is probably because acorns contain secondary compounds that interfere with the staining reaction.

Genetic Considerations

Genetic Differences within Oak Species

Restoration is defined as bringing something back to a former or normal condition. For restoration, therefore, only a given species of oak should be planted in areas where it naturally grows or grew in the past. But even within an oak species, the source of the acorns must be considered. Both blue oak and valley oak are widely distributed species in California, ranging in latitude over much of the length of the state and in elevation from near sea level to 5,600 feet (1,700 m) for valley oak (Griffin and Critchfield 1972), and to over 4,500 feet (1,400 m) for blue oak (McDonald 1990). Clearly, there is a very wide range of environments in which different populations within these species grow. For instance, blue oak grows on Santa Cruz and Santa Catalina Islands, as well as at lower to middle elevations in the northern Sierra Nevada. While the coastal environment is generally temperate and mild, growing seasons in Northern California are shorter, and frosts commonly occur in late spring. If acorns collected from coastal trees were planted in the north, they may grow quite well for a number of years. But in the life span of an oak tree (which can be 200 to 300 years), it is likely there will be an environmental extreme that they are not genetically adapted to. A serious freeze in late spring, for instance, could seriously damage or kill a tree from a coastal source, while local trees may suffer few negative effects.

Although there has not been a lot of research on the genetics of native California oaks, Rice, Richards, and Matzner (1997) found evidence for local adaptation of blue oak populations collected at the University of California Sierra Foothill Research and Extension Center and at the University of California Hopland Research and Extension Center. However, Riggs, Millar, and Delany (1991) found only relatively small genetic differences within valley and blue oak populations using biochemical assay techniques and could detect no geographic pattern in variation in these biochemical markers.

Genetic Contamination

Another potential problem of moving oaks from one locale to another is genetic contamination. Oaks are wind pollinated and require pollen from male flowers to pollinate and fertilize female flowers. If pollen-producing trees are from off-site locations and contain genetic traits poorly adapted to the area where they are growing, there is a risk that they could introduce these ill-adapted traits into the population via newly produced acorns. While there certainly is debate over how serious a threat this is for oaks as well as for other species, it makes sense to avoid this potential danger when possible. It is, therefore, recommended that acorns be collected as near to the planting site as possible. Furthermore, to ensure adequate genetic variability within the local population, Lippitt (1992) recommends collecting acorns from at least 15 trees at any given site.

Timing of Acorn Planting

As mentioned above, blue and valley oak acorns generally ripen in late summer to mid fall. However, at this time soils can still be extremely dry because the first heavy, fall rains may not have occurred. While even fairly dry soils can have relatively high humidities under the surface, these soils can also be extremely hard, and, even if acorns do germinate, root penetration is likely difficult. We, therefore, recommend that acorns are only directly planted in the field after there has been sufficient rainfall to soak the soil at least several inches down. But how soon after these rains should acorns be planted? In a trial at the University of California Sierra Foothill Research and Extension Center with blue and valley oaks, we compared field performances of acorns sown at monthly intervals for 5 months starting in early November

(McCreary 1990a). Acorns for each species were collected from single trees in early October and were stored in the refrigerator for intervals ranging from 1 to 5 months before planting. We then recorded emergence date, total emergence, first- and second-year heights and diameters, and survival of seedlings in the field. There were profound and consistent effects of acorn planting date, with better performance for those that were sown earlier. They tended to emerge earlier, have higher survival, and grow more. While early emergence might increase the risk of frost damage, we have never observed such damage at SFREC. Sowing acorns on the last date in early March was particularly harmful since the seedlings seemed to get such a late start that they apparently were not able to grow a very large root system before the summer dry period. Based on these results, we recommend that blue and valley oak acorns be planted early in the season, as soon as possible after the soil is sufficiently wet. As a rule of thumb, planting should take place no later than the end of January, and even this may be too late in areas with less rainfall and shorter winters.

How to Sow Acorns

Planting Depth

When directly sowing acorns in the field, it is important to bury them since the likelihood of depredation, as well as desiccation damage, is much greater for exposed rather than buried acorns. In a study with blue, valley, and coast live oaks, Griffin (1971) found that burying acorns did not eliminate rodent damage but did reduce losses. And Borchert et al. (1989) reported that recruitment of buried blue oak acorns was twice that of surface-sown ones. We generally sow acorns ½ to 1 inch (1.0 to 2.5 cm) deep, but in some situations it may be better to plant them deeper. In an area where rodents were a threat, Tietje et al. (1991) found that, in general, emergence was better for blue oak and valley oak acorns planted 2 inches (5 cm) in the ground because shallower plantings (½ in [1 cm]) had much higher depredation, while deeper plantings (4 in [10 cm]) made it too difficult for shoots to grow up through to the soil surface. However, if acorn depredation is not a serious concern, shallower plantings are generally preferred.

Recommended Methods for Sowing Acorns of Rangeland Oaks in the Field

- Sow acorns in the fall and early winter, as soon as soil has been moistened several inches down.
- If possible, pregerminate acorns before planting and outplant when radicles are ¼ inch to ½ inch (½ to 1 cm) long.
- Cover acorns with ½ to 1 inch (1 to 2 ½ cm) of soil.
- If acorn depredation is suspected as a serious problem (high populations of rodents are present), plant deeper, up to 2 inches (5 cm).
- If acorns begin to germinate during storage, outplant as soon as possible with the radicle pointing down. Use a screwdriver or pencil to make a hole in the soil for the radicle.
- If radicles become too long, tangled, and unwieldy to permit planting, clip them back to ½ inch (1 cm) and outplant.
- If acorn planting spots have aboveground protection (treeshelters), and acorns have not been pregerminated, plant two or three acorns per planting spot and thin to the best seedling after 1 year. (See chapter 4.)
- Keep planting spots free of weeds for at least 3 years after planting. (See chapter 4.)

Pregermination

We have found that by pregerminating acorns before field planting, more than 90 percent will initially grow. Pregerminating acorns is easily done by filling pie pans or other shallow dishes with moist vermiculite, sand, or peat. Acorns are then placed on their sides and gently pressed into the medium (fig. 7). It is important that the material stay moist, but not overly saturated, while the acorns are germinating. The trays can be placed at room temperature on a table, windowsill, or bench for observation. Blue oaks generally begin germinating in 1 to 2 weeks, as evidenced by a white tip, or radicle, protruding from the pointed end of the acorn. They are then ready to outplant. When planting pregerminated acorns with developed radicles, use a pencil, screwdriver, or other pointed object to make a hole in the soil and carefully position the acorn in the hole with the radicle pointing downward. Acorns can then be covered as described above.

Figure 7. Place acorns in trays of moist vermiculite for easy pregermination.

Multiple Seeding

When directly planting acorns, it is a good idea either to sow those that you are sure will germinate or several at each planting spot to ensure germination of at least one individual. Some restorationists feel it is important to plant two or three acorns per planting spot (Bush and Thompson 1989). This is particularly important if planting spots are protected with cages or tubes because such planting requires considerable expense and effort. Since acorns are generally easy to obtain, multiple seeding is far less expensive than replanting. However, multiple seedlings should eventually be thinned to the single best plant, which is not always easy to do inside of tubes. This can be time consuming and expensive, and, if acorn quality is extremely good and expected germination rates are above 90 percent, it is probably not necessary to sow more than one acorn per spot.

Acorn Orientation

Some researchers have questioned how acorns should be oriented when planted. Both the shoot and the root emerge from the pointed end of the acorn, so whether they are planted point up or point down may subsequently affect how seedlings grow. McDonald (1978) reported the results of a field test that compared point up vs. point down plantings of tanoak acorns (*Lithocarpus densiflorus*), a species closely related to *Quercus*. He found that planting point up resulted in earlier and more complete emergence. A study with northern red oak, however, found that, while planting position (point up, point down, or sideways) had no statistically significant effect on seedling survival and growth, acorns lying sideways had the highest average survival (Trencia 1996). In our research trials at SFREC, we have opted to plant acorns horizontally, and this has proven quite effective.

Acorns or Seedlings?

The choice of whether to plant acorns or seedlings depends on a host of factors including availability of suitable planting material and conditions at the planting site. Sometimes it is difficult to obtain seedlings from local sources. Only by collecting acorns yourself can you be sure that your planting will be adapted to local conditions. However, if large numbers of acorn-eating rodents, such as mice or ground squirrels (*Spermophilus beecheyi*), are present, it can be difficult and costly to successfully establish oaks by direct seeding. In these situations, the best solution may be to plant seedlings.

We have conducted several trials to compare the field performance of acorns and seedlings from the same seed source. In one study, we detected very little difference between blue oak seedlings that originated as directly sown acorns and those that were grown for 4 months in containers and then transplanted. Both had over 90 percent survival, and, after 5 years, there were no significant differences in height (McCreary and Tecklin 2001). This is consistent with a previous blue oak trial at the SFREC (McCreary 1996) in which these two stock types were also compared. In the 1996 trial, however, acorns had far greater growth than 1-year-old seedlings planted at the same time. It is important to note that both of these trials were conducted in highly controlled environments, and in less intensively managed wildland settings, transplants might perform better.

Because it is easier and less expensive to directly plant acorns, this method may be preferable in many situations. However, if direct sowing is used, it is important that steps be taken to ensure that acorn depredation will not be a problem since this can negate any benefits that might otherwise be realized. Our plots were kept fairly weed free, and, therefore, there were not many rodents, which are attracted to locations where weed cover is dense (see **Animals that Damage Acorns and Seedlings** in chapter 4).

3

Propagating Rangeland Oak Seedlings

Until a decade ago, there were relatively few native oaks produced for artificial regeneration in California, mainly because there was little demand. Historically, most California oak species have not been considered desirable landscape plants, partly because they had a reputation for growing slowly. Also, few seedlings were commercially grown because oaks in California have never been considered important timber trees. The lack of commercial importance also meant that there was almost no research carried out on how to grow oaks, either in containers or in bareroot nurseries. While such research has been extensive for commercially important eastern oak species, such as northern red oak (Johnson 1988; Ruehle and Kormanik 1986; Thompson and Schultz 1995), in California the propagation methods used have evolved from the growers' experiences and have been based largely on trial and error.

The last decade has seen a significant increase in demand for, and production of, oak seedlings. Oak seedling quality has also improved over the same period, reflecting improvements in nursery husbandry. Nurseries, such as Tree of Life in San Juan Capistrano, Circuit Rider in Windsor, and the California Department of Forestry and Fire Protection L. A. Moran Reforestation Center in Davis, have now been growing oaks for many years. Below are some general comments about propagation methods for container-grown oak seedlings, followed by case histories summarizing production methods used by these three nurseries. For further information about container production practices, consult one of the nurseries listed in appendix A.

Seedling Production in Containers

The vast majority of native oaks produced in California are grown in containers, which range in size from a few cubic inches to large boxes of many cubic feet. In general, oak seedlings tend to put a large amount of energy into producing a taproot with a carrot-like configuration. Seedlings can, therefore, quickly become pot-bound in small containers, meaning the volume of seedling roots produced can exceed the growing space in the container. Planting such stock can result in poor subsequent field performance or even death. It is, therefore, important not to grow seedlings in containers that are too small. Some nurseries start oaks in small sleeves called "liners"

Preparing Potting Mix

Combine the following:

5 ft^3 course peat moss

5 ft^3 course vermiculite

4 ft^3 fir bark (1/8- to 1/4-inch size)

1 lb lime

2 lb slow-release fertilizer granules

or in flats, and then transplant the seedlings to larger containers as they become bigger. In general, better quality oak seedlings are produced in narrower, deeper containers, rather than in wide, shallow containers. For this reason, a common container for raising oaks is a "treepot," with dimensions of approximately 4 by 4 by 14 inches (10 by 10 by 36 cm) although large-scale production is often started and completed in liners or small containers called "plant bands."

Preventing the Formation of Deformed Roots

Oak taproots generally reach the bottom of a container before the shoots emerge from the soil surface. Once at the bottom, these roots tend to circle around unless they are checked or prevented from growing. Such root circling creates a plant that is poorly adapted to growing in the field. Deformed roots can persist for years and even decades after field planting and can cause poor tree growth and lack of stability.

Air Pruning. Many container production systems employ air pruning to thwart root circling. As the seedling roots grow to the bottom of the container, they are exposed to air. This is accomplished by using open-ended containers that are placed on screens or mesh to prevent the soil from falling out while still exposing roots that reach the bottom. Since the air is dry, and roots need moisture, the root tips stop growing. This, in turn, causes the production of lateral branch roots farther up the main root, creating a much more fibrous root system. This type of air pruning is used at the California Department of Forestry L. A. Moran Reforestation Center with excellent results (Lippitt 1992).

Chemical Pruning. There are also commercially available copper compounds that can be painted on the interior of containers. These compounds arrest the growth of root tips (Regan, Landis, and Green 1993). When roots come in contact with these chemicals, they are pruned, causing further root branching and development of a more fibrous root system.

Planting Medium

Oak seedlings grow well in a variety of potting mixes. According to Schettler and Smith (1980), "nearly any reasonable planting medium can be used with good results as long as it is well-drained."

Fertilizing

Container seedlings generally need to be fertilized within a few weeks after sowing. Fertilizer can be provided in irrigation water or in slow-release fertilizers incorporated into the soil mix. A fertilization regime that has been used successfully is adding 20-20-20 at 100 parts per million of nitrogen in irrigation water, plus micronutrients.

When to Transplant

Most container seedlings are grown for a year or two before transplanting to the field. In some cases, however, the time in the container can be considerably longer as plants are repeatedly transplanted to increasingly larger containers in order to produce large-sized (and very expensive) landscape plants. At SFREC, we have experimented with a shorter production schedule. We collected acorns in October, sowed them in outdoor shadehouses at the California Department of Forestry Nursery in Davis in December, and then planted the young seedlings back at the University of California Sierra Foothill Research and Extension Center in late March. While these seedlings appeared quite fleshy and tender at the time of outplanting, they performed well in the field (McCreary 1996). In fact, in this trial they were superior to 1-year-old container stock in terms of survival and growth. Obviously, it is far less expensive to produce a 4-month-old seedling than one grown for a full year, so this stock type may be suitable in some situations.

Growing Your Own Seedlings

Germination

It is possible to grow your own oak seedlings without sophisticated greenhouses or other equipment. Acorns are easy to collect and germinate, and the requirements for small seedlings are relatively modest. Pregerminate acorns in shallow trays to make sure that all of the acorns that are planted are viable and ready to grow.

Containers and Potting Mix

As previously discussed, tall, narrow containers are preferable to short, wide ones. We have had good success with small milk-carton-like boxes that are open at both ends. These are available in a variety of sizes (see appendix A), and a size of 2 by 2 by 10 inches (5 by 5 by 26 cm) seems particularly well suited to growing oak seedlings. These containers are wide enough to lay acorns flat for planting, and tall enough to allow good root development. For growing large numbers of seedlings, the potting mix described in the box on page 20 has worked well. But for growing fewer than two hundred seedlings, it is probably easiest to buy commercially available potting mixes in 3⁄4-cubic-foot bags. Course mixes that have better drainage are preferable to finely textured ones.

To prevent the potting mix from falling out of the open-ended containers, we place a single sheet of newspaper in the bottom of the rack. These decompose about the time the roots reach the base of the containers, but by that time, there is little risk of the soil falling away. Racks should not be placed on a solid surface, but should be elevated slightly or placed on screen, narrow strips of wood, or mesh.

Containers can be kept indoors or outdoors; but if outdoors, the seedlings must be protected from severe freezes. It may also be necessary to make sure that birds or rodents do not remove acorns. While the roots start to grow right away, it may take several months for the shoots to emerge. As noted above, we have found that 4-month-old blue oak seedlings grown this way (sown in containers in December and field planted in March) have performed well in the field, as long as they are irrigated at the time of planting. But since the seedlings are fairly tender and fleshy, they need to be handled and planted carefully.

Recommended Procedures for Growing Oak Seedlings in Containers

- Grow oak seedlings in tall and narrow, rather than short and wide, containers.
- Select appropriate container sizes and transplant seedlings to larger-sized containers before seedlings become "pot-bound."
- Use containers that promote the pruning of root tips at the bottom.
- Use a coarse, well-drained, potting mix; keep it moist, but not saturated, and make sure it does not dry out during warm weather.
- Ensure seedlings have adequate nutrition by incorporating a slow-release fertilizer into the potting mix or using a balanced, liquid fertilizer in irrigation water.

Other Ways to Grow Oak Seedlings

There are also other ways to grow oak seedlings. A video and manual produced by the University of California Cooperative Extension in Calaveras County, *Oak Tree Project,* (Churches and Mitchell 1990) describes a program to collect acorns and grow seedlings, targeting school and community groups.

Nursery Case Histories Involving Container-Grown Seedlings

Circuit Rider Productions

Circuit Rider Productions is a nonprofit service corporation dedicated to the enhancement of environmental and human resources. Since 1978 they have operated a native plant nursery where they produce plants for restoration and revegetation projects, specializing in site-specific liner stock. From the beginning, they have grown a number of California oak species, including valley, blue, California black, coast live, canyon live (*Quercus chrysolepis* Liebm.), interior live, and Oregon white oaks (*Quercus garryana* Douglas ex Hook.).

Container Types. Many are grown in tapered plastic tubes called "super cells" (1½ inches [4 cm]in diameter and approximately 10 inches [26 cm] deep). These tubes have ribs on the internal walls that help direct roots downward, resulting in air pruning and preventing root circling. Other containers that are used at

Circuit Rider Productions include deepots (2 in [5 cm] in diameter and 10 in [26 cm] deep) and treepots (4 by 4 by 14 in [10 by 10 by 36 cm]). The containers are filled with a well-drained growing medium and are regularly irrigated during the dry season to ensure that the growing medium stays moist, but not saturated. A slow-release fertilizer is incorporated into the potting mix prior to sowing, and liquid fertilizer is added during the growing season. Oaks grown in super cells develop an 8-inch (21-cm) root and a shoot that is about 4 to 8 inches (10 to 21 cm) tall, and they are ready for field planting the fall following container planting. These seedlings are particularly suited for planting in remote areas because they are lightweight and easy to transport. Seedlings in deepots are also grown for a single season, while those in treepots are transplanted into larger containers and require 2 years to reach the desired size.

Acorn Collection and Storage. Acorns sown by Circuit Rider are generally collected close to the future planting site within the same watershed to ensure adaptation to local conditions. Collection sites are tracked by accession numbers and, for the more common oak species, collections are made at 20 to 25 different sites for a given year in Northern and Central California. Circuit Riders usually harvest acorns directly from trees, either by picking them from branches or by knocking them to the ground with poles. After discarding obviously defective acorns and sorting them by flotation, acorns are placed in small to medium resealable polyethylene bags containing a moist medium consisting of vermiculite or perlite, or a combination of the two. Acorns are mixed with a high volume of medium to maintain high acorn moisture during storage. The bags are then placed in a refrigerator at 40°F (4.4°C) until sowing in containers. If radicles become long and tangled during storage, they are trimmed prior to sowing. When planting in containers, acorns are sown with the pointed tip buried halfway at an angle of approximately 45 degrees and placed in a shadehouse to germinate. They are kept in partial shade during the summer to ensure that the containers don't dry out too quickly.

Tree of Life Nursery

The Tree of Life Nursery has been producing native California plants for more than two decades and claims to be the largest supplier of native plants in the state. Their grounds, located in San Juan Capistrano, include 30 acres of growing area with both shadehouses and greenhouses, and they maintain laboratory facilities for the propagation and testing of mycorrhizal plants and inoculum. They grow a wide variety of native oak species, including blue, valley, coast live, California black, canyon live, island (*Quercus tomentella* Engelm.), scrub (*Quercus berberidifolia* Liebm.), coastal scrub (*Quercus dumosa* Nutt.), and Engelmann oak. They are particularly well known for growing Engelmann oak seedlings since the nursery is located within the very narrow range of this species, and they have worked closely with conservation groups focusing on Engelmann oak restoration.

Acorn Storage and Sowing. The Tree of Life Nursery collects acorns from a variety of collection areas for most species, and records identifying the location of the seed source are maintained. Acorns are then put in water, with floaters discarded and sinkers placed in lugs or flats containing moist peat moss. After germination, radicles are pinched off, the acorns are sown in super cells, and the seedlings are grown for one growing season. Nursery manager Mike Evans feels that root pinching is beneficial since it promotes the early development of a more fibrous root system and improves the ratio of roots to shoots. The potting mix consists of 80 percent organic amendments, including bark products and peat, and 20 percent inorganic components, consisting of perlite, vermiculite, and sand. A slow-release, 18-6-12 fertilizer is incorporated into the potting mix prior to planting, and the seedlings are generally inoculated with an endomy-corrhizal fungi, VAM 80. This fungi is thought to enhance the ability of seedlings to take up nutrients following outplanting, thereby improving field performance.

Transplanting. After one growing season, seedlings are either sold or transplanted into larger containers. Many are planted in 1-gallon containers that promote the development of a much deeper root system, resulting in better growth and survival after outplanting. After 1 year in this size, some oak seedlings are sold, while the remainder are transplanted into 5-gallon containers. After one additional growing season, seedlings are either sold or transplanted to 15-gallon pots, the largest size grown by the nursery. At each stage of transplanting, excess roots are trimmed off prior to moving the seedlings to larger containers. Generally, the smaller seedling sizes are destined for revegetation plantings, while the larger sizes are for landscaping projects.

California Department of Forestry L. A. Moran Reforestation Center

The L. A. Moran Reforestation Center in Davis is the only container nursery operated by the California Department of Forestry and Fire Protection (CDF). Its primary mission is to sell tree and shrub seedlings to the public. While, historically, the main focus of the nursery has been to produce and sell commercial conifer species, there has been increased emphasis in recent years on growing native plants for restoration purposes. The nursery has produced native oak seedlings since 1987. Their primary species are blue and valley oaks, with lesser quantities of California black, coast live, canyon live, interior live, Engelmann, and Oregon white oaks. However, the species grown and number of seedlings produced depend largely on the availability of acorns, and during poor acorn years, the number of seedlings of a given oak species may be restricted. The nursery produces an average of approximately 5,000 oak seedlings annually and as many as 10,000 additional seedlings as contract requests.

Acorn Processing. CDF is particularly concerned with identifying the sources of all their acorns and only distributing seedlings from acorns that have been collected relatively near the planting area. Acorns are generally collected directly from the tree branches or knocked off trees with poles. They are upgraded by discarding obviously cracked or damaged ones, including those with multiple bore holes and uneven coloration. The CDF nursery then X-rays the seed lot, which provides an additional indication of quality. If the quality is good, no further treatment is done. If there are many empty acorns, the CDF nursery uses an air separator to cull them. After sorting, acorns are stored in plastic bags that are left slightly open at the top and refrigerated at 35°F (1.7°C) until planting.

Sowing. To prevent deterioration and premature germination, acorns are generally sown in early winter, preferably by mid-December. They are sown one per container on their side and covered with about ½ inch (1 cm) of coarse vermiculite. The containers are foil-covered, paper, plant sleeves that are 2½ by 2¼ by 12 inches (6 by 6 by 31 cm) and are open at the bottom to promote air pruning of the roots. A well-drained potting medium containing peat, bark, perlite, and vermiculite is used and a slow-release fertilizer is incorporated into the mix to promote the breakdown of the bark and to encourage initial root growth. Perlite is used as a top dressing to decrease drying. Following sowing, the containers are moved directly into a shadehouse where the acorns germinate. When germination appears complete, the empty containers are removed and the remainder consolidated. Regular irrigations from an overhead system usually commence in the spring and are designed to provide deep thorough soakings, with seedlings drying between each irrigation. A balanced fertilizer is added through irrigation water, but rates are kept low. The following winter, the seedlings are sized, graded, and made available for sale.

Bareroot Seedling Production

Few bareroot oak seedlings are produced in the state. However, the California Department of Forestry and Fire Protection Nursery at Magalia began growing and selling a limited number to the public about 10 years ago. To determine which cultural practices are most effective for bareroot production of blue oak seedlings, a study was initiated at the nursery in 1987 to compare several root pruning (drawing a blade through the soil 8 to 10 inches [21 to 26 cm] deep to cut off deep roots) and sowing treatments (Krelle and McCreary 1992).

Root Pruning

Undercutting roots is common in the production of commercially important oak species such as northern red oak in the East and Midwest (Johnson 1988). Results from the Magalia study indicated that it was essential to prune seedling roots in order to produce acceptable plants. If the roots were unpruned while in the nursery bed, they grew so deep that it was impos-

Recommended Procedures for Growing, Lifting, and Storing Rangeland Oak Seedlings in Bareroot Nurseries

- Sow acorns in nursery beds by the end of January at a density of no more than 12 to 14 per square foot (129 to $151/m^2$).
- Undercut seedling roots in both May and August to inhibit taproot development and promote a fibrous root system.
- Lift seedlings no later than early February and place in cold storage, making sure roots stay moist.
- Store seedlings for up to 2 months, but avoid extended storage for late-lifted stock (see chapter 4).

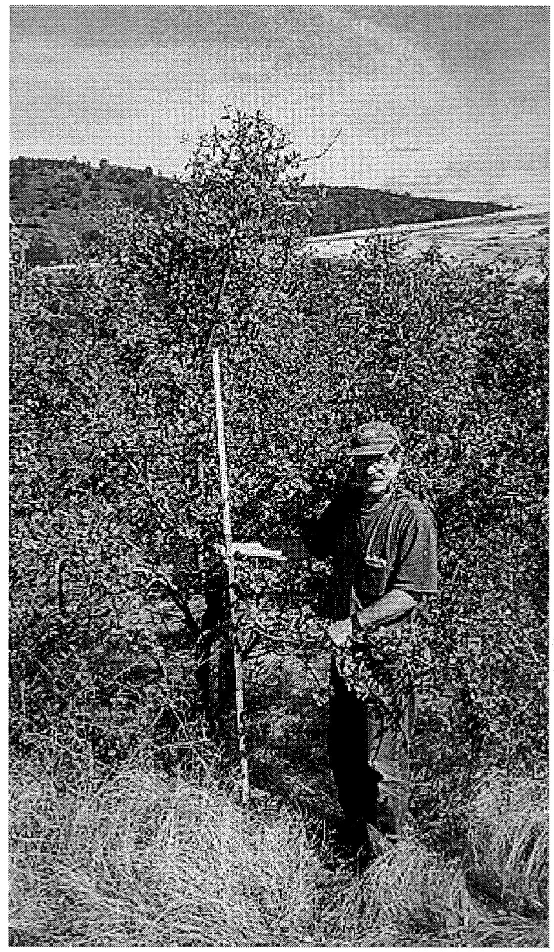

Figure 8. These bareroot seedlings were field-planted in 1989, and many are now over 10 feet (3 m) tall.

sible to "lift," or remove, them from the nursery beds without damaging them. However, the timing of the pruning was critical. If pruning was done too early, before the roots had grown down at least 8 inches (21 cm), then it had little or no effect on root form. If pruning occurred too late in the season, after seedlings had produced fairly thick, deep, carrot-like roots, then so much of the roots were lost during pruning that the seedlings were severely damaged, and, in many cases, died.

Based on the results of these experiments, nursery manager Bill Krelle opted for both an early (May) and a late (August) pruning treatment to produce the best blue oak seedlings, with the second pruning approximately 2 inches (5 cm) deeper than the first. This study also found that seedlings from a late fall or midwinter sowing performed much better than those from an early spring sowing since late sowing apparently delayed germination and resulted in greatly reduced growth. In this trial, seedlings were grown for a single season at a density of 12 to 14 per square foot (129 to 151/m^2), though much lower bed densities are common for growing northern red oak (Schultz and Thompson 1997).

Lifting Dates and Storage

The 1987 Magalia study also evaluated different lifting dates and seedling storage treatments and found that bareroot blue oak seedlings could be lifted over a fairly wide interval, extending from early December to early February, without seriously affecting seedling quality. They could also be cold-stored for up to 2 months without damage, as long as the roots were not allowed to dry out. Seedlings from this trial (McCreary and Tecklin 1994b) have now been growing at the University of California Sierra Foothill Research and Extension Center for 10 years, and many are 10 to 15 feet (3.0 to 4.6 m) tall with basal diameters exceeding 2 inches (5 cm) (fig. 8).

Recommended Procedures for Vegetative Propagation

Vegetative propagation may be a desirable alternative to growing seedlings in containers or in bareroot nurseries because it offers the opportunity to produce uniform, genetically superior plants selected for traits such as disease or drought resistance. Another advantage is that this production method does not depend on acorns. As noted previously, acorns do not store well, and because acorn crops are so variable, restoration planning can be very difficult and seedlings unavailable when needed.

At present, however, no vegetatively propagated oak seedlings are commercially produced in California. Even for important eastern species, such as northern red oak, commercial vegetative propagation is uncommon, though there has been considerable research on it. The most widely tested method of vegetative propagation for oaks is with the use of rooted cuttings. While it is generally recognized that oaks are more difficult to root than many other woody species, it can be done. Most of the successes are attributed to combinations of using cuttings from young plants and providing growth regulators, moisture, and shade (Davis 1970; Zaczek, Heuser, and Steiner 1997). Isebrands and Crow (1985) successfully rooted softwood cuttings of 3-week-old northern red oak in a greenhouse, and Drew and Dirr (1989) found that cuttings from younger flushes (a period of stem elongation) rooted better than those from older flushes. Morgan (1979) also reported that the younger the oak, the greater the rooting success. In almost all trials, cuttings were treated with the hormone indoyl butyric acid (IBA) to stimulate rooting.

In vitro plantlet regeneration of several oak species has also been reported. Shoot cultures of English oak have been established and multiplied using original material from both juvenile seedlings and stump sprouts from mature trees (Vieitez, San-Jose, and Vieitez 1985). However, this approach is difficult and expensive, and it is unlikely that California oaks produced in this manner will be available in the near future.

Mycorrhizal Inoculation

Inoculating oak seedlings with mycorrhizal fungi has been reported to improve field performance after outplanting (Garrett et al. 1979; Anderson, Clark, and Marx 1983; Ruehle 1984; Dixon et al. 1981). This improvement is attributed to an increased capacity of the root system to take up moisture and nutrients. On sites in California where oaks were cleared decades ago and have remained treeless since, a lack of mycorrhizal inoculum could be a factor inhibiting natural oak regeneration. While a number of mycorrhizal species can be found in oak woodlands, there has been little evidence that artificially inoculating California oak seedlings, either before or after planting, significantly improves growth and survival. At the University of California Sierra Foothill Research and Extension Center, we compared valley oak seedlings inoculated with the broad spectrum and commercially available *Pisolithus tinctorius* mycorrhizae to uninoculated controls but could detect no subsequent improvement in field performance after outplanting.

However, in a trial that incorporated litter from under Engelmann oak trees (and presumably inoculum of native mycorrhizae) into planting spots with Engelmann oak seedlings and acorns, significant increases in a number of growth variables were reported (Scott and Pratini 1997). While it could not be proven definitively that mycorrhizae from the native soil conferred a growth advantage, it was concluded that this was likely. Berman and Bledsoe (1998) also added soils from valley oak riparian areas to growth media for valley oak seedlings grown in a greenhouse and found that the percent mycorrhizal infection and mycorrhizal diversity on the seedlings were increased more by transfer of oak forest and woodland soil than agricultural field soil. While the benefits of mycorrhizal inoculation for native California oak seedlings are not yet well documented, the Tree of Life Nursery regularly inoculates their oak seedlings, and its staff believes it confers a significant benefit after outplanting.

4

Seedling Planting, Maintenance, and Protection

Regeneration research in California during the past 12 years has indicated that successful oak establishment is dependent upon proper planting, maintenance, and protection. The greatest barriers to success are weed competition and animal damage. Regard-less of how well acorns are collected and processed or how well seedlings are grown and planted, if competing vegetation is not controlled and acorns and seedlings are not protected from damaging animals, chances for success are slim. Below are discussions of techniques and practices that can greatly enhance the prospects that outplanted acorns and seedlings will grow into saplings and trees.

Planting Rangeland Oak Seedlings

When to Plant Seedlings

As with date of sowing acorns directly in the field, the planting date for seedlings can influence subsequent field performance. The greatest problems arise from planting seedlings too late in the season. For blue and valley oaks, March is usually too late, and it is preferable for seedlings to be planted by the end of January. Bareroot blue oak seedlings lifted on several dates and stored for varying intervals performed well as long as they were not planted after early March (McCreary and Tecklin 1994b), and 1-year-old container seedlings planted in mid-December tended to grow more than those planted 6 or 12 weeks later (McCreary and Tecklin 1993b). In environments with low average annual rainfall and early onsets of spring and summer, these planting dates should be moved up even earlier.

Because both blue and valley oaks are able to grow roots during winter, early planting allows them to develop well-established root systems while the soil is still moist. In the Mediterranean climate of California, having such a root system is critical because there might be little or no rain for nearly 6 months, and the soil, especially near the surface, can become exceedingly dry. Seedlings planted late in the season may simply not have sufficient time to develop an adequate root system before soil conditions preclude further growth. It should be mentioned, however, that we have successfully planted seedlings of the 4-month-old stock type described in **Seedling Production in Containers** (see chapter 3) in March and even April. But, in all instances, the seedlings have been thoroughly watered at time of planting to ensure sufficient soil moisture for initial root growth.

How to Plant Seedlings

There are standard procedures for planting conifer seedlings (Schubert, Adams, and Richey 1975), and these apply to oaks as well. First, the seedlings should be maintained properly prior to planting, so that they are not injured. Seedling roots are particularly vulnerable and should not be allowed to dry out, heat up, or freeze, and care should be taken to make sure seedlings are not physically damaged by rough handling. It is also important to plant seedlings at the proper depth so that the ground line at planting is roughly similar to the seedling's ground line when it was growing in its container or bare-root nursery bed (fig. 9). The planting hole should be deep enough so that the roots do not turn up ("J-rooting") at the bottom of the hole. Finally, the soil should be suitably moist, not frozen, and any air pockets in the ground adjacent to the roots should be eliminated by gently compacting the soil, or irrigating thoroughly around the seedling immediately after planting.

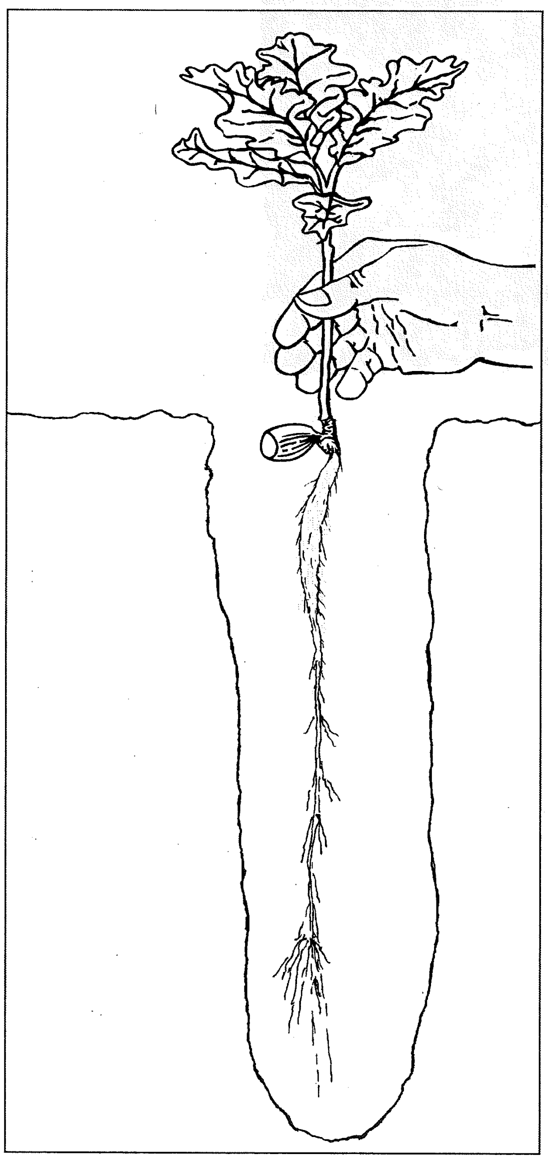

Figure 9. It is important to maintain the same ground line when outplanting oak seedlings.

There are a variety of tools that can be used to make holes prior to planting, including shovels, power augers, tiling spades, hoedads, and clamshell-type post-hole diggers. We have used the latter extensively at the University of California Sierra Foothill Research and Extension Center and have found that holes can be excavated fairly rapidly, as long as the soil is sufficiently moist and the ground is not too rocky or compacted. An additional benefit of post-hole diggers, compared with tools that create a slit in the ground, is that the holes created allow the root to initially have much more of a three dimensional configuration, which can be especially important when planting container seedlings that have a plug of soil and roots. Digging a hole with a post-hole digger also facilitates placement of fertilizer at the appropriate depth.

Auger Planting

Many of the hardwood rangelands in California have been grazed continuously for the past two centuries, compacting the soil in many locations. There are also areas underlaid with natural hard pack. Hard, compacted sites can make it difficult for oak roots, especially those of shallow-planted acorns, to penetrate downward. Augering planting spots (fig. 10) can greatly reduce the bulk density of the soil and make it much easier for the oak roots to grow downward. At SFREC, we evaluated three depths of augering (1, 2, and 3 ft [30, 60, and 90 cm]) and found that, compared to unaugered controls, all three depths improved the growth of surviving blue oak seedlings planted from acorns (McCreary 1995). However, we also found that the 3-foot augering had a negative side effect. In spite of efforts to compact the soil that we placed back in the holes for these deep-augered holes, the holes tended to subside several inches after the first heavy rains. In several instances, this caused acorns to become exposed, resulting in higher acorn depredation, probably from mice. As a consequence, overall mortality for this treatment was higher.

Figure 10. Tractor-mounted augers can be used to break through compacted soil.

We could also detect little difference between the three augering depths tested. We attributed this to the fact that most of the compaction was in the upper foot of the soil, and as long as this area was broken up, the oak roots had little trouble growing deeper. We therefore recommend either augering compacted soils prior to planting or excavating holes with a shovel or post-hole digger, but only to the depth required to penetrate the bottom of the compacted layer. It is important to auger well in advance of planting either acorns or seedlings so that the soil can settle thoroughly with natural rainfall. Finally, in wet, heavy soils, augering can result in a slick, smooth surface on the inside of the hole created. This can make it difficult for the oak roots to penetrate, and even slow water percolation so that the holes act like a pot. If holes become glazed from augering, use a shovel or tiling spade to rough up the sides of the hole before planting.

Selecting Microsites for Planting

Many areas targeted for oak regeneration contain a range of possible planting locations, or microsites, for individual seedlings. Even over short geographical distances, conditions at these planting sites can vary greatly. Some may be adjacent to rocks, logs, or stumps that provide natural protection and reduce direct solar radiation. Others may be close to gullies, swales, or even springs where soil moisture is greater. Still others may be far from obvious animal populations, as evidenced by gopher mounds or ground squirrel tunnels that can pose a threat to seedlings planted nearby. Finally, there is some evidence that certain shrubs may act as nurse plants for blue and valley oaks and promote establishment of seedlings planted near them (Callaway 1992). Because resources for plant restoration projects are generally limited, and it is too expensive to plant everywhere, it makes sense to choose microsites where seedlings will have the best chance to survive and grow. These may be difficult to determine, but insight can often be gained by looking at nearby areas where oaks are present and observing patterns where trees have become established naturally. In oak woodlands, south-facing, exposed ridges are generally less likely to have oaks than are north-facing slopes or drainages because soil conditions are much drier on southern aspects. And in grazed areas, oaks that have survived can often be found in locations that present some natural barrier to livestock and deer, such as rock outcrops. Mimicking such patterns in artificial regeneration efforts and choosing sites that afford some natural protection or better environmental conditions can often enhance success rates.

Planting Patterns

The number of acorns or seedlings to plant in a given area depends on how many oak trees are desired to grow there, as well as on attrition. Unfortunately, it is difficult to predict how many trees will be produced from plantings because a host of factors, including weather, animals, and competing vegetation, can influence survival. But following the steps described below on weed and animal control will help minimize mortality. Using these methods, it is not unreasonable to expect 70 to 80 percent, or higher, survival in many locales after the first 2 years.

The growth rates of seedlings also vary depending on species, site, and intensity of management. To predict the canopy cover after a given number of years, all of these factors need to be considered. A model of blue oak growth based upon the initial 10-year growth of a planting in 1987 (McCreary 1991) and stand structure models for this species developed by Standiford (1997) found that, under a high level of management (weed control for 3 years, protection from animals, fertilization), the canopy cover after 30 years would be 29 percent with 400 seedlings planted per acre (988/ha). With less intensive management (1 year of weed control, no protection), canopy cover over the same interval would be expected to be approximately 13 percent.

When planting, consider spacing seedlings or acorns in a naturalistic manner rather than in straight rows, using surrounding stands of oaks as a model. Also consider planting in small clumps or clusters, with some open areas between the clumps. Planting trees in clusters rather than with relatively uniform spacing can break up the landscape and provide more horizontal diversity of vegetation, which may benefit a wider range of wildlife.

Recommended Procedures for Planting Rangeland Oaks

- Plant oak seedlings early in the growing season, soon after the first fall rains have saturated the soil; do not plant after early March unless irrigation is planned.
- Make sure seedlings are not frozen, allowed to dry out, or physically damaged before, during, or after planting.
- Plant seedlings at proper depth, making sure they are not J-rooted, and eliminate air pockets in soil adjacent to seedling roots.
- In hard, compacted soils, break up soil (using a shovel, auger, or post-hole digger) through the compacted zone prior to planting to promote deeper rooting. If planting holes are augered, make sure the sides of the holes are not glazed.
- Select microsites for planting that afford some natural protection and provide the most favorable growing conditions.
- Plant in a natural pattern, avoiding straight, evenly spaced rows.

Weed Competition

How Weeds Impact Oak Seedlings

Competition for Soil Moisture. The primary effect of competing vegetation on both planted and natural oak seedlings is a reduction in soil moisture available for uptake. In the Mediterranean climate of California, where there is often little precipitation from April to October, a lack of moisture in the soil can limit growth and affect survival. Because all plants growing in an area compete for the same limited amount of water, more competition means less moisture available for oak seedlings (fig. 11). Eliminating this competition by the methods described in this section means greater access to moisture and a greater chance for growth and survival for oak seedlings.

Drought Resistance. Oak seedlings in California have evolved a number of mechanisms to deal with limited moisture in the dry part of the year (Rundel 1980). Germinating acorns tend to produce large and deep root systems before they start to grow a shoot. As mentioned above, this growth pattern allows oak seedlings to reach deeper soil where more moisture is available longer. In a 1986 report, Matsuda and McBride found that during the first growing season, 73 percent of the dry weight of blue oak was allocated to belowground material. They also found that California oaks showed much greater root elongation and smaller leaf area to root weight ratios than Japanese oak species. Their conclusion was that the extensive root systems and small leaf areas of California oaks help seedlings survive under dry conditions (1989b). Momen et al. (1994) evaluated the water relations of planted and natural blue oak seedlings and concluded that they also "resist drought by osmotic adjustment, particularly when seedling water stress progresses slowly because of lack of severe, belowground competition from grasses." Under extremely

Figure 11. Natural, or volunteer, oak seedlings often face severe competition from dense annual plants.

Figure 12. Oak seedlings typically grow a deep taproot with relatively little lateral root branching.

harsh conditions, oak seedlings can also grow very slowly. Phillips et al. (1997) found that more than 10 percent of blue oak seedlings less than 1 foot (31 cm) tall in portions of the southern Sierra Nevada Foothills were more than 25 years old, even though there was no evidence of browsing.

Taproots. Most oaks initially produce a primary taproot and relatively little side branching (fig. 12). But do nursery production systems that prune this initial taproot, and, therefore, prevent normal root development, predispose seedlings to slow growth or even death after outplanting? We have tried to answer this question by observing roots of both planted and natural, or "volunteer," oak seedlings, as well by monitoring the root growth of acorns planted in root observation boxes. Our experience suggests that the initial taproot configuration may not last long in nature and is probably not critical for regeneration success. Roots growing downward in soil may encounter rocks or other impenetrable objects. Soil microorganisms can also attack the root tips. The result is the development of several taproots at the point of injury or obstruction. These multiple roots continue growing downward and appear to function similarly to single taproots. In one study, we planted pregerminated, blue oak acorns that had intact radicles (and were, therefore, presumably predisposed to a single taproot configuration) alongside acorns that had radicles severed at approximately ½ inch (1 cm) to promote the development of multiple taproots. While this treatment clearly affected root morphology, we could detect no subsequent effect on field growth or survival (McCreary 1996). Koukoura and Menke (1994) found that pinching the roots of blue oak seedlings resulted in faster root growth but did not affect total root length and dry mass.

Competition for Nutrients and Light. In addition to vying for a limited amount of soil moisture, forbs and grasses also compete with oak seedlings for nutrients and light. Although these factors are generally not as important as moisture competition, in certain instances, such competition can severely impact oak seedlings.

Recommended Weed Control Procedures

- Select method of weed control (herbicides, physical weed removal, or mulching) based on environmental, fiscal, and philosophical considerations.
- Maintain a weed-free circle that is 4 feet (1.2 m) in diameter around individual seedlings or acorns for at least 2 to 3 years after planting; if using herbicides to control weeds, remove weeds in circle with a diameter of 6 feet (1.8 m).
- Initiate annual weed control by early spring to ensure that weeds do not become established and deplete soil moisture before oak roots can penetrate downward.
- Visit planting sites at least twice annually to remove both early- and late-season weeds and weeds that may have grown through mulch.
- If using postemergent herbicides, make sure that chemicals do not come in contact with foliage or the expanding buds of seedlings.
- After weed control is discontinued, visit plantings regularly to make sure vole populations and damage to seedlings have not increased. If increases are observed, remove thatch.

For example, regardless of moisture availability, small oak seedlings growing in dense competition with forbs and grasses may simply not receive sufficient light for growth.

Secondary Effects of Weeds

In addition to their primary competitive impacts, the undesirable dense growth of annual grasses and other exotics we call *weeds* can also have significant effects on oak seedlings by providing a favorable habitat for animals that can damage them. For instance, large amounts of dead annual grasses, or thatch, can provide an ideal habitat for voles or meadow mice *(Microtus californicus)*. The fecundity of these animals is high, and populations can increase dramatically when weeds are neither grazed nor artificially controlled. The result can be serious damage to oak seedlings. At the University of California Sierra Foothill Research and Extension Center, we have observed oak saplings that are 8 feet (2.4 m) tall and girdled half way up the stem when weed control was discontinued and thatch levels rose, providing ideal vole habitat (see **Length of Time for Weed Control,** below). Removing weeds even in relatively small areas around seedlings can greatly reduce vole damage (Davies and Pepper 1989; Tecklin and McCreary 1993).

Grasshopper herbivory is also affected by the amount of herbaceous vegetation in proximity to seedlings. We have successfully reduced grasshopper damage to blue and valley oaks by spraying herbicides and mowing grassy areas inside planting zones, thus reducing late-season green weeds that are attractive for grasshoppers. This usually requires treatment of the entire planting area (as well as a perimeter), rather than treating small areas around individual seedlings since grasshoppers can readily fly short distances from treated to untreated areas.

Weed Control

As indicated above, controlling weeds around planted acorns or seedlings is essential because direct weed competition and the habitat created by weeds can make it very difficult for oak seedlings to survive and grow. Studies have repeatedly shown that weed control can greatly enhance the field performance of blue and valley oaks (Adams et al. 1992; Adams, Sands, and McHenry 1997; McCreary and Tecklin 1997). There are a variety of methods that can be used to eradicate weeds. The actual procedure or technique chosen may depend on many variables, including equipment or materials available, oak species planted (deciduous or evergreen), and even a grower's philosophical orientation. For instance, some people prefer not to use herbicides of any sort because of concerns about health and environmental contamination. Whichever methods are chosen, weed control greatly improves the chances for the success of oak plantings.

Herbicides. These are generally the cheapest, easiest, and most effective method of eliminating weeds. While herbicides are routinely used in California around oak seedlings, there have been no large-scale trials to determine which chemicals are most effective for which weed species and soil types and which cause the least injury to nontarget plants. The most common chemical currently used is probably glyphosate. This is a broad-spectrum, postemergent herbicide that kills grasses and forbs. It is considered to be safer than many herbicides and carries a "caution" rating on the label, meaning that it is an unrestricted chemical. It breaks down rapidly and has no residual activity in the soil. It should not be sprayed on the foliage of oak leaves, however, especially the new growth and initial shoots emerging from planted acorns, because glyphosate might seriously damage or kill seedlings.

We have sprayed glyphosate directly over the tops of deciduous oaks in the winter when they have no leaves, but, even in this situation, a small percentage of seedlings demonstrated signs of herbicide injury. Seedlings appear to be more vulnerable to this type of damage when buds are swelling in the early spring. Even when seedlings are dormant, it is safest to avoid chemical contact with twigs or buds. For very small seedlings, individual plants can be covered with anything from paper cups to 1-gallon or larger containers. Alternatively, spray can be applied directionally away from plants, but it is important that the air be still so there is little chance of drift onto the seedlings. It is also possible to protect small- to medium-sized seedlings by placing a section of stovepipe over them (fig. 13) while spraying, being careful not to allow any drift to enter the open top. Pieces of cardboard or a similar shield can also be used to protect one side of a plant, rotating the cardboard around to the opposite side when spraying weeds on that side, as long as the side that has had contact with the herbicide does not touch the seedlings.

Spraying glyphosate early in the spring is advantageous from a soil moisture point of view because killing competing plants when they are small and have not yet seriously depleted soil moisture means that there will be more water available for the oak seedlings. However, one problem with foliage-active (as opposed to soil-active or pre-emergent) herbicides, such as glyphosate, is that they only affect the plants that are present when the chemical is applied. On California rangelands, there are many annual plants, mainly from the family Asteraceae, such as yellow starthistle *(Centaurea solstitialis),* that usually germinate quite late in the season and are not present during early-season applications. As a result, there can be a whole new contingent of plants competing with oak seedlings by late spring. If left untreated, these plants can create serious competition problems. We, therefore, recommend an additional weed treatment in May to eliminate these late-germinating plants.

Physical Weed Removal. Several years ago, we initiated an experiment to compare various sizes of weed-free areas around young blue oak seedlings (McCreary and Tecklin 1997). Weed removal was provided by using a hoe to scrape the surface vegetation, leaving only bare soil (fig. 14). This treatment was applied in early spring and not only removed weeds that were currently growing, but greatly reduced the seed bank in the upper inch or so of soil. This essentially eliminated competition in the early part of the growing season. Unfortunately, later in the spring, numerous weeds returned and a repeat scalping was necessary to keep the areas bare. All scalping treatments resulted in significantly better field performance than the control, and the larger the weed-free circles, the greater the subsequent seedling growth. However, it was extremely difficult and time consuming to scalp a 6-foot (1.8-m) diameter circle around each seedling. Scalping also becomes even more difficult in rocky or dry soil. Therefore, we can only recommend scalping when it is done on a small scale.

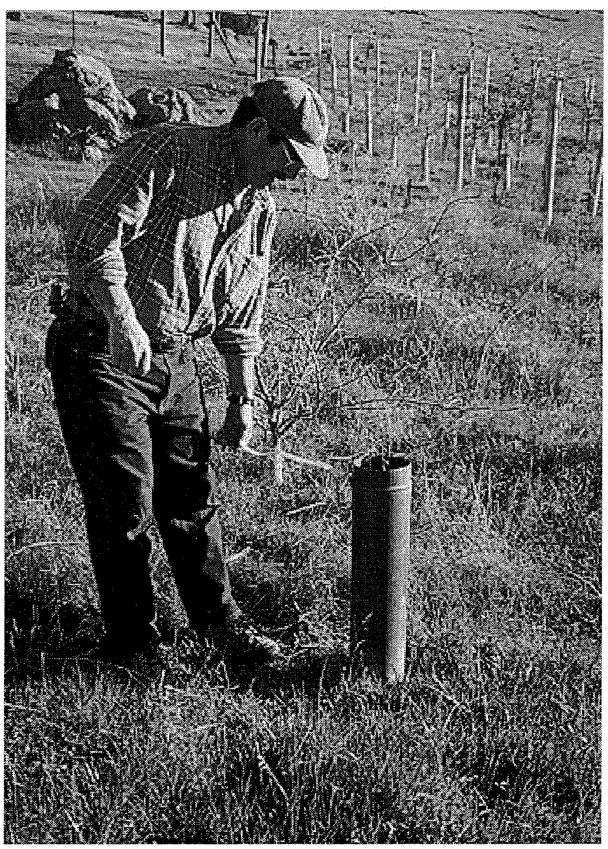

Figure 13. A stovepipe can be placed over oak seedlings to protect them while spraying weeds with postemergent herbicides.

We have also eliminated weeds around oaks late in the season using lawn mowers and weed-eaters. These treatments are not generally recommended because they only remove the top of the plants without killing them. If done early in the growing season, the plants will grow back rapidly and this treatment has little effect. It may even cause an increase in soil moisture loss as vigorous new growth following mowing, especially of grasses, can increase water use (Williamson 1992). However, if mowing is done in early or mid summer when most annuals have stopped growing and have turned brown, it can improve access and remove some of the habitat favorable to damaging animals, such as voles. In these conditions, the plants are not competing seriously with oak seedlings (except, perhaps, for light), but they are still providing habitat. Cutting weeds back may, therefore, reduce the potential for future animal damage. Cultivation is another technique for eliminating weeds but generally requires large equipment and multiple applications.

Figure 14. A hoe was used to remove ground vegetation from around this planted seedling, resulting in better field performance.

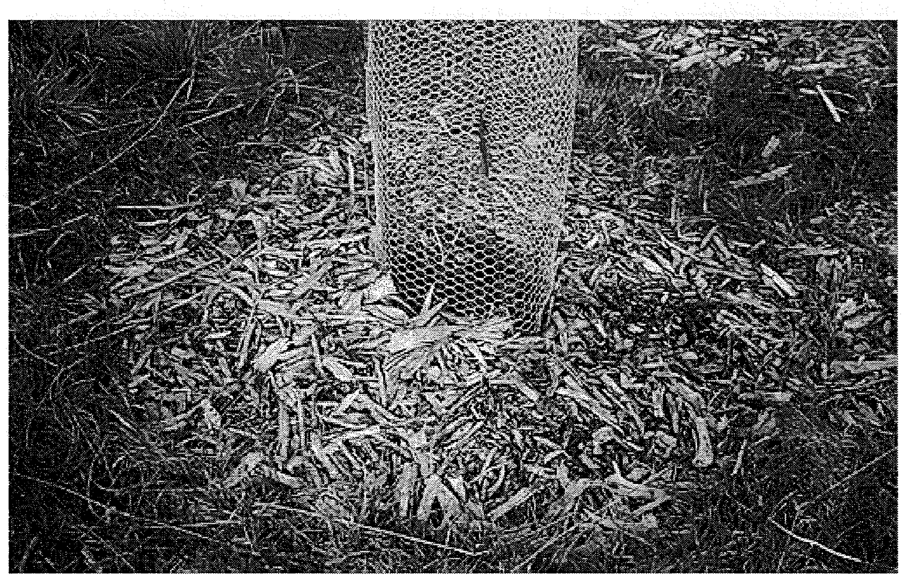

Figure 15. Organic mulches, such as bark chips, can effectively suppress weeds and reduce surface evaporation.

Mulches. There are a variety of organic and inorganic materials that can be used as mulches around young oaks. All of these materials tend to suppress weeds by physically covering them, thereby eliminating the light necessary for photosynthesis and growth. Organic materials include straw, wood chips, and compost (fig. 15). Plastic products are also commonly used, including those that are opaque but porous, allowing moisture to pass through but keeping light out. Mulches also conserve soil moisture by reducing evaporation from the soil surface, resulting in more moisture for the oak seedlings. Organic mulches can, over the long term, improve soil structure. As mulching materials break down and are incorporated into the soil, they tend to reduce soil bulk density, increase percolation, and improve the nutritional status of the soil.

It may be difficult to effectively suppress dense weeds that are already on-site using mulch alone unless the weeds are dealt with first. In these instances, it is often necessary to physically remove weeds before mulching, or to spray herbicides before putting the mulch in place, which reduces the likelihood that weeds will subsequently grow up through the mulch.

A study evaluating a variety of mulches, including black plastic, paper, and hay, on four oak species in the southern United States found that all of these materials positively affected growth for all species studied (Adams 1997). Adams, Sands, and McHenry (1997) compared impervious and porous plastic mulches on outplanted blue oak seedlings at the University of California's Hopland and Sierra Research and Extension Centers and found that both types of mulches significantly improved performance. Bernhardt and Swiecki (1991) also evaluated both organic mulch and polypropylene landscape fabric on valley oak plantings and found that both significantly increased growth. Circuit Rider Productions recommends installing a 3-foot-by-3-foot (91-by-91-cm) square of woven polypropylene fabric, secured with 6-inch (15-cm), heavy-gauge wire staples, around plantings to lessen competition for moisture and nutrients (Bush and Thompson 1990).

A problem with all mulches is that they do not last forever. Plastics tend to become brittle and photodegrade, while organic materials gradually decompose. Over time, weeds tend to grow through holes in the plastic or through shallow places in the organic mulch. For maximum benefit, these weeds should be regularly removed. In general, mulches are more expensive than herbicides and often require considerable upkeep and maintenance. As such, they are probably best suited for small plantings that can be managed intensively.

Area of Treatment. We have found that from a practical standpoint, circles with diameters of 4 feet (1.2 m) around individual seedlings are a good compromise between ease of application and effectiveness. While we found that even larger circles (6 ft [1.8 m]) promoted slightly greater growth (McCreary and Tecklin 1997), larger weed-free areas are considerably more difficult and expensive to provide (except with herbicides) and do not appear to be worth the extra effort and expense.

Length of Time for Weed Control. Determining when seedlings are fully established and need no further protection or maintenance involves site-specific judgments. It is, therefore, difficult to make generalizations about how long areas around oak plantings should be kept weed-free. This depends on the severity of the competition, the environmental conditions at the site, the growth rate of the seedlings, and the potential for animal damage once the weed control ceases. While we generally recommend a minimum of 2 to 3 years of weed control after planting, in some cases this may not be long enough. Although this interval may be adequate from a soil-moisture standpoint, it may not be adequate from an animal-damage standpoint unless other steps are taken to protect oak seedlings from animal damage (see **Treeshelters**, below).

Animal Damage and Control

Those involved in oak restoration projects know that there are many animals that eat or otherwise damage acorns and small oak seedlings. Damage from animals is not limited to artificially generated seedlings. An examination of natural seedlings often reveals shoot browsing, bark stripping, defoliation, and root clipping. Sometimes it seems remarkable that any oak seedlings are able to survive given the overabundance of damaging factors they must contend with in order to grow into trees.

Animals That Damage Acorns and Seedlings

Livestock. Both sheep and cattle browse young oak seedlings. In addition, both animals eagerly seek out acorns on the ground. The severity of browsing damage to young oak seedlings is related to the intensity of grazing (fig. 16). In pastures that are used rarely and for relatively short intervals, some oak seedlings may escape damage, especially if there is an abundance of other plants to eat. In intensively grazed pastures,

Figure 16. Cattle often graze in oak woodlands and can inhibit both natural and artificial regeneration.

Figure 17. Oak seedlings can be stunted from the repeated browsing of deer and cattle.

unprotected oak seedlings have little chance of escaping injury. Repeated browsing can keep plants stunted for years, even decades (fig. 17).

In addition to browsing young oaks and eating acorns, large-hoofed animals, such as cattle, can also cause damage to small oaks by trampling them. Hall et al. (1992) found that, in confined pastures, trampling damage from cattle accounted for nearly 15 percent of total damage to blue oak seedlings. This same study also evaluated the extent of damage to planted oak seedlings at different times of the year. Not surprisingly, browsing damage was greatest for deciduous blue oaks in the spring and summer when the plants were fully leafed out and other green vegetation was scarce, and was least in the winter when seedlings were bare. The timing and intensity of grazing can, therefore, influence the extent of damage to unprotected oaks in grazed pastures.

Deer. A common species of deer on hardwood rangelands in California is mule deer *(Odocoileus hemionus Californicus)*. The extent of their herbivory on both natural and planted oak seedlings varies greatly by site. In areas where deer are migratory and only pass through briefly at certain times of the year, damage will likely be minor. While annoying, such damage may be acceptable and not require protection. Such is the case at the University of California Sierra Foothill Research and Extension Center, where oak shoots are occasionally clipped off. However, in areas with resident deer herds, damage can be far greater (fig. 18). At the University of California Hopland Research and Extension Center in Mendocino County, deer browsing from a resident population precludes any successful attempt at artificially regenerating oaks without effective protection from these animals. Even oak stump sprouts there are clipped back to the trunk soon after they emerge.

In certain areas, repeated browsing can create bush-like plants that survive for decades. Griffin (1971) reported that it can take more than 20 years in a favorable habitat for coast live oak seedlings to grow above the reach of deer. At the Hastings Reserve in Carmel, White (1966) reported that only 12 percent of 154 oak seedlings were unbrowsed by deer and concluded that deer may be an important factor limiting seedling establishment (fig.19).

Rodents. Several rodents can seriously hamper oak restoration efforts. In a study evaluating various factors affecting survivorship of blue oak, Davis et al. (1991) stated that rodents were the most important predators of both acorns and seedlings. In blue and valley oak plantings at SFREC, the animals that have been the most troublesome are meadow mice, or voles (Tecklin and McCreary 1993), which thrive there in a dense cover of ground vegetation (fig. 20).

Acorns can also constitute a sizable portion of the diet of western gray *(Scirius griseus)* and California ground squirrels at certain times of the year (McDonald 1990), and these animals can destroy unprotected acorn plantings. Adams et al. (1987) reported that more than 5,000 blue and valley oak acorns were dug up at a planting in Madera County, presumably by ground squirrels. Deer mice (*Peromyscus* spp.) also eat acorns that are exposed or planted very shallow.

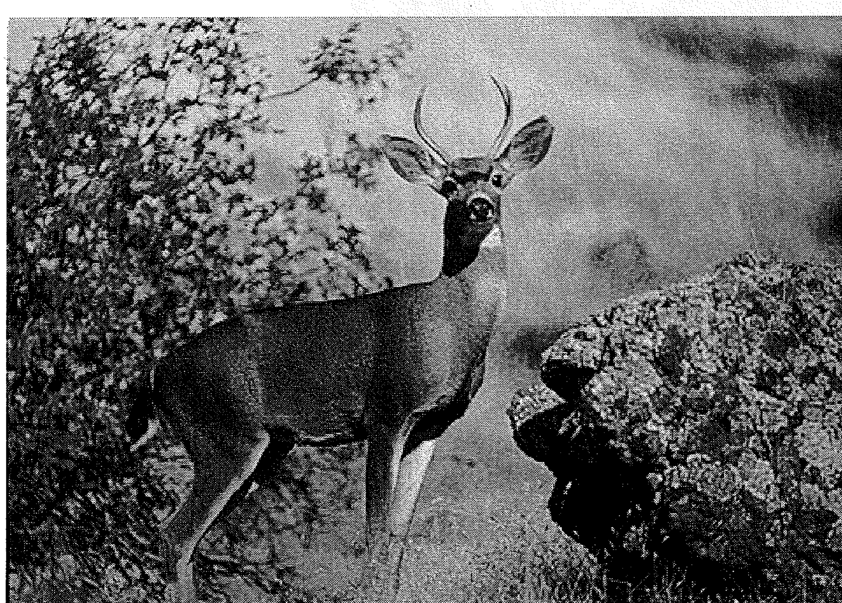

Figure 18. Many deer live among California's oaks, feeding on seedlings and other plants.

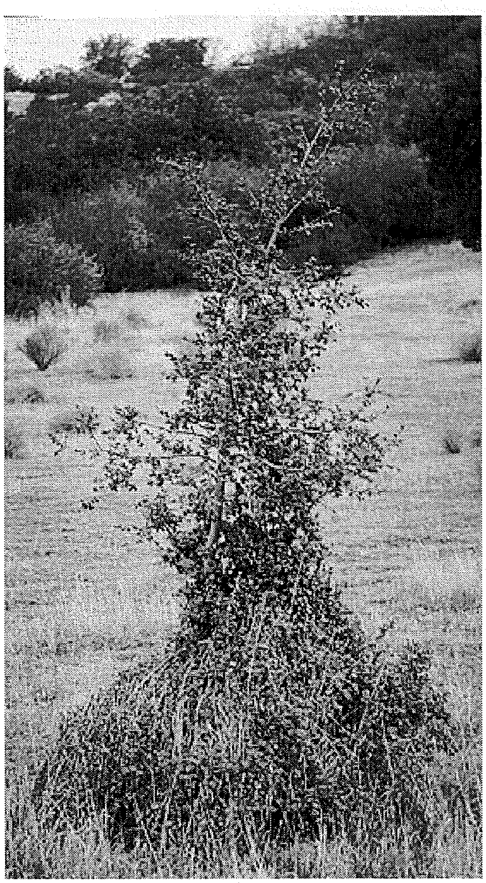

Figure 19. This oak was only able to release and elongate a dominant leader when the oak bush became so large that deer could no longer reach in and clip off shoots near the center.

Figure 20. This dense patch of dead grass and forbs, or thatch, is ideal vole habitat.

Pocket gophers *(Thomomys bottae)* constitute a serious pest in many oak plantings because they clip roots below the soil surface. In a study at the Hastings Reserve in Carmel in the early 1970s, Griffin (1971) noted that pocket gophers ate about 250 one-year-old seedlings in a woodland plot. Damage is not limited to newly planted seedlings, as gophers can kill oaks several years old, and also eat acorns (Griffin 1976). Gopher populations vary greatly by area and, in some locations, gophers are not a major concern. Where they are a problem, modifying the habitat can reduce populations and damage. However, this generally means treating entire areas and removing most or all of the surface vegetation. Gophers can also be effectively controlled by baiting with poisoned grain (see **Repellents and Baits,** below).

Insects. The primary insect damaging oak plantings at the University of California Sierra Foothill Research and Extension Center is the grasshopper, and in particular the species *Melanoplus devastator* (McCreary and Tecklin 1994a). As with many pests, populations fluctuate greatly from year to year, as well as over relatively short geographical distances. Even within the SFREC, we have observed large differences in the number of grasshoppers present within just a few hundred yards. Most commonly, populations seem to peak in late July and August. The cycle begins as eggs laid the previous fall hatch in the spring. Heavy rainfall years tend to promote the development and survival of large numbers because grasshoppers thrive in the abundant grass present in uncultivated areas. During years when populations are high, a single oak seedling can be covered with dozens of grasshoppers (fig. 21). During such outbreaks, almost all of the foliage on every unprotected seedling can be consumed. After the foliage is gone, the bark on seedlings is often stripped, and, in some cases, the seedling is completely girdled, killing the top. There are several other foliage-eating insects that also occasionally damage seedlings, but the injury is generally localized and not extensive.

The most common insect pests of California oak acorns are the filbert worm *(Melissopus latiferreanus)*

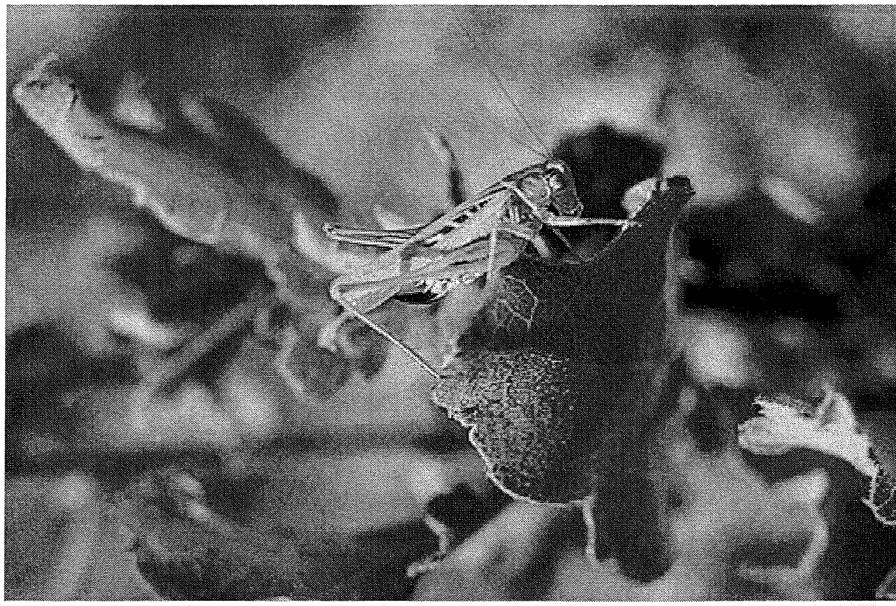

Figure 21. Grasshopper populations can explode during favorable conditions, and large numbers feed directly on oak seedlings.

and filbert weevils (*Curculio* spp.). The adults of the filbert worm lay their eggs on the surface of immature acorns, and, when the larvae hatch, they bore into the acorns. Adult filbert weevils penetrate the acorn skin or pericarp with their ovipositor and lay their eggs inside the acorns. As the larvae of both species grow, they feed on the cotyledons. Generally, the eggs are laid near the acorn cap and away from the pointed end of the acorn where the embryo is located. The larvae often emerge from the acorns during storage and accumulate in the bottom of bags or containers. Where there are multiple larvae in a single acorn, damage can be extensive. Griffin (1980) reported that over an 8-year period 21 percent of the valley acorns that dropped into collection traps were clearly nonviable due to insect damage, mainly from filbert weevils. However, even when much of the cotyledon is consumed, as long as the embryo is intact, the acorn can still germinate although there is less stored food available for initial root growth. The mature larvae usually chew their way through the shell of the acorn after the acorns drop to the ground in the fall (Brown and Eads 1965). In addition to the direct damage that larvae cause, their entrance and exit holes can also provide a site of entry for other pathogens that affect acorns (Swiecki, Bernhardt, and Arnold 1991).

A comprehensive listing of diseases and arthropods that affect native California oaks is contained in a host index database called CODA that was developed by Swiecki, Bernhardt, and Arnold (1997). CODA contains information on 45 native and cultivated oak species in California, 1,259 agents that affect these oaks, and 320 references that describe these interactions. It also contains information on 2,619 individual interactions between oaks and biotic or abiotic agents. It can be downloaded for free at http://www.phytosphere.com.

Protecting Rangeland Oaks from Animals

Without protection from animals, oak plantings often stand little chance of survival. However, the type of protection necessary depends on the type of damaging animals present. In some situations, large herbivores may be the primary species of concern, while in others, small insects may be the only threat. Below are descriptions of several general categories of animal protectors that have been used and some discussion about which animal pests they are most effective against.

Fences and Large Cages. It is estimated that over 80 percent of the hardwood rangelands in the state are privately owned (Bolsinger 1988). The primary economic use on many of these lands is livestock grazing. Because both cattle and sheep browse young oaks, it is often necessary to protect plants from them. Fences are obviously used to control livestock access to certain areas and can be built around oak plantings to keep animals out. But fences are not only costly to install and maintain, but if they exclude livestock from large areas, then these areas are removed from livestock production. If deer are a problem, higher and more costly fences are needed. Fences alone have not proven to be effective in promoting natural oak regeneration or in protecting artificial regeneration, except in small research exclosures with thorough weed control. This is because there are usually other animals, such as rodents and insects, that damage young oaks, even if livestock and deer are excluded.

However, in instances where deer and livestock are the only threats, fences may be effective. In these situations, it is important to weigh the costs of installing and maintaining fences against the costs of other types of protection. In England, the costs of fences were compared to the costs of protecting individual seedlings with treeshelters (see **Treeshelters**, below). It was concluded that if 450 trees per acre (1,112/ha) were planted, fences would only be cost-effective if more than 2 acres (0.81 ha) needed to be protected (Vickers 1999). However, this model did not consider the lost revenue from deferred grazing while fences excluded livestock.

Several types of small cages have also been used to keep livestock and deer away from individual oak seedlings or groups of seedlings. The simplest is a square exclosure, approximately 5 feet (1.5 m) per side, with metal fence posts at the corners and field fencing on the perimeter (fig. 22). This will effectively keep out livestock and deer since the protected area is too small to allow deer to jump inside. However, the cost is high, approximately $8 for four new fence posts and more for the field fencing and labor. In time, stock may also push the fencing over in efforts to reach young trees.

Figure 22. These exclosures, built with metal t posts and field fencing, effectively keep out deer and cattle.

Another type of cage using metal posts and field fencing has been described by Bernhardt and Swiecki (1991; 1997) and nicknamed a *vaca* cage (*vaca* is Spanish for *cow*). This is a circular structure approximately 4 feet (1.2 m) tall and 1½ feet (.5 m) in diameter, constructed from galvanized 12-gauge wire fencing with welded 2-by-4-inch (5-by-10-cm) mesh (fig. 23). The cage is secured to the ground with a t post and a 3-foot (.9-m) length of steel reinforcing bar. Materials costs per cage were $8 to $10 in 1997. Vaca cages are effective against deer and cattle although they do require periodic inspection and maintenance. They can be assembled and installed in about 12 minutes.

Screen Cages and the Collar-and-Screen Device. In oak regeneration studies initiated at the University of California Sierra Foothill Research and Extension Center in the late 1980s, seedlings were covered with cages made of aluminum window screen (McCreary 1989). These were constructed by cutting pieces of the screen into squares approximately 18 inches (46 cm) per side. These were then rolled into cylinders, folded closed at the top, and stapled to wooden stakes. The cylinders were placed over seedlings after field planting, and the stake was pounded into the ground (fig. 24).

These screen-cylinder cages cost about $1 each, plus labor, to construct. They were effective in preventing deer browsing, rabbit clipping, and grasshopper damage, but were worthless in pastures grazed by cattle since the ani-

Figure 23. This vaca cage costs approximately $8 to build and consists of a single t post, a 3-foot piece of rebar, and 5 feet of field fencing.

Figure 24. Tubes of aluminum window screen were initially used in oak regeneration trials at the SFREC.

Figure 25. When seedling growth reaches the top of aluminum screen cages, the screen should be opened to allow growth to progress normally.

Animals That Commonly Damage or Kill Rangeland Oak Seedlings and Recommended Seedling Protection

- Livestock, including cattle and sheep, eat oak foliage and consume acorns. In grazed pastures, seedlings must be protected, or they have little chance of growing. Fences can be used to keep livestock out of planting areas, but often other animals still damage plants. Treeshelters (see **Treeshelters**, below) secured to heavy metal posts can protect individual seedlings in moderately grazed areas.
- Deer browse seedlings and consume acorns. Damage is usually greatest when a resident herd is present. Planted areas can be fenced, or individual seedlings can be covered with treeshelters, screen cages, or seedling protection tubes.
- Voles, or meadow mice, strip bark from seedlings and saplings and can girdle and kill oaks. They thrive in dense grass or thatch, and populations can increase explosively. Damage levels can be greatly reduced by keeping the area within 2 feet (.6 m) of oaks free of vegetation.
- Pocket gophers commonly clip roots below the ground and can kill oak seedlings that are several years old. Seedling roots can be protected with hardwire cloth, aluminum window screen, or root guards, but material must degrade or be removed to ensure roots are not damaged as plants grow larger. Damage can be reduced by eliminating ground vegetation. In small areas, gophers can be effectively controlled by baiting.
- Ground squirrels clip seedlings and dig up acorns. High populations are usually evident by extensive mounds, holes, and burrows. Planting near such areas should be avoided.
- Grasshoppers eat foliage, and their damage is usually greatest in midsummer to late summer. Populations can fluctuate greatly from year to year, increasing dramatically during outbreak years. At these times, damage can be reduced by keeping the area where the oaks are planted free of ground vegetation.

mals easily knocked over and trampled them. The screens also presented another problem. As the seedlings grew taller, it was necessary to open them up, again making the tops of the seedlings vulnerable (fig. 25). If opening-up was delayed, the seedling became confined and deformed, a condition they do not soon recover from. In addition, insects and rodents could get underneath the screens if they were not buried or stapled down.

A modification of the screen cylinder method developed at the University of California, Davis, and refined by the Pacific Gas and Electric Company and Circuit Rider Productions (Bush and Thompson 1989) is the collar and screen. This consists, first, of a 1-quart (.95-L), plastic, yogurt or cottage cheese container with the bottom cut out. A square of aluminum screen is then wrapped around the plastic container and secured with wire and folded over at the top. The whole device is then placed over the seedling or direct-sown acorn with the plastic container sunk in the ground. This plastic container is believed to afford some protection against gophers (at least for shallow roots) and, if the plants are watered, creates a small, artificial reservoir. As long as plastic containers are available, this device is probably easier to assemble and less expensive than a screen cage.

Seedling Protection Tubes. Several manufacturers make seedling protection tubes from rigid plastic mesh (fig. 26). They can be purchased in lengths from 18 to 36 inches (.5 to .9 m) and are relatively inexpensive, with the 36-inch (.9-m) tubes costing about 28¢ each. They are usually secured to the ground with lath or bamboo stakes. They are not only reasonably effective in protecting against deer damage but also afford protection against rabbits. However, since the mesh is fairly wide, it is very easy for small animals, such as grasshoppers and even voles, to pass through, especially near the ground. As seedling shoots grow through the sides of the mesh (which is very common), the exposed portion is also vulnerable to browsing. Finally, these devices do not offer much protection in pastures grazed by cattle since they are easily uprooted or knocked over. Solid tubes called treeshelters were developed, in part, to overcome this limitation (see **Treeshelters**, below).

Underground Protection. As mentioned above, gophers and ground squirrels can be very troublesome in certain planting locations. In these situations, either the animals must be eliminated or the oak seedlings protected from them. Physical barriers have been successfully used to keep animals away from oak seedling roots. Plumb and Hannah (1991) reported that ¼-inch (6.5-mm) hardwire cloth buried 12 inches (31 cm) in

Figure 26. This seedling protection tube of rigid plastic mesh guards seedlings from deer and rabbits but not from grasshoppers or cattle.

the ground afforded some protection although they were concerned with the cost ($1 per seed spot) and the fact that these devices could restrict root growth as seedlings became larger. Adams and Weitkamp (1992) found that thin tubes of aluminum screening placed in the ground around seedling roots significantly reduced gopher damage. A metal mesh basket called "root guard" comes in several sizes and is designed to protect plant roots from gophers (see appendix B for source information).

Repellents and Baits. Some animals can be eliminated or controlled with poisons or baits. For gophers, probes can be used to place poisoned grain in underground tunnels. For large areas, however, this may not be practical. Also, baited areas must be regularly checked for evidence that gophers may have returned (distinctive C-shaped mounds will be present), and baiting repeated if necessary. Clearly, it is critical that no nontarget animals have access to the bait and that all pesticide labels be carefully adhered to when using any pesticide products.

The movement of grasshoppers into research plots from adjacent grassy areas can also be reduced using poisoned bait. A thin line of bait containing an insecticide can be placed around the perimeter of the oak planting area. The grasshoppers consume the bait as they move toward the plot and die before they reach the seedlings. This treatment has proven moderately effective at the University of California Sierra Foothill Research and Extension Center.

Habitat Modification. As mentioned earlier, animals require specific habitats to live and reproduce. If the habitat is significantly altered such that it is no longer suitable for their needs, the animals will leave or die. This knowledge of habitat requirements and preferences can be used to reduce or eliminate impacts from certain animals. The most effective way we have found to control voles, for instance, is to eliminate grass and forbs from an area. Even eliminating weeds in 4-foot (1.2-m) diameter circles around individual seedlings seems to provide a sufficient barrier that these animals are generally reluctant to cross, presumably because of predatory threats from hawks, owls, and other animals. Removing grasses and forbs in oak planting areas also helps to reduce grasshopper damage and has been used successfully to control pocket gophers in conifer plantations (Engeman et al. 1995).

Treeshelters

Treeshelters are individual, translucent, plastic protectors that fit over seedlings. Most are made from twin-wall polypropylene although some are made from single, flat sheets that are assembled on-site. Treeshelters were initially developed and tested in England 20 years ago (Tuley 1983; 1985). By 1984, over one million treeshelters were commercially manufactured and sold there. Although the number sold in England today is probably less, in 1991 it was estimated that annual production probably exceeds 10 million (Potter). They

Methods of Protecting Trees from Animals

- Fences and large cages are effective only if livestock and deer are the only animals of concern. Fences require a large initial investment and result in fenced areas being removed from livestock production. Fences and cages must be maintained regularly.
- Screen cylinders provide adequate short-term protection against insects, rodents, and deer but are ineffective against livestock and must be reopened once seedlings grow to the top, exposing plants.
- Seedling protection tubes are an inexpensive way to protect plants against rabbits and deer, but they are not effective against livestock, insects, or small rodents. Shoots that grow through the sides of tubes are vulnerable to browsing.
- Treeshelters have proven very effective in protecting rangeland oak seedlings from a wide range of animals and stimulating rapid, above-ground growth. They are relatively expensive but can greatly reduce the time required for seedlings to grow to sapling stage.
- Habitat modification can reduce damage from grasshoppers and some rodents, but it is ineffective for larger ranging animals, such as deer. Care must be taken to monitor the regrowth of vegetation or animals will quickly reoccupy site.

Recommended Procedures for Treeshelter Installation

- Select the size of treeshelter based on the browsing height of animals that are a threat.
- Install shelters so that they are upright and secure them to stakes using plastic ratchet clips or wire; make sure that seedlings are not damaged when shelters are secured to posts.
- Where treeshelters are used, plant in an aesthetic, "natural" arrangement rather than in regular, evenly spaced rows.
- Utilize stakes that are durable enough to last the length of time treeshelters will be in place and pound them at least 1 foot (31 cm) into the ground before planting seedlings.
- Make sure that the tops of stakes are lower than the tops of shelters to prevent access by rodents that can climb stakes and damage to seedling shoots from rubbing against stakes.
- To prevent seedling desiccation, install shelters with the base buried in the ground.
- To prevent bird access, install plastic netting over the tops of shelters.
- If treeshelters are placed in pastures grazed by livestock, secure the shelters to metal posts using wire and thread flexible wire through the top instead of using plastic netting.

are reported to not only protect seedlings from a variety of animals but also to stimulate above-ground growth. This growth stimulation seems to result from creating a mini-greenhouse inside the shelter, with elevated temperatures, humidity, and carbon dioxide concentrations. The higher relative humidity improves seedling moisture status by reducing transpiration. The treeshelters also help conserve moisture by condensing transpirational water on the tube interior. The condensation then drips back to the soil at the bottom of the shelter. Treeshelters can also make it easier to apply postemergent herbicides without risking contact of the chemical with the seedling's foliage (Potter 1988). Finally, treeshelters can help identify where seedlings are planted, which facilitates subsequent weed control and irrigation treatments; plants are also less likely to be accidentally mown or run over. As a result of these benefits, survival and growth in treeshelters is thought to be better. A large-scale survey of 193 sites in England that were planted with various tree species over the previous 12 years using treeshelters found that 89 percent of the shelters surveyed contained a living tree (Kerr 1995).

Although treeshelters have not been used for as long or as extensively in the United States, they have been evaluated in several oak field trials in California with promising results (Costello, Peters, and Giusti 1996; McCreary 1996; McCreary and Tecklin 1997; Tecklin, Connor, and McCreary 1997). They are effective in preventing animal damage from deer, rabbits, grasshoppers, and voles. When treeshelters are buried a few inches in the ground, they also seem to provide some protection against pocket gophers, though this has not been thoroughly evaluated. Finally, treeshelters show promise for use in pastures grazed by livestock (McCreary 1997; 1999) as long as they are secured to heavy-metal fence posts (fig. 27). But clearly they are not appropriate for all plantings, and, in many cases, it may be more cost-effective to utilize other protective measures.

Treeshelter Design, Construction, and Installation

There are several manufacturers of treeshelters and two main designs. The first design consists of flat sheets that can easily be shipped and transported. Once on site, they are rolled into cylinders or assembled into square boxes and placed over seedlings. The second major type of treeshelter design is made up of cylinders of extruded tubular plastic that need no assembly. The disadvantage of solid, cylindrical treeshelters is that they are bulky and expensive to ship and transport. Consequently, they are usually more expensive. Most types of treeshelters come in a range of heights.

Staking. Shelters more than 1 foot (31 cm) tall require attachment to a stake, usually with nylon ratchet clips, while some short types can be partially buried and are self-supporting. We have found that the nylon ratchet clips are easily broken when cattle rub against shelters and posts, and, therefore, recommend securing shelters to posts with wire in grazed pastures. It is important that the material securing the shelter to the stake not be wrapped directly around the seedling since this could obviously restrict growth and cause damage as seedlings become larger. After shelter installation, the supporting stakes should be several inches below the lip of the shelter to prevent contact with and damage to the emerging tree (fig. 28).

Stakes or posts can be made of a variety of materials, including wood, metal, and fiberglass. The stakes should be durable enough to last the length of time treeshelters are in place, be resistant to warping, offer frictional resistance to any twisting movement around

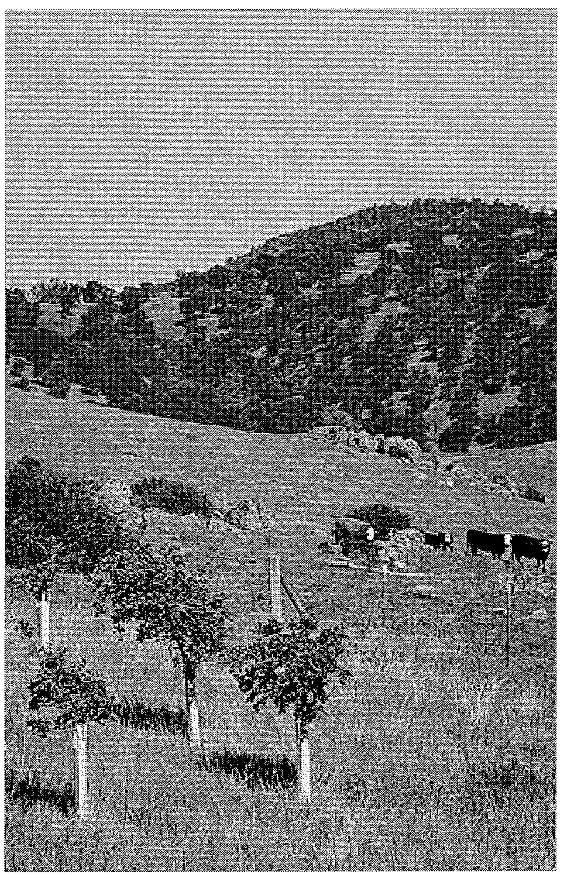

Figure 27. Treeshelters have been used effectively in establishing seedlings in areas grazed by cattle.

Figure 28. The supporting stakes on treeshelters should be several inches below the top of the tube itself.

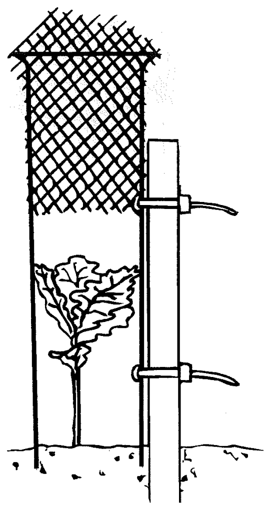

Figure 29. Treeshelters should be installed and maintained in an upright position.

Figure 30. This 13-foot giraffe tube was used to evaluate the effects of very tall treeshelters on oak seedling growth in England.

the stake, and be relatively easy to remove (Kerr 1996). We have found that oak stakes provided by manufacturers generally last 5 years, while 1-by-2-inch (2.5-by-5-cm) untreated, pine stakes can rot away below the ground after 1 or 2 years. We have also used 4-foot (1.2-m) pieces of rebar (steel-reinforcing rods) and standard metal fence posts. Both are durable and last far longer than necessary, but they generally require a post-pulling tool to take them out of the ground when the shelters are removed. It has been suggested that seedling root may grow around the metal flange at the bottom of the fence posts, causing injury to the seedling when the post is removed, but this has not yet been evaluated.

Advantages of Solid-Construction Treeshelters. While solid-construction treeshelters are generally more expensive, they have several advantages over types that require assembly. First, once on site they are relatively easy to place over planting spots. Second, they are inherently more sturdy and, consequently, can more easily be sunk into the ground around the seedlings. This can be important since a gap between the shelter base and the ground can create a "chimney effect," resulting in more desiccating conditions inside the shelter. In the Mediterranean climate of California where moisture stress often limits establishment success, such desiccation can be lethal. Solid shelters are also less likely to be dislodged or damaged by buffeting winds or animals that rub against them. Finally, solid-design treeshelters generally require less maintenance after they are installed, less frequent return visits to make sure they remain attached to the stake, do not have weeds growing inside them, and function properly. For woodland plantings in England, Vickers (1999) estimated that the average cost of maintaining solid-construction treeshelters to original specifications for a planting density of 450 per acre (1,112/ha) would vary between $50 and $150 per acre ($124 and $372/ha).

Colors. In addition to different shapes and sizes, treeshelters also come in several colors, including beige, orange, white, and clear. Beige shelters, which are designed to blend in with surrounding vegetation, are reported to reduce light intensity by approximately 50 percent, while white shelters reduce it by approximately 30 percent (Kjelgren, Montague, and Rupp 1997). In low light situations, such as plantings under canopies, white or clear shelters may, therefore, be preferable. From an aesthetic point of view, white shelters can be unsightly, especially if seedlings are planted in evenly spaced rows, which can give the planting area the appearance of a cemetery. In general, it is recommended that beige shelters be used in open-area plantings, with seedlings planted in irregular patterns, rather than in a systematic grid. Care should be taken to install and maintain shelters in an upright position and to check them and remove weeds that may be growing inside (fig. 29).

Heights. Treeshelters come in a variety of heights, ranging from 8 inches to 6 feet (20.5 cm to 1.8 m). Some trials in England have even used treeshelters that are 13 feet (4 m) tall (Windell 1993) (fig. 30). Not surprisingly, taller shelters are more expensive. Therefore, it is generally advisable to use shelters that are only as tall as necessary to protect against animals that are a threat. For example, if voles are the only concern, shelters that are 1 foot (31 cm) in height should be adequate. For rabbits, shelters that are 2 feet (.6 m) tall can be used. We have found that for deer and cattle at the University of California Sierra Foothill Research and Extension Center, 4-foot (1.2-m) shelters are tall enough. However, both deer and cattle can clearly reach up and nip seedlings emerging from the tops of 4-foot (1.2-m) shelters, so if browsing pressures are intense (resident deer or confined livestock), it may be necessary to use shelters that are 5 or even 6 feet (1.5 or 1.8 m) tall. It is also important to keep in mind that the effective height of a treeshelter is reduced when used on steep or uneven terrain since browsing animals can stand upslope and more easily reach seedlings. While treeshelters are relatively expensive compared to some other seedling protectors, the cost in the United States has dropped considerably in the last several years. Currently a 4-foot (1.2-m), solid-construction treeshelter, without the stake, costs approximately $3.

In 1995, a treeshelter conference in Pennsylvania surveyed the current state of knowledge on treeshelters used in reforestation and ecological restoration. The proceedings were published by the U. S. Forest Service (Brissette 1996) and are a good reference. Other references include a comprehensive booklet describing the use of treeshelters in Great Britain (Potter 1991) and a general description of the use of treeshelters in the United States and elsewhere (Windell 1992). A large U. S. Forest Service research project has also compared the effectiveness of various treeshelter designs and commercial products (Windell and Haywood 1996).

Trapped Birds. A potential problem associated with treeshelters is that birds can become trapped inside. Western blue birds *(Sialia mexicana)* have been identified as one species prone to this. To reduce the possibility of this happening, some manufacturers provide plastic netting to place over the tops of shelters, creating a physical barrier (albeit fairly flimsy) to entry. Advertisements also state that these nettings prevent the entry of butterflies that can also become trapped. We recommend using these net protectors and have observed them to work reasonably well, as long as they remain in place and are not blown off.

However, where livestock are present, netting is generally not effective. Cattle invariably take the netting in their mouths, chew it up and spit it out. Where cattle are present, we recommend replacing netting with flexible wire threaded through the top of the treeshelter as described by Tecklin (1993) (fig. 31). The wire should be removed as the tree grows up and out of the shelter.

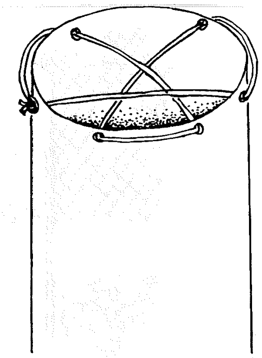

Figure 31. Flexible wire threaded through the top of a treeshelter can be substituted for netting to prevent bird entry when cattle are present.

Oak Seedling Growth in Treeshelters

In addition to providing effective protection against a wide range of animals, treeshelters have also increased the growth of blue and valley oak seedlings in trials at the University of California Sierra Foothill Research and Extension Center and elsewhere (McCreary 1997; McCreary and Tecklin 1993a, 1993c; McCreary and Tecklin 1996). On average, height growth in the first 2 years tripled compared with growth of unsheltered seedlings in plots where animal damage was not a consideration (fenced and weeded). Costello, Peters, and Giusti (1996) also reported better growth for blue oak, valley oak, and coast live oak protected with treeshelters, but these differences were greatest in irrigated, rather than unirrigated plots. In two separate trials (Burger, Forister, and Kiehl 1996; Burger, Forister, and Gross 1997), it was reported that valley and coast live oak seedlings in

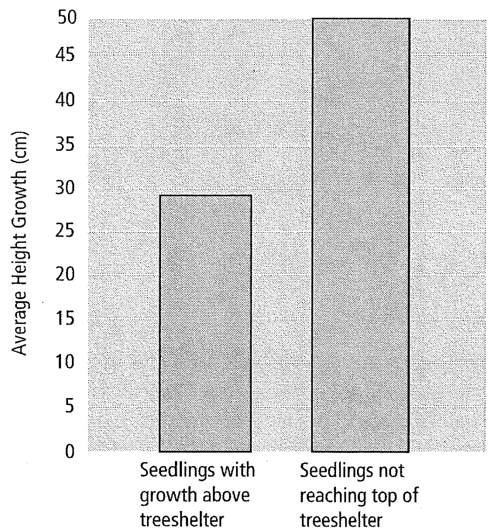

Figure 32. Annual height growth changes once a seedling grows above the top of the treeshelter.

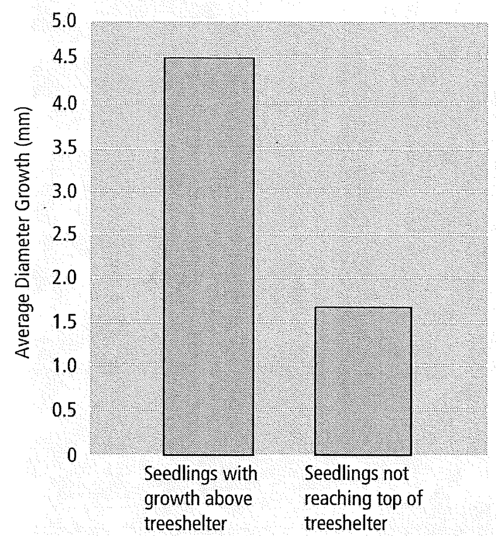

Figure 33. Annual diameter growth changes once the seedling grows above the top of the treeshelter.

treeshelters were taller compared to unsheltered seedlings during the first year of growth. After 2 years, however, they were not significantly taller.

Diameter Growth. Treeshelters do not seem to lead to an increase in the diameter growth of seedlings. In trials at the SFREC, most blue oak seedlings in treeshelters grew taller but had diameters similar to controls, resulting in seedlings inside shelters that were tall and thin. To evaluate this further, we established a trial to examine different shelter heights (2, 4, and 6 feet [.6, 1.2, and 1.8 m]). We measured the annual height and diameter growth while seedlings were still inside shelters, as well as after they had grown up and out of the tops (McCreary and Tecklin 2001). Height growth was consistently greater while seedlings were shorter than the shelters, regardless of shelter size (fig. 32). As soon as seedlings grew above the tops of the shelters, however, height growth diminished and diameter growth increased (fig. 33). As a consequence, when seedlings were below the tops of the tubes, they were tall and spindly. If the shelters had been removed at this point, the plants would almost certainly have toppled over without staking. After several years of growth above shelters, their girth increased greatly (while height growth slowed markedly), and they were larger, more robust plants than their unsheltered counterparts.

Costello, Peters, and Giusti (1996) found that when shelters were removed from three species of California oaks after 4 years, most saplings had sufficiently well-developed trunks to maintain an upright position (fig. 34). We recommend that shelters not be removed for at least 3 years after the seedlings have emerged from the tops. Treeshelters can be left in place longer, but should be removed before they restrict diameter growth (see **Treeshelter Durability and Maintenance**, below).

Burger, Forister, and Kiehl (1996), working with 10 species of landscape trees, including valley oak and coast live oak, recommended removing treeshelters as soon as young plants emerge from the tops and then staking them. They found that the benefits of shelters, in terms of accelerated growth, decreased with time. This research, however, focused on ornamental trees where greater costs of establishment—including staking—may be more easily justified. In almost all wildland planting situations, protecting oak seedlings from animals for at least 3 to 5 years is critical for success, and shelter removal before that time could result in unacceptable damage.

Effects on Roots. There is an additional concern that even though the use of treeshelters increases growth, this aboveground growth may be at the expense of the roots, resulting in plants that have a poor root to shoot

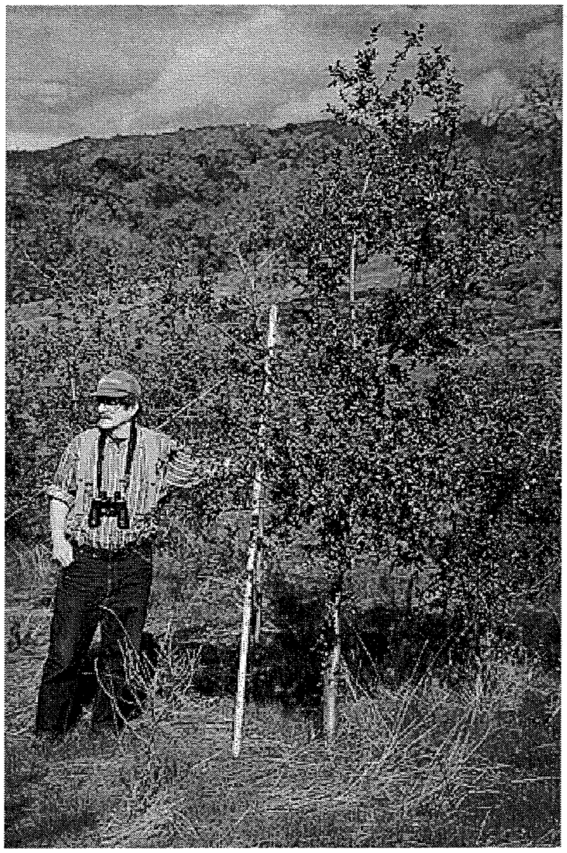

Figure 34. These seedlings were in treeshelters for 4 years. They continue to stand upright after the treeshelters are removed.

ratio. Rendle (1985) reported that treeshelters altered the distribution of dry matter in English oak, causing seedlings to have larger shoot to root ratios. Burger, Svihra, and Harris (1992) also found that oaks grown in containers had growth ratios for aboveground and belowground growth that were out of balance. Burger, Forister, and Gross (1997) further reported that after 2 years in a nursery setting, treeshelters reduced root dry mass, root to shoot ratios, total root length, and total root mass for valley oak, as well as the aboveground biomass for valley oak and coast live oak. However, these studies were of short duration, and these ratios may again change as plants grow older. Ponder (1996), for instance, found that sheltered, northern red oak seedlings, harvested 3 years after outplanting in forest openings, had both higher stem and root weights than seedlings not protected with shelters.

Treeshelters have also been effectively used to "retrofit" both natural and planted oak seedlings that are stunted (Gillespie, Rathfon, and Meyers 1996; Tecklin, Connor, and McCreary 1997; Shuler and Miller 1996). This has resulted in greatly accelerated growth. In the Tecklin trial at the SFREC, unprotected blue oak seedlings that had languished in an experiment for 2 years and averaged only 6 inches (15 cm) in height, suddenly grew vigorously when treeshelters were placed over them. After being protected for 2 years, they averaged more than 3 feet (.9 m) in height, while unprotected seedlings continued to grow slowly and averaged less than 1 foot (31 cm) tall.

Treeshelters with California Black Oak. We have also used treeshelters with California black oak, but with very different results. In a trial with this species, treeshelters did not promote accelerated height growth, and seedlings in all treatments, including uncovered controls and seedlings covered with seedling protection tubes, remained quite small, even after 3 years. Friske (1997) used treeshelters with California black oak in Yosemite National Park and, after 6 years, found that while seedlings in treeshelters were significantly taller than those in open plastic mesh, they averaged less than 2 feet (.6 m) in height. It is unclear why this oak species seems to initially grow so slowly, both with and without treeshelters.

Treeshelter Durability and Maintenance

Most shelters do not deteriorate readily. They remain intact for a number of years (for durability comparisons, see Windell and Hayward 1996) because they have stabilizing ultraviolet inhibitors added to the plastic. In early trials without stabilizers, treeshelters broke down before seedlings had grown large enough to be self-supporting. While attempts have been made to incorporate a quantity of inhibitors that will result in timely degradation (3 to 5 years), this has not been routinely successful and the treeshelters have not degraded as expected (Kerr 1992). Strobl and Wagner (1996) could detect no photodegradation of treeshelters after 5

Recommended Treeshelter Maintenance Procedures

- Visit shelters at least once each year to make sure they are upright, attached to the stake, buried in the ground, and functioning properly.
- Keep a 4-foot (1.2-m) diameter or larger circle around shelters free of weeds for at least 2 years after planting, and remove weeds that grow inside shelters.
- Replace flexible netting that has blown off shelter tops.
- Replace stakes that have rotted or broken.
- Leave shelters in place for at least 3 years after seedlings have grown out the tops, longer if shelters are still intact and are effectively protecting seedlings.
- Remove shelters if they are restricting growth or abrading seedlings; to remove solid shelters, slice down the sides with a razor or knife, being careful not to damage the seedling inside.

years. This raises the question of when treeshelters should be removed. In England, Kerr (1996) recommends removing shelters before they begin restricting the diameter growth of the saplings, or when treeshelters are abrading and severely damaging trees. Until this point, treeshelters help provide support and prevent damage from rabbits, squirrels (which are a terrible pest in England and can girdle trees by stripping bark), and deer (browsing and antler rubbing). For most California species, however, growing to this size could take a decade or more, and there may be aesthetic or environmental reasons to remove shelters earlier. However, it is important to leave shelters in place for at least 3 years after seedlings have emerged from the top.

By the time seedlings are taller than the tops of shelters, it is usually impossible to slip the solid shelters over the seedlings, but it is fairly easy to slice these shelters down the side using a razor or utility knife so they can easily be removed. It is especially important that treeshelters be split or removed before trees become so large that their diameters are as great as that of the shelters. At this point, stem deformation or even sapling death can occur. To reduce this possibility, some treeshelter manufacturers have begun incorporating a strip down the sides with a preformed weakness in the plastic. This is intended to permit the shelters to split apart when plants grow and press against the sides of the shelters. Whether or not this will work reliably is yet to be determined.

Finally, even though treeshelters have been shown to improve water relations and accelerate seedling growth, it is important to caution that they do not eliminate the need for weed control. Kerr (1996) noted that "the use of effective weed control in combination with treeshelters is very important to ensure rapid establishment of young trees." It is also important to remove weeds growing inside shelters because the favorable environment inside can lead to rapid weed growth.

Fertilization

There have been relatively few fertilization trials with native California oak plantings, and those that have been conducted have had mixed results. Adams, et al. (1987) reported a negative effect of granular, slow-release fertilizer (18-6-12) placed beneath blue and valley oak acorns and transplants at time of planting. Tappeiner and McDonald (1980), however, reported that annual fertilization with ¼ pound (113 g) per seedling of 16-20-0 enhanced survival and height growth of California black oak. McCreary (1996) also found that .74-ounce (21-gm), slow-release, fertilizer tablets (20-10-5), placed below outplanted blue oak acorns and seedlings, significantly increased both diameter and height growth. In the eastern and northern United States, fertilizers have been consistently reported to improve oak seedling performance (Johnson 1980). Differences in the California findings may be partially explained by an interaction with weed growth. In the first trial mentioned (Adams et al. 1987), weeds were not completely controlled and may have benefited more from the fertilizer than the seedlings, resulting in greater competition. In other trials, the plots were kept largely weed-free, and increased competition was not a problem. Obviously, soils can also vary tremendously in their fertility, and seedling response to fertilizers varies accordingly.

Compared with other costs associated with artificial regeneration, fertilization is inexpensive. The .74-ounce (21-gm) tablets used in the study above (McCreary 1996) cost about 5¢ each in 1993 when purchased in bulk, so even small improvements in performance were worth the costs. Since they are so inexpensive, we recommend using fertilizer tablets, placing them 3 to 4 inches (7.5 to 10 cm) below seedling roots at the time of planting.

Irrigation of Rangeland Oaks

When, Where, and How Much to Irrigate

In large-scale, wildland plantings, irrigation is generally not practical, especially if there is not an available water source near the planting area. In some settings, however, especially where cost is not as great a concern, it may be possible to water seedlings for several years after planting. Because water stress can seriously limit seedling survival and growth, irrigation can greatly improve the chances of establishment, especially on dry sites.

Effects of Different Soils. Sites and soils are very different and can have a tremendous effect on moisture-holding capacity and the availability of water for the seedlings. Plantings in deep, sandy, alluvial soils along the Sacramento River may need to be watered almost daily during the first year after planting. In the heavier, shallower soils at the University of California Sierra Foothill Research and Extension Center, however, this is not the case. We conducted a trial with newly planted valley oak seedlings at the SFREC that compared four treatments: no irrigation, 1 gallon (3.8 L) of water weekly, 1 gallon (3.8 L) every 2 weeks, and 1 gallon (3.8 L) every 4 weeks (McCreary 1990b). All 30 seedlings from each treatment in this study survived, indicating that irrigation was not necessary for establishment. After the first year, those that received any of the three irrigation treatments were significantly taller than unirrigated plants, but there were no significant differences among the three irrigated groups. This suggests that 1 gallon (3.8 L) of water every 4 weeks was sufficient during the first year in these soils and this environment.

In a study that evaluated soil moisture availability as a factor affecting valley oak establishment at The Nature Conservancy's Cosumnes River Preserve, irrigated, field-planted seedlings grew vigorously while unirrigated seedlings had greater water stress, less growth, and higher mortality (Meyer 1991). Bernhardt and Swiecki (1991) examined the value of irrigating direct-seeded valley oak and found that irrigation initially had a significant positive effect on seedling growth at two of three sites. However, irrigation was extremely expensive compared with moisture-conserving mulching treatments. Six years after planting, irrigation showed no positive effects on survival or growth, and it was observed that "irrigated seedlings generally sustained greater damage from small herbivores than did unirrigated seedlings. Damaging animals may be attracted to irrigated sites by the moist soil or increased succulence of oak tissues" (Bernhardt and Swiecki 1997).

Fertilization, Irrigation, and Top Pruning

- Place .74-ounce (21-g), slow-release fertilizer tablets (20-10-5) 3 to 4 inches (7.5 to 10 cm) below planted acorns or seedlings.
- Irrigation in many situations is not necessary if there is timely and thorough weed control.
- If irrigation is needed for establishment and the terrain is steep or percolation of water through soil is slow, construct earthen irrigation basins.
- Provide irrigation in the form of infrequent, deep irrigations rather than frequent, shallow irrigations; time irrigations to extend the rainy season.
- Always control competing vegetation, even in situations where supplemental irrigation is provided.
- Top-prune seedlings at the time of planting if they are too tall and are out of balance with root systems; prune small, liner stock back to a 6-inch (15-cm) top.

Irrigation Varies by Species. Light and Buchner (1999) found that optimum irrigation amounts varied for four oak species evaluated on California's North Coast. Providing water enhanced growth of each species, but there were levels of irrigation above which growth declined. Oregon white oak, for instance, performed best on a frequent irrigation schedule that caused blue oak growth to decline. At lower levels of irrigation, however, blue oak growth peaked, while the performance of Oregon white oak declined. They concluded that to thrive, all of the oak species evaluated (which also included California black oak and interior live oak) needed "appreciably more water than is available from rainfall alone."

Effects of Weed Control. It is important to remember that the need for irrigation is closely related to weed control. In almost all situations where there is little or no weed control, irrigated seedlings will still be under moisture stress. In fact, supplemental water can cause so much growth of competing plants that oak seedlings are adversely affected. Eliminating competing vegetation can lessen water stress and greatly reduce or even do away with the need for supplemental water. At the SFREC,

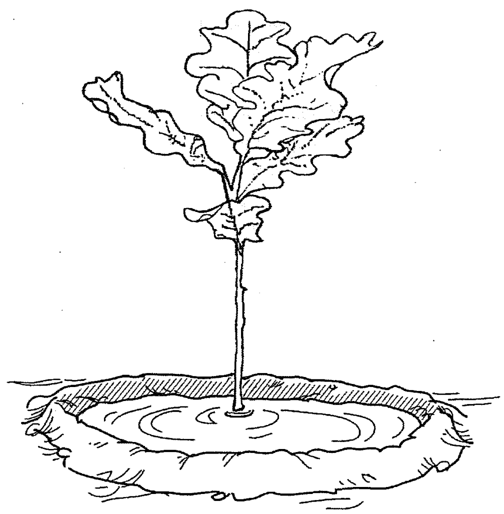

Figure 35. An earthen water basin can prevent rapid runoff of irrigation water.

which averages 28 inches (71 cm) of rainfall annually, we have concluded that supplemental irrigation is not necessary in our blue, valley, and interior live oak trials as long as we maintain areas around seedlings free of weeds for at least 2 years (preferably longer). Planting seedlings late in the season when soils are already becoming dry creates an exception. In this situation, we like to water-in seedlings to make sure that there is adequate initial moisture in the soil and air pockets are eliminated.

Earthen Basins. In many oak plantings that are irrigated, earthen basins are constructed around individual seedlings to form a reservoir that can hold several gallons of water (Bush and Thompson 1989). This is especially important in heavier soils where percolation can be slow and on slopes where irrigation water would run off too rapidly. With a basin, a large quantity of water can be added and then left to soak in gradually. Generally, these basins are 1 to 2 feet (30 to 61 cm) wide, with sides that are several inches tall (fig. 35). They need to be reasonably level, however, or water will drain out of them when they are filled. Basins have an added advantage of capturing greater quantities of rainfall, so even without irrigation, the soil moisture conditions in the rooting zone should be improved. Basins can be difficult and time consuming to construct, especially in hard, compacted, or rocky soil. This adds to the cost of planting and must be considered along with the benefits expected. In drier regions, and especially where plants will be irrigated occasionally, basin construction is probably a good investment. We generally do not use them at the SFREC since we have found that irrigation is not necessary, as long there is good weed control. At a planting in Walnut Creek, however, basins were essential because plantings were on steep slopes. Without basins, irrigation at this site would have been ineffective.

Potential Risks of Disease with Summer Irrigation

It is well recognized that summer irrigation around native California oaks can prove deadly, since diseases such as oak root fungus *(Armillaria mellea)* and crown rot *(Phytophthora cinnamomi)* proliferate where it is warm and wet, conditions which normally do not occur in the Mediterranean climate of the state (Raabe 1980). Irrigation around mature oak trees, which have evolved in conditions where summer rainfall is rare, should be avoided. Consult any arborist and you will hear horror stories of magnificent oak trees lost to disease after a homeowner put in a lawn beneath them and began watering. But, while there has not been much research on the summer irrigation of oak seedlings, it appears that small seedlings are less sensitive to diseases from warm and moist soils. Also, the benefits of summer irrigation can outweigh the risks for seedlings that are under substantial moisture stress. To reduce potential risks from watering, it is recommended that irrigation be deep and infrequent rather than often and shallow. If only several waterings are planned, it is better to time them to extend the normal rainy season into late spring rather than provide water in the middle of summer.

Superabsorbants

There are a variety of soil amendments on the market that claim to reduce moisture stress on plants. Many of these are superabsorbant hydrogels, polymers that absorb and retain several hundred times their own weight in water. Theoretically, they improve water relations by binding water when it is available and then slowly releasing it. These materials do not create any new water, but they can influence moisture availability over time. While the effectiveness of these materials is debated, it is hard to imagine a situation where they would be particularly useful for wildland oak plantings. First and foremost, it would be prohibitively expensive to mix these materials into the soil where the oaks are to be planted. A variation of these materials are containers similar to milk cartons that contain a polymer gel. These are placed in the ground next to planted seedlings. The material inside the 1-pint (.47-L) or 1-quart (.95-L) container is supposed to slowly release moisture to the target plant over a period of several months. We did a small field trial evaluating blue oaks with and without these containers and could find no benefit.

Shading Oak Seedlings

Blue oak has been characterized as highly intolerant of shade (Sudworth 1908), and it has been reported that blue oak saplings do not survive under dense shade (Swiecki and Bernhardt 1998). However, there is some evidence that providing artificial shade may improve field performance of planted blue oak in certain situations. Muick (1991) compared the response of directly-sown blue oak acorns in full sunlight and 50 percent shade and found that shade improved both emergence and survival. Artificial shade provided by placing commercially available "shadecards" on the south side of seedlings has been reported to improve Douglas fir survival in some situations (Helgerson 1990), and shade may offer some benefit for oaks on dry exposed sites, although the gains are likely to be small. We used black plastic shadecards in one study with blue oaks at the University of California Sierra Foothill Research and Extension Center but found that seedlings quickly grew above them. We could detect no improvement in survival or growth (McCreary 1989) from this treatment and have not used shadecards since.

Top Pruning Oak Seedlings

Studies outside of California have indicated that there are benefits from top pruning oak seedlings, both before and after lifting from bareroot nurseries (South 1996; Johnson 1984) or just after outplanting (Adams 1984). This is done to create plants of uniform size with more favorable shoot to root ratios. In California there has been no research on top pruning oaks in nurseries. At SFREC, we did a trial to test whether top pruning after field planting would be beneficial (McCreary and Tecklin 1993b). One-year-old blue oak seedlings in containers were top pruned at the time of field planting and compared with both large and small, unpruned controls. After two growing seasons, top pruned seedlings had significantly greater height and caliper increments than the other seedling types, suggesting that seedlings with large tops should be top pruned before or just after field planting to enhance performance.

Appendix A

Nurseries That Sell Oak Seedlings and Saplings

Below is a list of some of the wholesale and retail nurseries in California that produce native oaks in various sizes, ranging from seedlings in liners to specimen trees. The species of oaks grown at each nursery are not identified since this depends on several factors, such as acorn availability and demand, and can vary from year to year. Please contact the nursery for a current list of species and stock sizes available.

All Seasons Nursery
McKnew Enterprises
P. O. Box 2128
Elk Grove, CA 95759
916-689-0902
http://www.growtube.com

Arrowhead Growers
990 Rutherford Cross Road
P. O. Box 398
Rutherford, CA 94573
707-963-5800

Bitterroot Restoration Inc.
55 Sierra College Boulevard
Lincoln, CA 95648
916-434-9695

Blue Oak Nursery
2731 Mountain Oak Lane
Rescue, CA 95672
530-677-2111

Calaveras Nursery
1622 Highway 12
Valley Springs, CA 95252
209-772-1823

California Conservation Corps
Napa Satellite Center
P. O. Box 7199
Napa, CA 94558
707-253-7783

California Department of Forestry and Fire Protection
L. A. Moran Reforestation Center
P. O. Box 1590
Davis, CA 95617
530-753-2441

California Flora Nursery
2990 Somers Street
P. O. Box 3
Fulton, CA 95439
707-528-8813

Circuit Rider Productions, Inc.
Native Plant Nursery
9619 Old Redwood Highway
Windsor, CA 95492
707-838-6641

Cornflower Farms
P. O. Box 896
Elk Grove, CA 95759
916-689-1015

Drought Resistant Nursery
850 Park Avenue
Monterey, CA 93940
831-375-2120

Elkhorn Native Plant Nursery
P. O. Box 270
Moss Landing, CA 95039
831-763-1207

Freshwater Farms
5851 Myrtle Avenue
Eureka, CA 95503
800-200-8969

J. M. Oak Tree Nursery
430 La Lata Place
Buellton, CA 93427
805-688-5563 *(by appointment only)*

King Island Wholesale Nursery
8458 West Eight Mile Road
Stockton, CA 95219
209-957-6212

Las Pilitas Nursery
3232 Las Pilitas Road
Santa Margarita, CA 93453
805-438-5992
http://www.laspilitas.com

Matsuda Nursery
8501 Jackson Road
Sacramento, CA 95826
916-381-1625

Native Oak Nursery
45 Webb Road
Watsonville, CA 95076
831-728-8662

Native Revival Nursery
8022 Soquel Drive
Aptos, CA 95003
831-684-1811

Native Sons Wholesale Nursery
379 West El Campo Road
Arroyo Grande, CA 93420
805-481-5996

North Coast Native Nursery
P. O. Box 744
Petaluma, CA 94953
707-769-1213

Specialty Oaks Inc.
12552 Highway 29
Lower Lake, CA 95457
707-995-2275
http://www.specialtyoaks.com

Tree of Life Wholesale Nursery
P. O. Box 736
San Juan Capistrano, CA 92693
949-728-0685

Village Nurseries
1589 North Main Street
Orange, CA 92867
800-542-0209

Yerba Buena Nursery
19500 Skyline Boulevard
Woodside, CA 94062
650-851-1668

Appendix B

Sources of Materials for Oak Regeneration Projects

TREESHELTERS AND
SEEDLING PROTECTION TUBES

All Seasons Nursery
McKnew Enterprises
P. O. Box 2128
Elk Grove, CA 95759
916-689-0902
http://www.growtube.com

Treegard—Albert F. Kubiske
3825 Highridge Road
Madison, WI 53704
608-837-9093

Terra Tech
International Reforestation Suppliers
2635 West 7th Place
Eugene, OR 97402
800-321-1037
503-345-0597

American Forestry Technology, Inc.
100 North 500 West
West Lafayette, IN 47906
765-583-3311

Tree Pro
3180 West 250 North
West Lafayette, IN 47906
800-875-8071
http://www.treepro.com

Tree Sentry Treeshelters
P. O. Box 607
Perrysburg, OH 43552
419-874-6950

Treessentials Company
2371 Waters Drive
Mendota Heights, MN 55120-1163
800-248-8239

ROOT GUARD

Digger's Product Development, Inc.
P. O. Box 1551
Soquel, CA 95073-2531
831-462-6095

CONTAINERS

Stuewe & Sons, Inc.
2290 Southeast Kiger Island Drive
Corvallis, OR 97333
800-553-5331
http://www.stuewe.com

Monarch Manufacturing
13154 County Road 140
Salida, CO 81201
800-284-0390
http://www.monarchmfg.com

Spencer-Lemaire Industries Limited
11406—119th Street
Edmonton, Alberta
Canada T5G 2X6
800-668-8530

SHADECARDS

Terra Tech
International Reforestation Suppliers
2635 West 7th Place
Eugene, OR 97402
800-321-1037
503-345-0597

MULCH MATS

Treessentials Company
2371 Waters Drive
Mendota Heights, MN 55120-1163
800-248-8239

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Attachment #2

Modeling the Effectiveness of Tree Planting to Mitigate Habitat Loss in Blue Oak Woodlands[1]

Richard B. Standiford,[2] Douglas McCreary,[3] and William Frost[4]

Abstract

Many local conservation policies have attempted to mitigate the loss of oak woodland habitat resulting from conversion to urban or intensive agricultural land uses through tree planting. This paper models the development of blue oak (*Quercus douglasii*) stand structure attributes over 50 years after planting. The model uses a single tree, distance independent growth model, calibrated to data derived from a blue oak plantation. The results vary based on initial planting density and plantation management intensity. Data on crown cover, basal area, and average tree diameter and height are presented. For the range of modeled conditions, canopy cover after 50 years is projected to range from 7 to 33 percent, with an average DBH after 50 years ranging from 3.4 to 4.1 inches (8.6 to 10.4 cm). The cost of these tree replacement strategies is evaluated, and the effectiveness of tree planting as a mitigation tool, especially as it relates to the creation of wildlife habitat, is discussed.

Introduction

California has one of the most rapidly growing human populations in the world. The state's population has grown from less than 100,000 people in 1850, to over 31 million people today (an average annual rate of growth of 3.4 percent) to a projected 63 million people in the next 50 years (Medvitz and Sokolow 1995). This population growth is having an impact on oak woodlands. Although California's oak woodlands cover 7.4 percent of the state (Bolsinger 1988), and are the most biologically diverse broad habitat in the state (Pavlik and others 1991), they are also one of the most rapidly urbanizing areas in California (Duane 1999). A survey of oak woodland owners showed that the majority of all owners now live less than 5 miles (8 km) from a subdivision (Huntsinger and Fortmann 1990, Huntsinger and others 1997). This also showed that approximately one-third of the properties changed owners between 1985 and 1992, and 5 percent were subdivided for residential development.

Over the past 40 years, California's oak woodlands have decreased by over one million acres (405,000 ha) on a statewide scale (Bolsinger 1988) due to human-induced factors. Major losses from 1945 through 1973 were from rangeland clearing for forage production enhancement. Major losses since 1973 were from conversions to residential and industrial developments. Regionally, some oak woodlands have

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[1] An abbreviated version of this paper was presented at the Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape, October 22-25, 2001, San Diego, California.

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decreased from urban expansion (Doak 1989), firewood harvesting (Standiford and others 1996), range improvement (Bolsinger 1988), and conversion to intensive agriculture (Brooks and others 1999). Habitat fragmentation, increased conflicts between people with different value systems, predator problems, and soil and water erosion, have resulted. Blue oak woodlands (*Quercus douglasii* Hook. and Arn.), covering 23 percent of the state's woodlands (Bolsinger 1988), are one of the areas with the largest concerns about conversion.

Concerns about conserving the environmental values of oak woodland resources in the face of conversions to other land uses from rapid urbanization and changing agricultural markets, has led planners to develop strategies to mitigate these effects. Tree planting technologies for blue oak have improved tremendously in the past 15 years, and widespread success from planting is possible (McCreary 1990, McCreary 1995b, McCreary and Lippit 1996, McCreary and Tecklin 1993). Tree planting is often proposed as part of mitigation strategies to replace habitat losses (Giusti and Tinnin 1993, Bernhardt and Swiecki 1991, Fulton 1999). Many mitigation plans regularly call for tree planting on a replacement basis (1:1 to as high as 20:1) for trees lost. However, since there is little experience with growth rates of planted native oaks beyond 10 to 15 years, there has not been an opportunity to assess how oak woodland habitats will develop over time from areas planted, and whether this mitigation approach on overall habitat quality is effective.

The purpose of this study was to evaluate blue oak tree planting as a mitigation strategy for habitat loss. The results should help assess the long-term impacts of tree planting on oak woodland habitat development.

There have been a number of studies evaluating growth of blue oak seedlings, and reporting on height, diameter, and canopy development with various management strategies (McCreary 1990, 1995a, 1995b; McCreary and Lippit 1996; McCreary and Tecklin 1993). There is no information on stand structure development extending beyond 10 to 15 years. There have been several long term whole stand growth models of blue oak woodlands developed by Pillsbury and DeLasaux (1985), and Standiford and Howitt (1988, 1993). However, these do not provide detailed information on stand structure development, but only general volume and basal area growth. A single tree, distance independent growth model has been developed for blue oak natural stands (Standiford 1997) which offers some promise for a more detailed assessment of stand development.

Methods

This study utilized a modeling approach to evaluate blue oak plantation development. *Figure 1* depicts the model used to predict the attributes of a planted stand over time. The individual tree size data (height, diameter, crown spread) 10 years after planting provided the input variables for the model. Individual tree basal area growth was modeled as a function of tree size, competition of each tree with adjacent trees, and site quality (Standiford 1997). Individual tree height growth and canopy development were correlated with basal area increment. The summation of the individual trees provided the stand totals for the first 10 years (basal area per acre, average DBH, average height, crown cover percent). The tree list and stand attributes were updated for every 10-year interval by a growth model that was based on actual blue oak stand age and structure data (Standiford 1997). Woodland productivity was assessed with a height-diameter site index relationship developed for blue oak sites

(Standiford and Howitt 1988). This was derived to give an index number for the height of a dominant tree in a stand when it averages 10 inches (25 cm) diameter at breast height (DBH). A site index of 50 feet (15 m) was assumed for the models presented below, which means that when the dominant trees average 10 inches (25 cm) DBH, they will average 50 feet (15 m) in height.

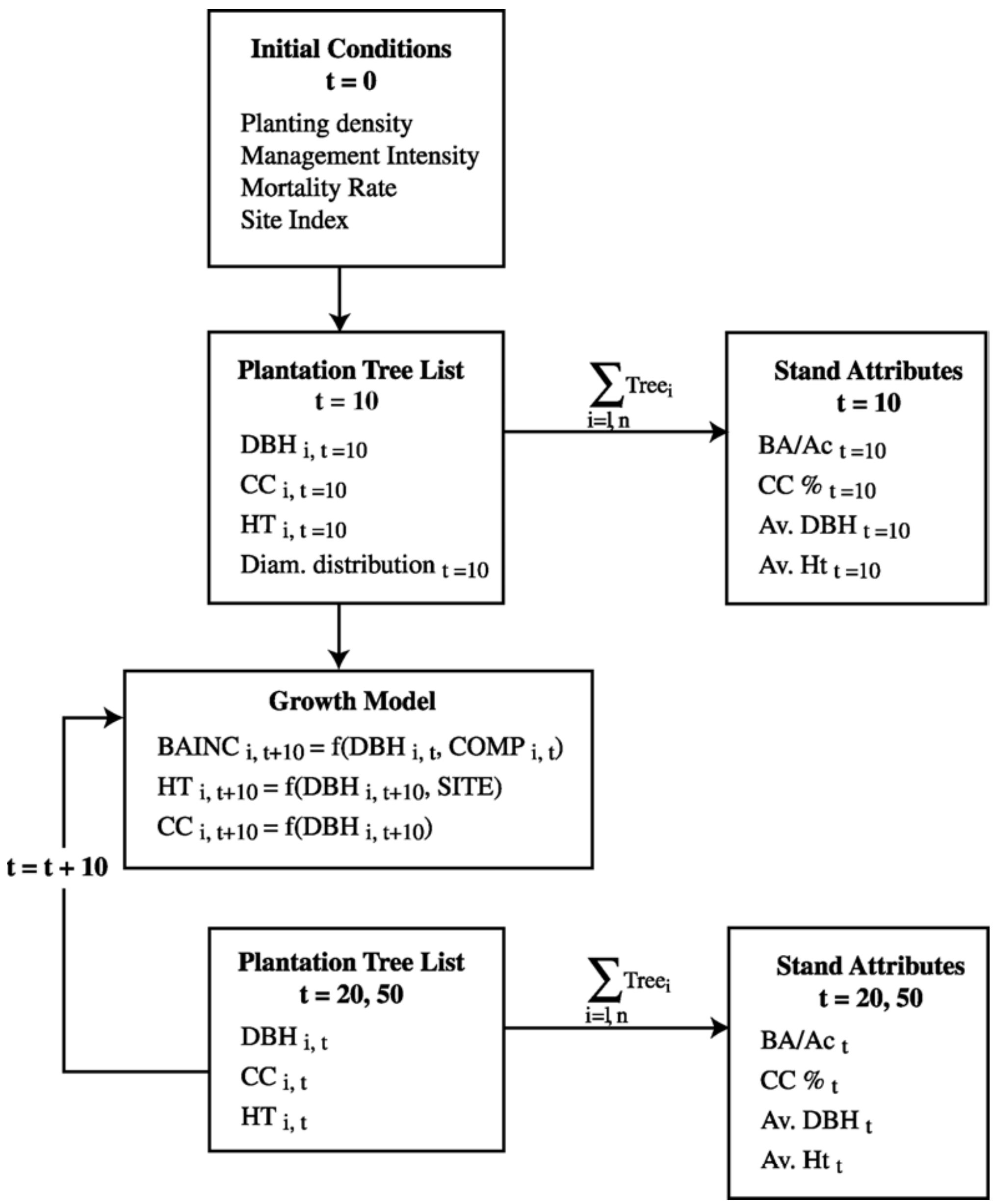

Figure 1—Modeling schematic to evaluate individual tree growth and stand characteristics of planted blue oaks over time. Where: $DBH_{i,t}$ is diameter at breast ht. (4.5 ft) of tree i at time t, $CC_{i,t}$ is canopy cover in sq. ft. of tree i at time t, $HT_{i,t}$ = total height of tree i at time t; $BAINC_{i,t+10}$ is basal area increment model for tree i for ten year period after time t, $COMP_{i,t}$ = competition index (Standiford 1997) for tree i at time t, BA/Ac_t = stand basal area in square feet per acre at time t.

Data was collected from 55 sample blue oak trees in a ten-year old blue oak plantation at the Sierra Foothill Research and Extension Center (SFREC) in Yuba County, California, approximately 40 miles (64 km) northeast of Sacramento. The correlation between individual tree basal area and height and crown surface area was evaluated.

Based on the yield table of modeled stand attributes, a general assessment of wildlife habitat relationships was made using the Version 7.0 California Wildlife Habitat Relationships (CWHR) model (Giles and others 1999). The modeled stand is referred to as a "mitigated stand" since it represents tree planting designed to mitigate expected environmental impacts from tree removal in a particular project. The CWHR habitat types were evaluated based on the attributes of the mitigated stand, and applying the classification rules for CWHR (Mayer and Laudenslayer 1988). The list of vertebrate species generated by CWHR for the mitigated stand at different time periods was compared to a natural mature blue oak stand. These differences in vertebrate species were evaluated to see how the mitigated stand compared to the habitat lost in the mature stand.

Results

A regression equation was developed to predict the height and crown canopy area of the individual trees on the basis of the basal area of the individual tree at breast height (derived from DBH). This relationship helped to assess height and crown changes of the planted trees over time, for which there were no existing growth models. Equations 1 and 2 show the results of the regression of blue oak plantation tree height and crown surface area with individual tree basal area. A logarithmic form was utilized to represent the curvilinear shape of the relationship.

$$\ln(HT_i) = 3.164 + 0.213 \times \ln(BA_i) \quad (1)$$

(**) (**) R2 = .67

$$\ln(CC_i) = 5.018 + 0.427 \times \ln(BA_i) \quad (2)$$

(**) (**) R2 = .60

where: CC_i is canopy cover of tree i in square feet per tree, HT_i is total height of tree i in feet, BA_i is basal area of tree i at breast height (4.5 feet) in square feet per tree, ln is natural logarithm, and ** is significant at 0.01 level

These equations were applied to individual tree basal area, and basal area after growth projections, to develop tree height and crown cover for each tree. The initial tree list was based on diameter distribution data for a plantation that was monitored for 10 years after planting. Two different management regimes were assumed. A high management intensity scenario assumed that complete weed control was maintained for a 3-year period, and that best management strategies for planting seedlings were followed (McCreary 1995a). The assumption is that these stands would average 2 inches (5 cm) DBH after 10 years, and there would be a 90 percent seedling survival. The moderate management scenario assumed that weed control was for the first year only, resulting in stands averaging 1.5 inches (3.8 cm) DBH, with an 85 percent seedling survival. These assumptions are based on actual plantation growth

(McCreary 1990, 1995a, 1995b; McCreary and Lippit 1996; McCreary and Tecklin 1993) and observations of operational restoration projects.

Table 1 shows the results of the simulation of the blue oak mitigation planting. Initial planting densities were evaluated from 100 to 400 trees per acre (247 to 988 trees per hectare) for both the high and moderate management intensities. These results show that for both the high and moderate intensity category, planting only 100 trees per acre (247 trees per hectare) does not result in a stand with over 10 percent canopy cover after 50 years. Mature blue oak stands may only have 40 to 50 trees per acre (99 to 124 trees per hectare) (Bolsinger 1988), so planting 100 trees per acre (247 trees per hectare) would represent a 2:1 replacement strategy. After 50 years, these planted stands would still be classed as annual grasslands by the CWHR classification system since tree canopy cover is less than 10 percent.

Table 1 also shows the CWHR habitat seral stages for the mitigated stand over the 50-year simulation period. The two habitat stages projected to occur in the planted stands 50 years from establishment (Blue oak 2S and Blue oak 2P) were evaluated with the CWHR model. Since the purpose of the modeling was to evaluate the impacts on wildlife species associated with the hardwood tree component of blue oak woodlands, the list of species was reduced by eliminating species primarily associated with aquatic or conifer habitats, and species with an average habitat quality less than "medium." The area chosen for study was the central Sierra Nevada foothills. The results of the vertebrate wildlife projected to occur in these stands showed that 73 species would have medium or high quality habitat values in the two habitat stages projected to exist in planted stands in 50 years (1 amphibian, 40 bird, 19 mammal, and 13 reptile species).

The mitigated stand species list was compared to a natural blue oak stand, averaging 10 inches (25 cm) DBH, with a 30 percent canopy cover (Blue Oak 3P seral stage). The natural stand is assumed to have small and medium size downed wood, snags, acorns and trees with cavities. A natural stand with this habitat condition is projected to have 102 vertebrate wildlife species with medium or good habitat. The impacts were compared by evaluating the percent change in habitat quality between the natural and mitigated stand, using equation 3 below:

$$\left(\frac{H_{nat} - H_{mit}}{H_{nat}}\right) \times 100 = \text{Percent change} \qquad (3)$$

where: H_{nat} is habitat quality for natural stand, H_{mit} is habitat quality for mitigated/planted stand.

Garrison (1994) points out the difficulties in determining the biological significance of CWHR predictions. Garrison and Standiford (1997) address the tenuous nature of these predictions by utilizing a 50 percent change as the significant impact threshold. This is considered a relatively conservative threshold, representing an average habitat suitability change of at least one rating class.

Table 1—*Modeled blue oak stand characteristics after planting*

Planting density	Management intensity[1]	Age yrs.	Crown cover pct.	Basal area sq. ft/ac (sq. m/ha)	Av. diam. breast ht. in. (cm)	Av. height ft. (m)	CWHR seral stage[2]
100 trees per acre (247 trees per hectare)	High	10	6	2.0 (0.5)	2.0 (5.1)	11 (3.4)	AG 1D
		20	7	3.0 (0.7)	2.6 (6.6)	14 (4.3)	AG 1D
		30	7	4.2 (1.0)	3.1 (7.9)	15 (4.6)	AG 1D
		40	8	5.4 (1.2)	3.6 (9.1)	18 (5.5)	AG 1M
		50	9	6.7 (1.5)	4.1 (10.4)	21 (6.4)	AG 1M
	Moderate	10	4	1.1 (0.3)	1.5 (3.8)	10 (3.0)	AG 1D
		20	5	1.9 (0.4)	2.1 (5.3)	12 (3.7)	AG 1D
		30	6	2.8 (0.6)	2.6 (6.6)	14 (4.3)	AG 1D
		40	7	3.8 (0.9)	3.1 (7.9)	15 (4.6)	AG 1D
		50	7	4.9 (1.1)	3.6 (9.1)	18 (5.5)	AG 1D
200 trees per acre (494 trees per hectare)	High	10	12	4.1 (0.9)	2.0 (5.1)	11 (3.4)	BO 2S
		20	13	6.0 (1.3)	2.5 (6.4)	14 (4.3)	BO 2S
		30	15	8.1 (1.9)	3.0 (7.6)	15 (4.6)	BO 2S
		40	16	10.4 (2.4)	3.5 (8.9)	18 (5.5)	BO 2S
		50	17	12.8 (2.9)	4.0 (10.2)	20 (6.1)	BO 2S
	Moderate	10	9	2.2 (0.5)	1.5 (3.8)	10 (3.0)	AG 1M
		20	11	3.6 (0.8)	2.0 (5.1)	12 (3.7)	BO 2S
		30	12	5.3 (1.2)	2.5 (6.4)	13 (4.0)	BO 2S
		40	13	7.3 (1.7)	3.0 (7.6)	15 (4.6)	BO 2S
		50	14	9.3 (2.1)	3.5 (8.9)	17 (5.2)	BO 2S
300 trees per acre (741 trees per hectare)	High	10	18	6.1 (1.4)	2.0 (5.1)	11 (3.4)	BO 2S
		20	20	8.9 (2.0)	2.5 (6.4)	14 (4.3)	BO 2S
		30	22	11.9 (2.7)	3.0 (7.6)	15 (4.6)	BO 2S
		40	24	15.3 (3.5)	3.5 (8.9)	17 (5.2)	BO 2S
		50	25	18.8 (4.3)	3.9 (9.9)	20 (6.1)	BO 2P
	Moderate	10	13	3.3 (0.8)	1.5 (3.8)	10 (3.0)	BO 2S
		20	16	5.4 (1.2)	2.0 (5.1)	12 (3.7)	BO 2S
		30	18	7.9 (1.8)	2.5 (6.4)	13 (4.0)	BO 2S
		40	20	10.6 (2.4)	3.0 (7.6)	14 (4.3)	BO 2S
		50	21	13.6 (3.1)	3.5 (8.9)	17 (5.2)	BO 2S
400 trees per acre (988 trees per hectare)	High	10	24	8.2 (1.9)	2.0 (5.1)	11 (3.4)	BO 2S
		20	27	11.8 (2.7)	2.5 (6.4)	14 (4.3)	BO 2P
		30	29	15.8 (3.1)	3.0 (7.6)	15 (4.6)	BO 2P
		40	31	20.1 (4.6)	3.4 (8.6)	17 (5.2)	BO 2P
		50	33	24.6 (5.1)	3.9 (9.9)	20 (6.1)	BO 2P
	Moderate	10	18	4.3 (1.0)	1.5 (3.8)	10 (3.0)	BO 2S
		20	21	7.1 (1.6)	2.0 (5.1)	12 (3.7)	BO 2S
		30	24	10.3 (2.4)	2.5 (6.4)	13 (4.0)	BO 2S
		40	26	13.9 (3.2)	3.0 (7.6)	14 (4.3)	BO 2P
		50	28	17.8 (4.1)	3.4 (8.6)	17 (5.2)	BO 2P

[1] Management Intensity Assumptions—10 years after Planting—High–average 2 inches (5 cm) DBH with 90 percent survival; Moderate–1.5 inches (3.8 cm) DBH with 85 percent survival.

[2] CWHR Seral Stages—AG 1D is annual grassland, grass height less than 12 inches (0.3 m), over 60 pct. cover; AG 1M is annual grassland, grass height less than 12 inches (0.3 m), 40 to 59 pct. cover; BO 2S is blue oak woodland, 1-6 in. (2.5 to 15.2 cm) DBH, 10-24 pct. cover; BO 2P is blue oak woodland, 1-6 in. (2.5 to 15.2 cm) DBH, 25-39 pct. cover.

The mature blue oak (3P) was compared to planted blue oak stands (2P and 2S). The mitigation resulted in 17 species that showed significant decreases in habitat compared to the natural stand. For the 2S seral stage (projected to occur with planting densities of 200 trees per acre), 18 species had a significant increase in habitat quality after the mitigation. There were 10 species with a significant increase in habitat quality for the 2P seral stage (projected to occur with planting of 300 to 400 trees per acre [740 to 988 trees per hectare]). Seventy-five species had no significant change in quality for the 2S stage, and 67 had no change for the 2P stage.

The species that were projected to have significant decreases in habitat suitability were acorn and cavity dependent species such as various woodpecker species, the western bluebird, and the western gray squirrel. Species with significant increases in habitat suitability were wildlife that prefer meadows and open stand types, including the California pocket mouse, the California vole, the horned lark, and the Western meadowlark.

Discussion

This approach provides planners, developers and the restoration community with a tool to evaluate how important characteristics of the stand will develop over time. The projected structure of planted blue oak stands over a 50 year period from this study can be compared directly to actual stand data for areas that will possibly be lost in a conversion project that will need mitigation.

The general results of this study raise questions as to whether the structure of planted stands adequately mitigate the loss of mature stands. As these results show, average tree size after 50 years under fairly aggressive restoration efforts, is still quite small. The largest mean diameter of the stand is only 3.9 inches (9.9 cm), with a canopy cover of 33 percent.

Using CWHR as a tool to evaluate the wildlife habitat quality of the planted stand showed that in general, the overall biodiversity figures are not greatly affected from the mature stand chosen for comparison in this paper. However, the species composition shifts from wildlife species that utilize cavities, acorns, and downed wood, to species that utilize open meadows and grasslands.

Another factor to be considered is the cost of tree planting as a mitigation strategy. Although planting technology has advanced tremendously, restoration costs may range from $210 (moderate intensity) to $280 (high intensity) per acre for 100 trees per acre ($519 to $692 per hectare for 247 trees per hectare), up to $470 (moderate intensity) to $765 (high intensity) per acre for 400 trees per acre ($1161 to $1890 per hectare for 988 trees per hectare) (Standiford and Appleton 1993). These costs were updated to 2001 dollars using the producer price index. In some cases, it may be more cost effective to utilize the mitigation funds to ensure that existing mature habitat is conserved, through the purchase of conservation easements, the set aside of large blocks of commonly-owned land and density credits, or the establishment of public open space.

Conclusion

The results suggest that it is important to evaluate if tree planting is a viable method of mitigation. It appears to be a very costly, long-term effort, to restore an area. Many important habitat elements, such as cavities, acorns, snags, and woody debris may not be mitigated - at least in the 50-year interval evaluated in this study - through a tree planting strategy alone. Although procedures for discounting habitat decreases for woodland species and habitat increases for meadow species are not established, the results can be used as part of discussions about appropriate mitigation strategies.

These results rely on modeling extrapolated from relatively young tree plantations and natural stand growing conditions. It will be important to consider if the long-term growth of planted stands follows these preliminary projections. Actual height and crown growth models are needed, rather than relying on the correlation with basal area growth. Continued evaluation of planted stands is required to develop these improved models. It is also important to conduct on-site wildlife evaluations to determine the reliability of CWHR projections.

Although the results of this work point out that blue oak plantations develop habitat conditions slowly, and it may take in excess of 50 years to replace mature habitat that is lost in a particular project, tree planting is still an important conservation tool. The great strides that have been made in oak planting on hardwood rangelands should still be encouraged as part of an overall restoration strategy. Effective mitigation, however, may well require a more diverse array of tools to address the impacts of various woodland conversion projects.

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Attachment #3

Quercus kelloggii Newb.

California Black Oak

Fagaceae -- Beech family

Philip M. McDonald

California black oak *(Quercus kelloggii.)* exceeds all other California oaks in volume, distribution, and altitudinal range. Yet this deciduous hardwood has had little sustained commercial use and almost no management, even though its wood closely resembles that of its valuable, managed, and heavily used counterpart-northern red oak *(Quercus rubra)*-in the Eastern United States.

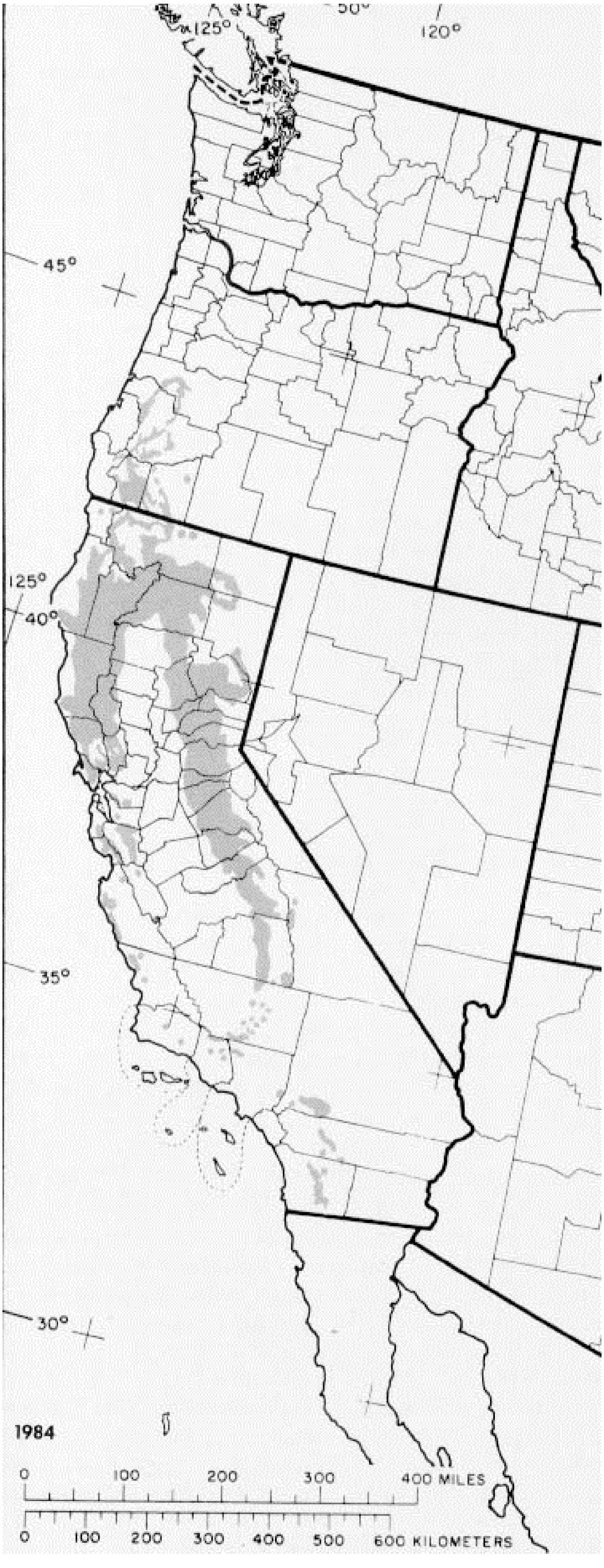
First collected in 1846 near Sonoma, CA, the species was not named until. 1857 when John Newberry called it *kelloggii* in honor of Albert Kellogg, a pioneer California botanist and physician (17). In later botanical works, the species was called Q. californica and black oak or Kellogg's oak.

Acorns of California black oak were carried from San Francisco to England in 1878. Thirty-two years later, trees from these acorns were described as being 30 feet tall and making good growth (10).

Habitat

Native Range

The north-south range of California black oak is about 1255 kin (780 mi). In Oregon, its natural range extends from just north of Eugene, southward through the valleys west of the Cascade Range. The species is especially frequent along lower slopes in fairly dry sections of the Klamath and Cascade Mountains but never grows near the Pacific Ocean. In California, black oak is found in the northern Coast Range from the Oregon State line to Marin County and then intermittently in the Santa Cruz and Santa Lucia Mountains. This oak becomes more common on the San Bernardino, San Jacinto, and Agua Tibia Mountains, extending to just south of Mt. Laguna, and is now recognized as being in Baja California (5). In California's Sierra Nevada, the species grows abundantly along the west side, from near Lassen Peak to near. Kings Canyon. California black oak becomes intermittent southward to the Tehachapi Mountains, where it again increases in abundance. California black oak is generally confined to the westside, but a few stands have been found along the eastside of the Sierra Nevada. The species approaches the Nevada State line northeast of Beckwourth Pass but is not reported in Nevada.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-*The native range of California black oak.*

Climate

Hot dry summers and cool. moist winters characterize the climate where California black oak grows. Within the species' natural range, average annual precipitation varies widely. In the valleys of southwestern Oregon, it exceeds 760 mm (30 in); in northwestern California, it ranges from 760 to 2540 mm (30 to 100 in); and in northeastern California, only 300 to 380 mm (12 to 15 in) of rainfall annually. Throughout the range of black oak in north-central and central California, annual precipitation averages 1010 to 1780 mm (40 to 70 in) but may exceed 2920 mm (115 in) locally. In these areas less than 4 percent of the yearly precipitation falls from. June through September. In the mountains of southern California, precipitation averages 910 mm (36 in). Black oak achieves its best size and abundance in areas where snowfall accounts for 10 to 50 percent of the year's precipitation.

Average mean daily temperatures range from -1° to 8° C (31° to 46° F) during January, and from 19° to 28° C (66° to 82° F) in July. The last killing spring frost is expected between March 15 and June 9, and the first killing frost in the fall between August 30 and November 30. Periods free of killing frosts range from 82 to 270 days. Throughout an 18-year period, the highest temperature recorded at 1125 m (3,700 ft) elevation in the center of black oak's zone of greatest size and abundance was 39° C (103° F); the minimum temperature was -15° C (5° F). The maximum number of frost-free days was 215 and the minimum was 116 (35).

Soils and Topography

Probably the most important single soil variable that limits the presence of California black oak is internal drainage. Black oak is not found growing "with its feet wet." The species is adapted to soils derived from diverse parent materials-andesite, basalt, granite, pumice, quartz diorite, sandstone, schist, shale, and volcanic tuffs and breccias. California black oak only rarely is found on soils originating from serpentine. Occasionally it grows on soils derived from ultrabasic parent material, but mostly where above-average amounts of calcium seem to offset the deleterious effects of magnesium.

Soil textures favoring this oak range from medium-textured loams and clay-loams to the more coarse-textured gravelly-clay-loams and sandy-loams. Increasing clay content in the surface soil usually means a decreasing incidence of black oak. In fact, this species rarely is found on soils with clay topsoils, particularly if the clay is heavy and sticky. Black oak usually grows on thin soils and rocky slopes, but always at the cost of abundance or form, or both. In general, black oak grows best on medium- to coarse-textured, deep, and well-drained soils.

About 75 soil series in California have been identified by the California Cooperative Soil-Vegetation Survey and the National Cooperative Soil Survey as supporting California black oak. Important soil series in the California Coast Range include Boomer, Cohasset, Josephine, Sites, and Sheridan. In the Sierra Nevada, Aiken, Chawanakee, Holland, Stump Springs, Corbett, and Tish Tang support abundant black oak. Soils in the southern Cascade and Klamath Mountains that often are clothed with black oak include Aiken, Cohasset, McCarthy, Sites, Tournquist, Behemotosh, Horseshoe, and Neuns. Fourteen soil series have been identified in Oregon, mostly on series similar to those in California. Most of the soils in both States are found at higher elevations and support forest vegetation rather than oak woodland or chaparral. Soil orders are mostly Alfisols and Inceptisols, occasionally Mollisols.

The best black oak stands in the Coast Range and Klamath Mountains are found on deep, slightly acid loams and gravelly-clay-loams derived from sandstone and shale. In the southern Cascade Range and northern Sierra Nevada, black oak grows best on deep loams and clay-loams originating from metavolcanic rocks. In the central and southern Sierra Nevada and in the Transverse and Peninsular Ranges, this oak grows well on deep, acid to moderately acid sandy-loam soils derived from granitic rock.

California black oak grows within a wide elevational range-from the level gravelly floors of low valleys to alluvial slopes, rocky ridges, and high plateaus. Most of the terrain is rugged, steep, and dissected by major streams and ephemeral drainages.

In Oregon, the elevational range of black oak varies from 137 in (450 ft) near Eugene, to more than 305 m (1,000 ft) on the low rounded hills in the Umpqua River drainage (13). The oak also is found within this elevational range on the eastern slopes of the Coast Range and the western slopes of the Cascades. In south central Oregon and the Klamath Mountains, black oak grows at higher elevations of 610 to 915 m (2,000 to 3,000 ft).

In California's Coast Range, black oak is found from about 152 in (500 ft) along the Mattole River in Humboldt County to 1830 in (6,000 ft) in the Yolla Bolly Mountains. Black oak reaches its lowest elevation (60 m or 200 ft) in the Napa and Santa Rosa Valleys. Most black oak in the central portion of the Coast Range grows between 305 to 1525 m (1,000 to 5,000 ft), gradually increasing in elevation but narrowing in range to 1220 to 1982 m (4,000 to 6,500 ft) in Santa Barbara and eastern Ventura Counties. Farther south in the Transverse Range the species is found at elevations of 1403 to 2135 m (4,600 to 7,000 ft) (39). In the San Jacinto Mountains, black oak reaches 2440 in (8,000 ft) and, at its southernmost extension in the Peninsular Range of San Diego County, it grows within the 1525- to 1830-m (5,000 to 6,000-ft) elevation.

The elevational range of black oak in California's Cascade Range is from about 183 m (600 ft) in western Shasta County to 1906 in (6,250 ft) in southcentral Shasta County. In the Sierra Nevada, lower elevational limits for black oak range from 458 in (1,500 ft) in the north to 1220 in (4,000 ft) in the south. Upper limits increase north to south from about 1982 to 2380 m (6,500 to 7,800 ft).

California black oak is most abundant and attains its largest size in the Sierra Nevada. Extensive stands of excellent development also are found in eastern Mendocino and Humboldt Counties of the north Coast Range. Elevation and aspect often interact to govern abundance and development. At elevations below 305 in (1,000 ft) in north-central California, black oak is found primarily in sheltered draws or on north slopes. With increasing elevation, favorable aspects increase until at 762 to 915 m (2,500 to 3,000 ft) all aspects support California black oak, providing soil is deep enough. Above 1067 in (3,500 ft), north- and east-facing slopes often are devoid of black oak, although other vegetation grows well. In the southernmost mountains, black oak is found on west-facing slopes, but only where soils are deep, temperatures are cool, and soil moisture is adequate.

Associated Forest Cover

California black oak is a component of six forest cover types (11). It is the prime constituent of California Black Oak (Society of American Foresters Type 246) and a major component in two others: Douglas-Fir-Tanoak-Pacific Madrone (Type 234) and Pacific Ponderosa Pine-Douglas-Fir (Type 244). Black oak becomes important in Sierra Nevada Mixed Conifer (Type 243) and Pacific Ponderosa Pine (Type 245) after severe disturbance or fire. The oak is a minor component in Canyon Live Oak (Type 249).

The successional status of California black oak is not clear. It has been implied that the species was climax because the type in which it was a part represented a degree of mesophytism between that of the chaparral and the conifer forest (7). The species was also thought to be more a persistent subclimax than climax.

California black oak, or its fossilized equivalent *(Quercus pseudolyrata),* was much more widespread in past ages than now. Fossil remains indicate that the species was abundant in sedimentary deposits near Spokane and Ellensburg, WA, in the John Day Valley and Blue Mountains of Oregon, and in northwestern Nevada (6). These deposits date back to the Miocene epoch of 12 to 26 million years ago. Increasing aridity is the probable cause for the smaller natural range of black oak today.

The most common botanical associate of black oak is ponderosa pine *(Pinus ponderosa* var. *ponderosa).* The two species intermingle over vast acreages, except that black oak is found at lower elevations, on sites too poor to support pine, and in certain areas within the redwood region of California where pine does not grow. Another exception is that this oak is rarely found in Interior Ponderosa Pine (Type 237) (11). In California and Oregon, therefore, where the natural ranges of the two species coincide, ponderosa pine sites generally are fertile ground for black oak. And black oak sites are almost always fertile ground for ponderosa pine.

At lower elevations, black oak often serves as a nurse tree to conifers. Ponderosa pine, Douglas-fir *(Pseudotsuga menziesii),* and incense-cedar *(Libocedrus decurrens)* seedlings often become established beneath the sheltering crowns of large black oaks while adjacent ground remains bare (2).

A rule-of-thumb is that black oak never grows through a stand of ponderosa pine but can grow through brush (9). Without disturbance, black oak is eventually crowded out of the best sites and remains only as scattered remnants in mixed-conifer forests. Here it often exists on "islands" of soil or terrain not favorable for natural regeneration of conifers.

Black oak grows individually or in groves, some of which are quite extensive. Usually each grove is of one age-class, the result of sprouting after fire (34). Rarely does it exist as an understory, especially beneath a closed canopy. The species is usually a component of hardwood stands or of mixed hardwood and conifer forests. Tanoak *(Lithocarpus densiflorus)* and Pacific madrone *(Arbutus menziesii)* are the most common hardwood associates of black oak. Other hardwood associates at lower elevations are Oregon white oak *(Quercus garryana),* interior live oak *(Q. wislizenii),* coast live oak *(Q. agrifolia),* Engelmann oak *(Q. engelmannii),* and blue oak *(Q. douglasii).* At higher elevations Pacific dogwood *(Cornus nuttallii),* bigleaf maple *(Acer macrophyllum),* California-laurel *(Umbellularia californica),* and canyon live oak *(Quercus chrysolepis)* intermix with California black oak.

Besides ponderosa pine, conifer associates at low elevations are knobcone pine *(Pinus attenuata),* Monterey pine (P. *radiata),* Digger pine *(P. sabiniana),* and redwood *(Sequoia sempervirens).* At intermediate elevations within the natural range of California black oak are California white fir *(Abies concolor* var. *lowiana),* grand fir *(A. grandis),* incense-cedar, Coulter pine *(Pinus coulteri),* sugar pine *(P. lambertiana),* giant sequoia *(Sequoiadendron giganteum),* Douglas-fir, California torreya *(Torreya californica),* and bigcone Douglas-fir *(Pseudotsuga macrocarpa).* At higher elevations black oak intermingles with western juniper *(Juniperus occidentalis)* and Jeffrey pine *(Pinus jeffreyi).*

Shrub associates include at least 30 species, some of the most important of which are greenleaf manzanita *(Arctostaphylos patula),* whiteleaf manzanita *(A. viscida),* deerbrush *(Ceanothus integerrimus),* bear-clover *(Chamaebatia foliolosa),* oceanspray *(Holodiscus discolor),* Brewer oak *(Quercus garryana* var. *breweri),* Sierra coffeeberry *(Rhamnus rubra),* Sierra gooseberry *(Ribes roezlii),* and poison-oak *(Toxicodendron diversilobum).* In parts of Shasta and Trinity Counties, and perhaps elsewhere, black oak itself takes a shrub form. The stands so formed usually are dense and tangled-ideal habitat for deer and upland game.

Except on the fringe of black oak's natural range, especially at the lowermost elevations, most shrubs generally are not competitive, nor particularly abundant over most of the forest land where black oak grows. After heavy cutting or fire, however, some of the more aggressive shrubs often compete strongly with black oak sprouts.

When compared with 15 of its most common shrub associates in the Klamath Mountains of northern California, black oak ranked ninth in need of soil moisture, third in demand on soil nutrients, eighth in terms of tolerance, and first in rapidity of sprouting (32). The species is able to withstand high moisture stress (37) and to become established and grow well on harsh sites where few other species are capable.

Life History

Reproduction and Early Growth

Flowering and Fruiting- California black oak flowers from mid-March to mid-May depending on elevation, physiography, and local climatic conditions. In general, trees near the coast and at lower elevations bloom earliest.

Flowers on black oak are unisexual. The plant is monoecious. Staminate flowers are long (3.5 to 7.5 cm or 1.4 to 3.0 in) hairy aments that emerge from buds in the leaf axils of the previous year's growth. The five to nine stamens in each ament have bright red anthers and pale green filaments. The calyx is light green. Pistillate flowers are borne singly or two to seven on a short stalk that originates from leaf axils of the current year's growth. The stigmas are dark red.

Acorns mature in the second year. Early in the second summer the immature acorn resembles a small globe about 6 mm (0.2 in) in diameter. At this stage, the acorn is completely encapsulated in the cup. At maturity the light brown, thin-scaled cup encloses from 0.5 to 0.75 of the acorn. Acorns form singly, or in clusters of two to six, and vary widely in dimension. Sizes range from 1.9 to 4.4 cm (0.7 to 1.7 in) long and from 0.9 to 3.8 cm (0.4 to 1.5 in) in diameter.

Seed Production and Dissemination- In natural stands, black oak must be 30 years or older before it produces viable seed. The oak produces some acorns sporadically between ages 30 and 75 but seldom large quantities before 80 to 100 years. A few trees bear at least some acorns every year. Others of similar diameter and crown characteristics rarely produce acorns. Trees that are good seed producers continue abundant acorn production at least to 200 years.

Age, diameter of bole, and crown width influence acorn yield (22). A general relationship for a medium seed crop on a good forest site is that acorn yield increases as bole and crown diameter increase, at least through age 200:

Age	Bole diameter		Crown diameter		Acorn yield	
yr	*cm*	*in*	*m*	*ft*	*kg*	*lb*
30	13	5	5	15	0	0
50	23	9	6	20	2	5
80	33	13	8	26	9	20
100	43	17	10	32	27	60
150	61	24	12	41	45	100
200	81	32	16	52	64	140

Estimates of acorn production by tree or size of seed crop are scarce. One large, 150- to 200-year-old black oak in Butte County, CA, produced about 6,500 acorns for a crop year rated as fair. Acorns were large and heavy, numbering 115/kg (52/lb). Black oak acorns usually are smaller, numbering between 115 and 324/kg (52 and 147/lb). Large acorns have been observed at both low and high elevations and small acorns at medium elevations. The factors influencing acorn size probably are many, but little is known about their interaction. A single, large, well-developed tree at a low elevation in Shasta County, CA, produced sound acorns each year as follows:

1974	700
1975	1,000
1976	65
1977	0
1978	320

1979	231
1980	125

The magnitude and periodicity of seed crops appear to be quite variable. One study reported that abundant seed crops for entire stands were produced at 2- to 3-year intervals (31). At 760 m (2,500 ft) elevation in Yuba County, CA, medium to bumper seed crops were produced in 4 of 20 years. At 850 in (2,800 ft) elevation in south-central Shasta County, medium to bumper crops were borne on large black oaks in 4 of 8 years. At a lower elevation in Shasta County (170 m or 560 ft), black oaks yielded sound acorns in 6 of 7 years. Of these, two each rated as bumper, medium, and light.

Insects destroy many acorns, primarily in the developmental stage. Immature acorns are attacked by both lepidopterous and coleopterous pests. The filbertworm *(Melissopus latiferreanus)* and the filbert weevil *(Curculio uniformis)* are particularly destructive, in some places infesting up to 95 percent of the acorns and destroying most of a crop (16). Fire may lessen these losses. On the Shasta-Trinity National Forests in California, a prescribed burn in March 1978 resulted in a bumper crop of sound black oak acorns, while trees on unburned ground nearby bore only unsound acorns. Apparently, destructive insects in the duff and soil were reduced greatly by the fire (33).

Fully developed acorns begin falling in mid-August at lower elevations, and in mid-September at higher elevations. Almost all acorns that fall first are hollow or infested with insects. Some are still green or greenish yellow. Sound acorns begin dropping from late September to early November and cease by November 15 at lower elevations. At higher elevations almost all acorns have fallen by early December.

Acorns generally drop just before or during leaf fall. Once on the ground, temperature can be critical to continued viability, and fallen leaves help keep acorn temperatures below lethal thresholds. In one instance, fully mature acorns exposed to the hot fall sun had withered cotyledons after 9 days. Acorns from the same trees showed full-sized cotyledons after 21 days, if protected by leaves and branches (21). Likewise, cotyledons of acorns exposed to freezing temperatures turned gray and flaccid, although cotyledons of acorns beneath tree crowns and covered with leaves remained white, crisp, and firm.

A blue-gray mold also damages fallen seed. At one location, acorns covered for about 2 months by wet leaves showed mold at the blunt ends that had progressed well within the seeds. For other acorns in this same environment, cutting tests showed that cotyledons were unaffected. American Indians, however, gathered only freshly fallen acorns to avoid the mold (15).

Because the acorns are large and heavy, most fall directly beneath tree crowns. Few bounce or roll far on steep slopes covered by duff, leaves, and litter. Animals play a vital role in dissemination of acorns because they transport some of them away from the parent tree. The western gray squirrel and the scrub jay are the most important disseminators, for they bury the acorns, sometimes spreading the species to areas nearby.

Black oak acorns are eaten by at least 14 species of song and game birds, many species and subspecies of small mammals (mostly rodents), and mule deer (20). Black bears in the San Bernardino Mountains of southern California utilize the California black oak type in spring, summer, and fall (28). For many of these creatures, acorns are the primary foodstuff in the fall. Without acorns, populations are affected. Fawn survival rates, for example, increase and decrease with the size of the acorn crop.

Cattle, and, to a lesser extent, sheep, also consume many black oak acorns each year.

Seedling Development- California black oak reproduces from seed, but natural regeneration tends to be scanty, poorly distributed, and uncertain. The most likely place to find black oak seedlings is beneath large parent trees, where they number up to $45/m^2$ ($4/ft^2$).

Before the seeds begin to germinate, a period of after-ripening to overcome dormancy is required. Overwintering beneath the litter on the forest floor normally breaks dormancy under natural conditions. For artificial regeneration, acorns can be stratified by cold storage in sealed polyethylene bags thick enough to inhibit moisture loss, but porous enough to freely emit respiration byproducts. Storage temperature should be just above freezing and moisture content of acorns maintained at a level where cotyledons are turgid or slightly flaccid, but not dried out.

Natural seedbed requirements for germination are not exacting. Either undisturbed leaflitter or, to a lesser extent, moist, well-aerated mineral soil are good seedbeds. Establishment of black oak is almost nonexistent on heavy clay soils or soils compacted by logging machinery. These conditions reduce the ability of the radicle to penetrate the soil far enough and fast enough to avoid searing soil surface temperatures or the seasonal drying of upper soil layers.

Acorns germinate in the spring when the weather warms. Germination is hypogeal and highly variable, both in magnitude and timing. The radicle is first to emerge and grows downward for some time, often 10 to 20 days, before the epicotyl appears above ground. This process benefits the seedling in getting to and staying in available soil moisture, and in minimizing transpirational losses. Sometimes a single acorn may put forth several epicotyls, particularly if upward progress is hampered by a stony or crusty soil.

Under optimum conditions, 15 to 25 days elapse between sowing of stratified acorns and the beginning of germination. In nature, the germination period may be several weeks or even months. Germinative capacity varies considerably and changes with degree of insect infestation, amount of mold, and depth of acorn in soil, among other variables. Germination has been reported as high as 95 percent and also as scanty (21 percent). Germinative capacities in large-scale field tests in the northern Sierra Nevada were 31 and 38 percent (22).

Black oak seedlings often reach heights of 10 to 15 cm (4 to 6 in) and extend their taproots downward as deep as 76 cm (30 in) in the first growing season. Development of a deep-thrusting vertical root is necessary for seedlings to cope with the hot dry summers characteristic of California black oak's range. For the first few years, therefore, both lateral root development and shoot growth are slow. Shoot growth probably does not begin to accelerate until root capacity is extensive enough to obtain adequate moisture. This may take 6 or 7 years or longer. Shoot growth of some seedlings, particularly those stressed by competing *vegetation, never accelerates and these* seedlings eventually die.

Studies evaluating artificially regenerated California black oak on the Plumas and Angeles National Forests in California indicate that artificial regeneration of black oak is possible, providing that competing vegetation and pocket gophers are controlled. Fall planting of 1-year-old seedlings, without artificial watering, resulted in good survival and growth on the San Bernardino National Forest, California (30).

Fertilization appears to be one technique for enlarging root capacity and stimulating height development of seedlings. In a test in the northern Sierra Nevada, fertilized seedlings were more than three times taller than unfertilized seedlings (0.2 as against 0.8 m or 0.7 as against 2.5 ft) after five growing seasons. Fertilizer in the proportion of 1620-0 for nitrogen, phosphorus, and potassium was applied at about 0.1 kg (0.25 lb) per seedling early in the spring of each year (22).

Young black oak seedlings are killed mostly by drought and pocket gophers. Grasshoppers and other insects damage young seedlings, and freezing by late spring frosts injures them. These injuries usually are mitigated by sprouting from the root crown.

Vegetative Reproduction- California black oak sprouts profusely after trees are cut or burned. Most sprouts develop from latent buds, which lie under the bark at, or slightly above, the root collar. Other sprouts originate from the top of the stump or between the top and the ground. These are called stool sprouts and are undesirable for two reasons. They are weakly attached to the parent stump and frequently broken off by wind and snow, and are prone to heart rot at an early age.

The size and vigor of the parent tree determine the number of sprouts and their height and crown spread. In general, stumps from larger trees produce a larger number of sprouts and more vigorous ones. Only old, moribund trees fail to produce sprouts after cutting.

Low stumps of nearly all diameters produce many more sprouts than high stumps. High-stumping an older, larger tree yields undesirable stool sprouts, and often no sprouts from below ground.

Root crown sprouts grow vigorously, especially in full sunlight. Forty-nine stumps were studied in stands on a good site in the northern Sierra Nevada. Sprout density, height, and crown width were evaluated in clearcuttings and in shelterwood stands where 50 percent of the basal area had been removed (22). Number of sprouts, crown width, and especially height growth were consistently greater in the clearcuttings (table 1).

Table- Development of California black oak stump sprouts in a northern Sierra Nevada forest 10 years after cutting

Year after	Sprouts per stump		Height		Crown width	
cutting	Clearcut	Shelterwood	Clearcut	Shelterwood	Clearcut	Shelterwood

	no.			m		
0	55+	28	--	-- --	--	--
2	55+	23	1.2	0.9	1.2	0.7
4	35	17	2.4	1.2	1.8	1
6	23	15	3.7	1.5	2.3	1.2
8	18	13	4.9	1.8	2.6	1.6
10	15	12	6	2.1	2.9	2.2
	no.			ft		
0	55+	28	--	--	--	--
2	55+	23	4	3	4	2
4	35	17	8	4	6	3
6	23	15	12	5	8	4
8	18	13	16	6	9	5
10	15	12	20	7	10	7

The environment typical of shelterwood cuttings apparently is more favorable to a cynipid gall wasp *(Callirhytis perdens)* than that in clearcuttings. Damage to terminal shoots by this pest is greater under shelterwood stands, accounting in part for the poorer height growth of sprouts. Thinning sprouts to three or four per stump at age 4 showed no gain in height but resulted in undesirable damage to the bole from sunscald and increased forking of stems (22).

Young black oak sprouts grow faster in height than other vegetation, including coniferous associates. Consequently, they remain dominant for many years. Although black oak seedlings extend the species into new areas, sprouts keep the oak in the same area and are responsible for regenerating many more stands than seedlings. Only after the living crown has moved considerably up the bole does black oak begin its role as a nurse tree, aiding conifers to become established and grow to equal or dominant positions in the stand.

Propagation by layering, rooting of cuttings, or grafting has not been reported. But the wartime shortage of cork in the 1940's stimulated grafting of cork oak *(Quercus suber)* to black oak stocks. In a greenhouse trial, 70 percent of the grafts were successful (27).

Sapling and Pole Stages to Maturity

Growth and Yield- Because fire incidence throughout its natural range is high, nearly all black oak trees originated from sprouts. Consequently most California black oak stands are even-aged.

Number of sprouts per stump influences growth, form and, eventually, yield. The number per clump decreases rapidly with age. By the time the sprouts are pole-size, competition within individual clumps has reduced them to two or three, or occasionally, four stems. By age 100, only one or two stems remain. These data are based on 180 clumps at many California sites (21).

The form of California black oak varies greatly. On the fringe of its range and on marginal sites, black oak trees assume a scrubby form. In closed stands on good sites, the oaks tend to be tall and straight with clear boles and thin crowns. When open-grown, black oaks generally fork repeatedly, becoming multistemmed and broad-crowned.

The general age-height relationship of California black oak, based on 393 dominant trees in northern and central California, is curvilinear until age 140. Thereafter, tree height remains constant regardless of age. Selected age-heights are 20 years, 8 m (26 ft); 40 years, 13 m (43 ft); 60 years, 17 m (56 ft); 100 years, 22 m (72 ft); and 140 years, 25 m (82 ft) (21).

Position on long continuous slopes also influences growth and form. Trees at the toe of slopes or on gently sloping benches, where deeper soils are likely, generally grow best and have good form. Those at midslope are shorter and more scrubby. On upper slopes, trees grow slowly and are even shorter. Aspect also influences growth. Of the 393 trees noted earlier, 100-year-old trees averaged about 26 m (85 ft) in height on east aspects; 22 m (72 ft) on north aspects; 21 m (68 ft) on west; and 17 m (56 ft) in height on south aspects.

Average site index at base age 50 years is about 15 m (50 ft); better than average, about 18 m (60 ft); and poor, only 11 to 12 m (35 to 40 ft) (29).

Diameter growth is often slow during the first 25 years of a black oak's life. Competition for position in the canopy tends to favor height growth over diameter growth. At 25 years, the average tree is nearly 11 m (35 ft) tall and about 10 cm (4 in) in d.b.h. and is one of three sprouts in the clump. Black oak grows fastest in diameter from age 25 to 65 (table 2). Its growth can reach one ring per centimeter or three rings per inch. At age 65 the tree is about 29 cm (11.5 in) in d.b.h. and has grown almost 0.5 cm/yr (0.2 in/yr).

Table 2- Diameter growth in natural stands, California black oak, 1968[1]

Age	**D.b.h.**		**Average cumulative increment per decade**	
yr	***cm***	***in***	***cm***	***in***
20	9	3.4	4.32	1.7
30	14	5.4	4.57	1.8
40	18	7.2	4.57	1.8
50	23	9	4.57	1.8
60	27	10.8	4.57	1.8
70	31	12.2	4.42	1.74
80	34	13.4	4.27	1.68
90	37	14.6	4.11	1.62
100	40	15.6	3.96	1.56
110	42	16.6	3.84	1.51

120	44	17.5	3.71	1.46

[1] Basis: 405 dominant trees in 45 even-aged stands, many California sites.

Black oak in an understocked stand averages 33 to 35 cm (13 to 14 in) in d.b.h. at 65 years; in an overstocked stand, it averages between 18 and 23 cm (7 to 9 in). After age 65, diameter growth slowly declines. By age 90 most trees are mature.

Diameter growth of California black oak can be increased greatly by thinning. On a good site in the northern Sierra Nevada, diameter growth rates of trees thinned when 60 years old were twice that of unthinned trees of similar age 8 years after thinning (23).

Black oak may live to be almost 500 years old, but age-diameter relationships beyond 120 years are uncertain. Trees 51 cm (20 in) in d.b.h. can range between 70 and 175 years. Trees 41 to 63 cm (16 to 25 in) in d.b.h. were 175 to 275 years old, and those more than 102 cm (40 in) were 175 to 325 years old.

Black oak seldom exceeds 1.5 m (5 ft) in d.b.h. or 40 m (130 ft) in height. The largest living black oak known measures 274 cm (108 in) in d.b.h. and 37.8 m (124 ft) in height. This tree grows in the Siskiyou National Forest, OR (1).

Yield data are difficult to find. The "average" stand contains 1,086 trees per hectare (440/acre), 8.9 cm (3.5 in) and larger in d.b.h., and would yield slightly more than 409 m^3/ha (5,845 ft^3 or 65 cords/acre). In 60-year-old mixed-hardwood stands on good sites in the northern Sierra Nevada, black oak produces 76 m^3/ha (1,085 ft^3 or 12.1 cords/acre).

Rooting Habit- Various investigators have described the rooting system of black oak as having no taproot but large spreading roots (18); as deep and long lived; with a strong taproot; and possessing strong laterals, more or less deep, depending on depth to ground water (3).

Observations at road cuts indicate the general rooting pattern of this oak. Usually, from one to several vertical roots extend through the soil and penetrate to rock. Then they become lateral and spread out directly above the rock. At fissures, "sinker" roots penetrate the rock itself. A number of roots are found near the surface, probably to exploit the nutrients there.

Reaction to Competition- The tolerance of black oak to shade varies with age. It most accurately can be classed as intolerant because this condition exists throughout most of its life (9). The oak is moderately tolerant in early life, growing well in full sunlight but persisting in dense shade (31). As a sapling and small pole, black oak is less tolerant and often grows tall and thin until it reaches a position in the canopy where it can receive light. The need for top light increases as the tree ages. In dense stands, black oak often fills a "hole" in the canopy, sometimes leaning 15 to 20 degrees to do so. If overtopped, the oak either dies outright or dies back successively each year. Short epicormic branches keep the tree alive for a time, but with continued overtopping, death is inevitable.

Damaging Agents- Fire is black oak's worst enemy. Crown fires kill trees of all ages and ground fires are often fatal. Only a little radiative heat kills the cambium and only a small amount of flame along the trunk leaves long vertical wounds. Bark thickness on mature trees varies from 2 to 5 cm (1 to 2 in), but even the thickest bark provides little insulation to fire. Scars from burning can become a point of entry for fungi. On larger trees, repeated fires often enlarge old scars, sometimes toppling the tree. Fluctuations in weather also cause injury. Heavy, wet snow breaks branches and stems, particularly at forks, and sudden high temperatures following cool wet weather severely injure leaves (25).

California black oak is especially susceptible to fungi. Heart rot of the bole and large limbs of living trees, caused mainly by two pathogens, *Inonotus dryophilus* and *Laetiporus sulphureus,* is the principal damage (24). These rots enter the tree through broken branches or open wounds resulting from fire or logging. Both fungi often reduce the bole and large limbs of older, decadent trees to mere shells. The hedgehog fungus *(Hydnum erinaceus)* also is found in the heartwood of living trees and *Polyporus adustus* in the sapwood, though neither is prevalent.

By the time a natural black oak stand is 85 years old, the proportion of infected trees begins to increase rapidly. Almost 40 percent of trees 110 to 120 years old show incipient heart rot (21). Rotation age of stands grown for wood products could be influenced by this incidence-age relationship.

Another serious pathogen, *Armillaria mellea,* causes decay of the roots and butt of older decadent black oak. Sometimes it weakens the root system so much that the tree topples over on a perfectly calm, still day (36). This pathogen is indigenous in black oak, but younger vigorous trees do not seem to be affected by it.

A comparatively recent damaging agent to black oak in the San Bernardino Mountains of southern California is air pollution. Although the oak appears less susceptible to air pollution damage than associated conifers, radial growth has decreased in some trees (12). Where high ambient oxidant air pollution levels are chronic, damage to California black oak is expected to be significant (26).

One virulent pathogen that black oak escapes, and indeed is resistant to, is *Heterobasidion annosum* (14). For this reason, California black oak is being planted in numerous infection centers in southern California forests where conifers are dead or dying.

California black oak is prone to several leaf diseases including the oak leaf fungus *(Septoria quercicola),* oak anthracnose *(Gnomonia veneta),* powdery mildews *(Microsphaera* and *Sphaerotheca* spp.), a leaf blister fungus *(Taphrina caerulescens),* a leaf rust *(Cronartium* spp.*),* and true mistletoe *(Phoradendron villosum* subsp. *villosum).* Damage from each of these pests has not been determined but loss of growth increment probably is minor.

Animal damage to black oak is mostly from browsing. Foliage is eaten during all seasons, but especially in spring when new growth is tender and in winter when twigs are eaten. Deer eat acorns, seedlings, sprouts, and foliage. Even in midsummer, newly germinated seedlings with acorns attached often are consumed (8). Occasionally, browsing is fatal. In Mendocino County, CA, for example, a deer population of 1/2.4 ha (1/6 acres) almost eliminated oak over large areas of the Coast Range. Cattle also browse black oak, but in national forests, at least, their numbers are declining.

Many insects derive sustenance from black oak. The damage is usually secondary, reducing growth but seldom killing trees. Among sucking insects, the pit scales *(Asterolecanium minus* and *A. quercicola)* have the greatest potential for damage (4). The most destructive insect, however, is probably the carpenterworm *(Prionoxystus robiniae),* whose larvae mine the wood of trunk and limbs and cause injuries that appear later as defects in lumber (16).

Other insects are capable of heavy damage, especially when infestations become epidemic. The Pacific oak twig girdler *(Agrilus angelicus)* is the most damaging insect to oak in southern California during drought years (4). In northern California, the California oakworm *(Phryganidia californica)* is noted for defoliating trees. So is the fruit-tree leafroller *(Archips argyrospila)* which, in 1968, caused heavy damage throughout a wide area in the Sacramento River drainage.

Special Uses

Several attributes qualify the wood of California black oak for commercial use: attractive grain and figure for paneling and furniture, hardness and finishing qualities for flooring, and strength properties for pallets, industrial flooring, and other uses (19). The forks of open-grown black oaks were put to good use in the 1870-80's in Mendocino County.

Those of specific dimensions were used as "naturally assembled" ship keels and ribs. Wood products currently produced are high grade lumber and pallets, industrial timbers, sawdust for mulching, and bulk and prepackaged firewood. The wood is prized for fuelwood and in some areas unrestricted cutting is eliminating oak stands.

Although not presently utilized, black oak acorns, high in edible oils, are a potential source for thousands of tons of human food (38).

Genetics

Two natural hybrids are recognized: *Quercus x ganderi C. B. Wolf (Q. agrifolia x Q. kelloggii)* and *Quercus x moreha* Kellogg *(Q. kelloggii x wislizenii).* Another hybrid, *Quercus x chasei (Q. agrifolia x kelloggii)* has been described in Monterey and Santa Clara Counties, CA.

Of the hybrids, *Q. moreha* is by far the most widespread, ranging throughout California and even found, though rarely, in south-central Oregon. The tree is distinguished readily in the winter by its sparse evergreen foliage in contrast to the completely deciduous black oak. New leaves in spring form a dense mass of shiny green foliage on the hybrid.

Forma cibata, a form by which black oak has been described, is a low shrub common to steep, rocky, talus slopes at higher elevations. Although described as a true shrub form, this status is questionable. No criteria are known for distinguishing between it and scrubby black oak trees.

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Attachment #4

Quercus wislizeni

Table of Contents

INTRODUCTORY

An interior live oak woodland in Mariposa County, California. Photo courtesy of Charles Webber © California Academy of Sciences.

AUTHORSHIP AND CITATION:
Fryer, Janet L. 2012. Quercus wislizeni. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [ ].

FEIS ABBREVIATION:
QUEWIS
QUEWISW

QUEWISF

COMMON NAMES:
For *Quercus wislizeni* (the species) and *Quercus wislizeni* var. *wislizeni* (the typical variety):
interior live oak
Sierra scrub oak

For *Quercus wislizeni* var. *frutescens*:
scrub interior live oak
dwarf interior live oak

TAXONOMY:
The scientific name of interior live oak is *Quercus wislizeni* A. DC. (Fagaceae) [75,107,126,192,198]. It is in the red or black oak subgenus (*Lobatae*) [34,58]. There are 2 varieties of interior live oak [75,192,198]:

Quercus wislizeni A. DC. var. *wislizeni*, typical variety of interior live oak
Quercus wislizeni A. DC. var. *frutescens* Englem., scrub interior live oak

Most information on interior live oak is written at the species level. In this review, "interior live oak" refers to the species as a whole, and the varieties are referred as "the typical variety" or "scrub interior live oak".

Hybridization: Facile hybridization among red oaks makes the separation of species within that subgenus a taxonomic challenge. Among California's red oaks, interior live oak hybridizes frequently with coast live oak (*Q. agrifolia*) [45,46,59,61,126,198,204], Santa Cruz Island oak (*Q. parvula*) [59], California black oak (*Q. kelloggii*) [59,198,199], and oracle oak (*Q.* × *moreha* Kell.) [126]. Oracle oak is a stable California black oak × interior live oak hybrid [198].

In California, all red oak species show some degree of introgression with other red oaks. Interior live oak populations in northern California show genetic evidence of considerable introgression with coast live oak and Shreve oak (*Q. parvula* var. *shrevei*); all 3 taxa are evergreen. Interior live oak populations show less introgression with California black oak, which is deciduous [57,58]. Backcrossing and hybrid swarms are most common between interior live oak and coast live oak [61], which genetic tests show are the most closely related of California's red oaks [58,61]. Dodd and others [62] suggest that coastal populations of interior live oak, which have high amounts of introgression overall, should be reclassified as Santa Cruz Island oak, with gene flow from interior live oak to coast live oak, then to Santa Cruz Island oak, making separation of the 3 species difficult in coastal locations. Interior live oak and Santa Cruz Island oak are sometimes treated as synonyms [62], but are treated as distinct species in this review.

SYNONYMS:
Quercus wislizenii A. DC. [68,96]

LIFE FORM:
For *Quercus wislizeni* var. *wislizeni*:

Tree-shrub

For *Quercus wislizeni* var. *frutescens*:
Shrub-tree

DISTRIBUTION AND OCCURRENCE

SPECIES: Quercus wislizeni

- GENERAL DISTRIBUTION
- SITE CHARACTERISTICS AND PLANT COMMUNITIES

GENERAL DISTRIBUTION:

1976 USDA, Forest Service map provided by [193]

Interior live oak is a native California-Baja California endemic. It occurs over about 16% of California's landscape [165]. Interior live oak is most common in the Inner Coast Ranges, the foothills of the southern Cascade Range [181], and the Sierra Nevada [125,126]. It also occurs on Santa Cruz Island [125]. Both varieties are common in northern California. Scrub interior live oak is most common in southern California, especially in the Transverse and Peninsular ranges [155]. The distributions of both varieties extend to Baja California Norte [75].

As of 2011, only one English-language publication provided information on interior live oak populations in Baja California Norte, so except for that source [143], all geographical locations referred to in this review are in California.

States and provinces [125,200]:
United States: CA
Mexico

SITE CHARACTERISTICS AND PLANT COMMUNITIES:

Site characteristics: Interior live oak mostly grows on harsh sites that other oaks cannot tolerate.

Climate and moisture regime: Interior live oak grows strictly in a mediterrean climate, which is characterized by mild, wet winters and hot, dry summers [18,22,23]. It is adapted to dry sites [102]; among California's red oaks, interior live oak has the highest tolerance for xeric conditions [60,179]. Mean annual precipitation across interior live oak's distribution in California ranges from 15 to 50 inches (380-1,300 mm) [155]. Except for the deserts, the oak (*Quercus* spp.) woodland/grassland regions of the Sierra Nevada are driest areas in California [202], typically receiving <25 inches (625 mm) of precipitation annually. During the fire season, maximum summer temperatures in interior live oak foothill communities sometimes reach 105° F (41° C), with ≤5% relative humidity [23].

Interior live oak's evergreen leaves help protect it from desiccation, but it is not well adapted to snowy or cold sites. The branches do not hold snow loads well, and the evergreen leaves freeze easily. California black oak, which is better adapted to snow and cold, usually replaces interior live oak on upper foothills [155].

Interior live oak sometimes grows in riparian and other wetland areas. It may be frequent to dominant in riparian zones, especially in southern California [174,214]. In the East Bay Hills, it is a component of coast live oak communities on hillside springs [4].

Elevation and topography: A major vegetation survey (>17,000 plots) across California's oak communities found interior live oak had the greatest elevational range among California's 5 most frequently dominant oaks: blue oak (*Q. douglasii*), California black oak, canyon live oak (*Q. chrysolepis*), interior live oak, and valley oak (*Q. lobata*). Survey data suggested that interior live oak was becoming more common in montane regions compared to its 1930s distribution [195].

Interior live oak grows from 1,000 to 6,200 feet (300-1,900 m) elevation across its range [68]. It tends to occur at lower elevations in northern than in southern California. Mixed-oak woodlands with interior live oak, valley oak, and/or blue oak occur from 3,000 to 4,000 feet (914-1,218 m) along the entire west slope of the Sacramento River valley [171]. Interior live oak chaparral may occur in scattered clumps at the highest elevations (>5,500 feet (1,700 m)) of foothills in southern California [136]. Scrub interior live oak grows at elevations from 1,000 to 6,600 feet (300-2,000 m) across its range [96], occurring at elevations up to 2,000 feet (600 m) in northern California [137] and usually from 3,500 to 6,200 feet (1,200-1,900 m) in southern California [68,99].

Landforms with interior live oak include dry valleys, canyons, and foothill slopes [68,96]. Interior live oak prefers north-facing or other relatively mesic slopes within these dry habitats [120,190]. A 1932 publication noted that on the basalt table mountains above San Joaquin Valley, interior live oak was dominant on north-facing slopes and had a scattered presence on south- and west-facing slopes. All slopes had mostly shallow soils and ephemeral streams, so they were dry for most of the year [76].

Soils: Interior live oak tends to occur on shallow soils in chaparral and on deeper soils in oak woodlands. Chaparral soils are nearly always dry and shallow [98]. On sites with minimal soil development, interior live oak roots may force their way through fractured rock to reach groundwater [48,124]. The soils of California's oak woodlands are typically deep and productive [21,23]; hence, the frequent management of oak woodlands as rangelands. Interior live oak woodlands may occur on shallow to deep soils, but they generally occupy shallower soils than those of other oak series. In the San Bernardino Mountains, canyon live oak stands grade into interior live oak stands on shallow soils and ridgetops [51]. However, interior live oak and other oak chaparral communities usually occur on relatively more productive and deeper soils than soils supporting chamise (*Adenostoma fasciculatum*) or manzanita (*Arctostaphylos*) chaparral [151].

Interior live oak typically grows in soil of igneous [24,128] or granitic [213] origin. Interior live oak communities in Tehama County have formed over volcanic breccia. Soils are 2.5 to 5 feet (0.8-1.5 m) deep and slightly acid [24]. In the San Luis Obispo Valley, scrub interior live oak grows in siliceous sandstone [210]. Interior live oak is rarely associated with serpentine soils [155]. It does not grow with gray pine (*Pinus sabiniana*) on serpentine sites, but it is commonly associated with gray pine on nonserpentine sites [93,98]. Interior live oak does, however, grow in serpentine and other ultramafic soils in knobcone pine (*P. attenuata*) communities of the Klamath Mountains and the North Coast Ranges [98].

Interior live oak grows in soils of all textures. Interior live oak-blue oak communities in Sutter County occur on gravelly loams and shallow to moderately deep (<41 inches (100 cm)), well-drained sandy loams. One blue oak-interior live oak series had a claypan layer from 15 to 30 inches (38-76 cm) deep. Wood production of interior live oak and blue oak was greatest on sites with moderately deep soils without claypans [128].

Plant communities:

Interior live oak communities on Table Mountain and in Coal Canyon, Butte County. Photo by Mark W. Skinner @ USDA-NRCS PLANTS Database.

Interior live oak occurs in chaparral, oak woodland, and conifer-oak woodland [96] communities. Typically, communities dominated by nonnative annual grasses [27] and/or chaparral shrubs [21] bound or form a mosaic with oak woodlands at low elevations, and oak woodlands meld into ponderosa pine (*Pinus ponderosa*) communities on upper foothills [27]. Interior live oak scrub chaparral merges into interior live oak woodlands on some sites; a more frequent fire-return interval and/or drier soils apparently helps maintain the scrub type [98]. Two interior live oak vegetation types were identified on the San Bernardino National Forest: chaparral and forest. Interior live oak chaparral occurred on steep (x = 45°), dry slopes, and associated vegetation was mostly sprouting, sun-tolerant chaparral species including chaparral whitethorn (*Ceanothus leucodermis*) and chamise. Interior live oak forest occurred on more moderate (x = 20°), mesic slopes with a sparse, mixed understory of "obligate seeders" (that is, species that are killed by fire and establish afterwards from seed) and shade-tolerant sprouting shrubs such as Pacific poison-oak (*Toxicodendron diversilobum*). These types were not discrete on most sites; instead, the 2 types formed a blended continuum [211].

Gray pine and California buckeye (*Aesculus californica*) commonly associate with interior live oak across the ranges of all 3 species [15,18,155]. Pacific poison-oak is widespread in most woodlands with interior live oak (for example, [2,42,90,212]). As well as dominating California's annual grasslands, nonnative annual grasses comprise most of the groundlayer vegetation in California's chaparral [6] and oak woodlands [3]. These annuals also dominate the groundlayer of chaparral ecosystems in Baja California [143]. Wild oat (*Avena fatua*), ripgut brome (*Bromus diandrus*), soft chess (*B. hordeaceus*), and hare barley (*Hordeummurinum* subsp. *leporinum*) are typical annual grass dominants [87,183,196]. Composition of the groundlayer prior to European settlement is unknown [3]. Interior live oak may finger into annual grasslands on valley floors. For example, interior live oak is an occasional species in annual grasslands of El Dorado County [213].

Chaparral: "Chaparra" translates from Spanish to "scrub oak" in English. Scrub oak chaparral, in which scrub interior live oak is often a primary component, comprises about 15% of the chaparral landscape of California. Codominant and associated species in scrub oak chaparral are mostly shrubs such as chamise and deer brush (*C. integerrimus*) [33]. The associated shrubs are often a mix of species that sprout after fire, such as chamise, and obligate seeders [56] such as wedgeleaf ceanothus (*C. cuneatus*) [108].

Interior live oak usually dominates the "scrub" or "live oak" chaparral vegetation types in the Inner Coast Ranges and the Sierra Nevada [23,98,106,120]. About 25% of interior live oak's total population lies within chaparral ecosystems [195]. Sawyer and others [178] place a plant community in the interior live oak scrub series if >60% of the overstory is shrubby interior live oak. If cover of shrubby interior live oak is less, the series is classified as mixed chaparral [178]. Interior live oak-dominated chaparral typically occurs on slopes; soils may be alluvial or derived from bedrock, and they are often rocky. Chamise, wedgeleaf ceanothus and other *Ceanothus*, and barberry-leaved scrub oak (*Q. berberidifolia*) often codominate with interior live oak in chaparral communities [27].

Northern California: In interior northern California, interior live oak is typically the dominant evergreen in scrub oak communities [49]. Interior live oak scrub communities are most common on north-facing slopes [120]. Chamise, manzanita, wedgeleaf ceanothus [23], and whitethorn ceanothus (*C. cordulatus*) [178] are common codominants or associates. Interior live oak occurs in and sometimes dominates montane chaparral in the Sierra Nevada [120]. Van Wagtendonk [201] describes the montane chaparral-woodlands of Yosemite National Park as overstories of interior live oak, canyon live oak, and gray pine with whiteleaf manzanita (*A. viscida*), deer brush, birchleaf mountain-mahogany (*Cercocarpus montanus* var. *glaber*), and other chaparral shrubs in the midstories. A foothill mixed-chaparral type is described along the Kaweah River in Sequoia National Park. Interior live oak, California buckeye, and canyon live oak codominate the mix. Tree cover is around 40% to 60%, shrub cover from 30% to 60%, and cover of annual herbs around 50% to 75%. There has been some influx of forest conifers that is attributed to fire exclusion [203].

Interior live oak is a minor to important associate in scrub oak communities dominated by other oaks, usually coast live oak [66] or canyon live oak [194]. Interior live oak is rare in barberry-leaved scrub oak communities of Sonoma County [40].

Interior live oak is a characteristic to dominant species in mixed chaparral of northern California; chamise, and sometimes barberry-leaved scrub oak, are usually codominant [98,140]. In the Outer North Coast Ranges of Santa Cruz County, interior live oak is "quite common" in the chaparral belt [105]. In mixed chaparral near Lakeport, interior live oak and Eastwood manzanita (*A. glandulosa*) tend to dominate on north- and west-facing facing slopes, while chamise tends to dominate on south- and east-facing slopes [190].

Southern California: Interior live oak scrub communities of southern California are likely maintained by frequent fire [178]. Coast live oak, canyon live oak [106], barberry-leaved scrub oak, and/or coastal sage scrub oak (*Q. dumosa*) [98] often codominate. Generally, interior live oak or coastal sage scrub oak dominate oak scrub of the Inner Southern Coast Ranges, while barberry-leaved scrub oak dominates oak scrub of the Outer Southern Coast Ranges [111]. The interior live oak scrub vegetation type is common on xeric slopes, often sandwiched between mixed chaparral at low and conifer forests at high elevations. Shrubby interior live oaks may spread into mixed chaparral in intermittent stream draws [157]. In the San Bernardino Mountains, interior live oak may dominate the upper reaches of barberry-leaved scrub oak and coastal sage scrub oak types [100]. Interior live oak is the primary dominant in some oak scrub series in the western Transverse Mountains, where it codominates with canyon live oak, barberry-leaved scrub oak, birchleaf mountain-mahogany, chamise, and/or chaparral whitethorn. It is occasional in riparian coast live oak and other riparian oak woodlands [41].

Mexico: Interior live oak was rare in barberry-leaved scrub oak chaparral of the Sierra de San Pedro Mártir in Baja California. It was found on west-facing slopes near 5,200 feet (1,600 m) elevation [143].

Oak woodlands and forests: Interior live oak-dominated woodlands and occasional forests are most common in northern California, occupying west slopes of the Southern Cascade Range and the Sierra Nevada. In 1844, the explorer John Fremont made the first recorded observation of interior live oak when descending into the Sacramento Valley near the American River from upper slopes of the Sierra Nevada: "At every step the country improved in beauty; the pines were rapidly disappearing and oaks became the principal trees of the forest. Among these the prevailing tree was the evergreen live oak" [155]. Interior live oak gains dominance with elevation in the foothills; interior live oak-gray pine woodland/annual grasslands extend from about 1,000 to 2,500 feet (300-800 m) elevation in the Sierra Nevada [178].

The interior live oak series is placed in the mixed broadleaved, evergreen-cold deciduous woodland formation. The series often grades in from lower-elevation interior live oak scrub. Woodlands and occasional forests dominated by tree-sized interior live oaks occur on valleys, slopes, and ridgetops; these landforms often have moderately to excessively drained, shallow soils [178]. On foothills surrounding the Sacramento and San Joaquin valleys, interior live oak tends to dominate the drier slopes of the Sierra Nevada, while coast live oak tends to dominate the relatively wetter slopes of the Coast Ranges [45]. Shrubs are typically chaparral types such as toyon (*Heteromeles arbutifolia*), wedgeleaf ceanothus, and whiteleaf manzanita. In the Sierra Nevada, interior live oak woodlands ranged from a low of 1,144 feet (249 m) for the interior live oak-gray pine/whiteleaf manzanita subseries to 2,120 feet (646 m) for the interior live oak/yerba santa (*Eriodictyon californicum*)/annual grass subseries [2]. Interior live oak woodlands are rare in Pinnacles National Monument, and they are the only oak woodlands in the Monument. Sprouting shrubs, including toyon, creeping snowberry (*Symphoricarpos mollis*), and Pacific poison-oak are common in the type [90]. In the San Bernardino Mountains, interior live oak may dominate upper reaches of canyon live oak woodlands [158].

Interior live oak is frequent to codominant in many blue oak woodlands [11,16]. Interior live oak-blue oak-gray pine communities lie just beneath the ponderosa pine belt [117]. Blue oak-interior live oak/annual grass woodlands typically occupy the lowest foothills, with gray pine often codominating [1,2,5,98]. They average about 1,550 feet (500 m) elevation [2]. Near Clear Lake, blue oak-interior live oak communities tend to occupy north-facing slopes, while chamise or mixed manzanita (*Arctostaphylos*)-chamise chaparral occupies south-facing slopes [26]. Interior live oak is common, but rarely dominant, in blue oak communities in the low foothills of Sequoia National Park [11]. A blue oak-interior live oak/whickerbrush (*Leptosiphon ciliatus*) community occurs on fine loamy soils in northern Santa Barbara County [35].

Many mixed-oak woodland communities contain interior live oak as an associated or codominant species. Codominant oaks may include coast live oak, blue oak, valley oak, and/or Oregon white oak (*Q. garryana*) in the northern portion of interior live oak's distribution and Engelmann oak (*Q. engelmannii*) [15,18], barberry-leaved scrub oak, and/or coastal sage scrub oak [27] in the south. Interior live oak is a characteristic species in some Oregon oak woodlands of the North Coast Ranges [50,98] and the Klamath Mountains [98]. On the Hopland Research Station in Mendocino County, interior live oak codominates with coast live oak, blue oak, and California black oak [43]. Latting [120] describes a northern oak woodland type that occurs inland from redwood (*Sequoia sempervirens*) forests north of the Bay Area. These woodlands are composed of Oregon white oak, California black oak, canyon live oak, interior live oak, and other broadleaved species. They range from 3,000 to 5,000 feet (900-2,00 m) elevation in the North Coast Ranges and the Yolla Bolly Mountains [120].

Interior live oak is incidental to dominant in riparian oak or other hardwood riparian communities of northern California [174], and it may be frequent in riparian zones of otherwise dry slopes in southern California [214]. In riparian areas, interior live oak cover is sometimes dense enough to form a closed-canopy forest (see the photo of Coal Canyon Creek area). Interior live oak riparian communities occur below about 3,000 feet (900 m) in northern California and above about 6,000 feet (2,000 m) in southern California [98]. In Sequoia National Park, riparian interior live oak-blue oak-California buckeye communities occur at low elevations (1,300-3,300 feet (390-1,000 m)), with denser stands than those of upland blue oak-interior live oak communities [174]. The typical variety of interior live oak is occasional in riparian woodlands in the San Gabriel Mountains [120].

Conifer-oak: Interior live oak is a component of many pine-oak and other conifer-oak communities. It may finger into [120], and sometimes codominate in, ponderosa pine communities. In Monterey County, ponderosa pine-interior live oak-canyon live oak communities occur around 3,000 feet (900 m) elevation [86]. Scrub interior live oak associates with knobcone pine in the North Coast Ranges [5,12]. Interior live oak is an associated species in Coulter pine (*P. coulteri*) communities in the Machesna Mountain Wilderness [37] and other locations on the Los Padres National Forest [38]. It codominates with Coulter pine at high elevations 4,890 to 4,920 feet (1,490-1,500 m) of the Santa Lucia Range [84]. Interior live oak associates with bishop pine (*P. muricata*) on Santa Cruz Island [5].

Mixed-evergreen and mixed-conifer zones may support interior live oaks, with interior live oaks becoming increasingly scattered with increasing elevation. The interior live oak-Pacific madrone (*Arbutus menziesii*)/Pacific poison-oak series occurs on mesic foothills at around 1,500 feet (450 m) in the North Coast Ranges and the Sierra Nevada [1]. Interior live oak is a minor [103] to characteristic [179] associate in Douglas-fir-tanoak (*Pseudotsuga menziesii-Lithocarpus densiflorus*), Douglas-fir-Pacific madrone, and other mixed-evergreen forests. In Santa Cruz County, it was noted in a redwood-mixed evergreen-hardwood forest in Big Basin Redwoods State Park [101]. Interior live oak was rare in redwood forests of southern Monterey County [39]. In the Sierra Nevada, it is sometimes associated in the mixed-conifer overstory with ponderosa pine, Douglas-fir, white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), Jeffrey pine (*Pinus jeffreyi*), and/or red fir (*A. magnifica*) [67,145,166]. In mixed-evergreen forests of the Santa Lucia Range, interior live oak codominates with bristlecone fir (*A. bracteata*), coast live oak, and canyon live oak [191]. On the eastern Transverse Ranges, it fingers into bigcone Douglas-fir (*Pseudotsuga macrocarpa*) communities from lower-elevation (~780 feet (230 m)) chamise chaparral [139]. In the San Gabriel Mountains, interior live oak is confined to north-facing slopes and draws; bigcone Douglas-fir and canyon live oak are commonly associated species [97]. Scrub interior live oak sprouts are often prominent in early postfire, seral bigcone Douglas-fir woodlands [5].

See the Fire Regime Table for a list of plant communities in which interior live oak may occur and information on the fire regimes associated with those communities.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Quercus wislizeni

- GENERAL BOTANICAL CHARACTERISTICS
- SEASONAL DEVELOPMENT
- REGENERATION PROCESSES
- SUCCESSIONAL STATUS

GENERAL BOTANICAL CHARACTERISTICS:

- **Botanical description**
- **Raunkiaer life form**

Twig of an interior live oak near Redding, California. Photo by Julie Kierstead Nelson.

Botanical description: This description covers characteristics that may be relevant to fire ecology and is not meant for identification. Keys for identifying California's oak species are available in these sources: [68,96]. However, identifying oaks is often difficult due to hybridization, and interior live oak hybrids are common. Tucker [199] pointed out that scrub oak hybrids do not "key down" well. Brophy and Parnell [45] provide a key to help identify interior live oak-coast live oak hybrids.

The varieties of interior live oak are distinguished by their growth form. The typical variety (*Q. wislizeni* var. *wislizeni*) grows as a tree, and scrub interior live oak (*Q. wislizeni* var. *frutescens*) grows as a shrub [96]. The typical variety reaches from 33 to 75 feet (10-23 m) tall [96,159]. Open-grown trees have a dense, rounded crown [155,164], with branches that may extend to the ground [164]. Trunks are one to several [164]. Scrub interior live oak typically reaches 7 to 20 feet (2-6 m) tall [96] and is intricately branched [137]. In Tehama County, interior live oak is typically 8 to 10 feet (2-3 m) tall and shrubby in form [24]. Limited water in the substrate may be a factor driving the shrub or scrub form [89], although frequent fire may produce the same result.

Interior live oak typically has numerous, short branches, regardless of form. In a study comparing leaf and branch architecture of 6 cooccurring sclerophyllous tree species in Mendocino County, interior live oak had more densely packed branches and leaves than Pacific madrone, canyon live oak, tanoak, giant chinquapin (*Chrysolepis chrysophylla*), and California bay (*Umbellularia californica*); this was true for both sun- and shade-grown interior live oaks [102].

Interior live oak wood is strong, dense, and close-grained [137]. The bark is relatively thin [78,164] on most trees and is composed mainly of live cambium that is susceptible to fire damage. Bark of a 3-inch (7 cm) diameter interior live oak was 0.1 inch (0.3 cm) thick with a very thin layer of outer bark; bark of a 12-inch (30.5 cm) diameter tree was 0.3 inch thick with a "small amount of dead bark" on the outer surface [164]. Bark of large trees can be up to 3.0 inches (7.5 cm) thick [137].

The leaves and fruits of interior live oak are relatively small. The leaves are evergreen and sclerophyllous; the margins may be spine-toothed to entire [96,164]. The leaves are elliptical and about 1 to 3 inches (2.5-8 cm) long [155]. Male catkins are about as long as the leaves [102]. The smaller, female flowers are born in the leaf axils in clusters of 2 to 4 [159]. The fruits are acorns, a type of nut [96]. They are about 0.3 to 0.5 inch (0.8-1.3 cm) wide [164].

Interior live oak is deep-rooted. In a review comparing maximum root depths of sclerophyllous species around the globe, interior live oak had greatest average root depths of all oaks and most other species that were compared; only *Eucalyptus* had greater maximum root depths [48]. A study in Placer County found interior live oak roots extended at least 24.3 feet (7.4 m) feet through fractured rock before reaching groundwater [124].

Interior live oak is apparently not long-lived. Trees may live 150 to 200 years, although studies of interior live oak's longevity are few [164]. Because interior live oaks sprout, their root systems may be several generations older than their trunks [164].

Interior live oak does not tolerate flooding. When the Terminus Reservoir near Visalia flooded, interior live oaks died if water covered the soil around their trunks for more than 1 week [92].

Raunkiaer [170] **life form:**
Phanerophyte

SEASONAL DEVELOPMENT:
Interior live oak's growing season peaks in early spring; in the Sierra Nevada, most vegetative occurs in March [175]. Interior live oak flowers [68] and sheds pollen in late spring. Photoperiod evidently regulates release of interior live oak pollen [204]. Acorns ripen from mid-August [160] to October [144,207]. The leaves are retained for 2 years [137,159]. Acorns germinate slowly over fall and winter [131,132].

In the Santa Lucia Mountains, time of germination initiation varied with elevation but regardless of elevation, interior live oak germination took several months to complete. Acorns began germinating in November at low elevations (76 feet (23 m)); they began germinating in

December at high elevations (4,460 feet (1,360 m)). Germination was complete for acorns at low and midelevations (1,840 feet (560 m)) by February, while acorns at high elevations finished germination by March [132].

REGENERATION PROCESSES:

- Pollination and breeding system
- Seed production
- Seed dispersal
- Seed banking
- Germination
- Seedling establishment and plant growth
- Vegetative regeneration

Interior live oak is a hardy oak that can regenerate from acorns or by sprouting. Sprouting is apparently the most common method of interior live oak regeneration.

Interior live oak is well adapted to regenerating after fire or cutting. The Hopland Research Field Station was nearly de-wooded from 1959 to 1965 in the belief that removing trees would provide more livestock forage and increase water yields (see Other Management Considerations for a discussion of this practice). After almost complete clearcutting except for a few large trees left for shade and a prescribed fire in 1965, a different management practice was started: Trees were allowed to regenerate. Despite the cutting and burning, oak regeneration on slopes ranging from 0° to 40° was significantly higher in 1996 compared to pretreatment levels in 1952 ($P>0.05$). Among tree species, interior live oak had gained greatest cover (28.4%) by 1996. This was attributed mainly to sprouting after cutting and burning [43].

Pollination and breeding system: Wind disperses interior live oak pollen [57,58].

Interior live oak is monoecious [34]. Dodd and Kashani [60] suggest that past population fragmentation has resulted in a metapopulation structure for interior live oak. Pollen-mediated gene flow is relatively free among interior live oak populations, and introgression with other red oaks contributes to interior live oak's genetic diversity [57,58,59] (see Hybridization). For successful pollination between interior live oak and other red oaks, genetic studies show that climate compatibilities of interior live oak and the other parent are more important than distance from the pollen source [59].

Seed production: There are usually 5 to 7 years between large crops of interior live oak acorns (reviews by [34,159]).

Seed dispersal: Gravity and animals disperse interior live oak acorns. Scrub jays cache acorns in the ground, where unretreived acorns are likely an important source of oak regeneration [85].

Seed banking: Oaks have a transient seed bank [34]. After falling off the tree, acorns remain viable only through that growing season [144].

Germination: Interior live oak acorns require 2 years of development on the tree to complete maturation [45,68,96].

Fresh interior live oak acorns are not dormant [159], so when there is enough moisture, they may germinate soon after dispersal. Fully mature, fresh acorns have germinated in the laboratory a few days after collection (review by [47]), and interior live oak seedlings may begin germinating in late fall in the field. Momen and others [146] suggest that for germination and seedling establishment, interior live oak and other evergreen oaks are adapted to use soil moisture from late-fall rains, when deciduous species are dormant. Interior live oak showed 75% mean germination after 30 to 60 days of cold stratification in the laboratory. Increased rates of interior live oak germination after cold stratification in the laboratory (review of Bonner's [34] laboratory studies) suggest that winter temperatures enhance its germination rates in the field.

Seedling establishment and plant growth: Little information was available as of 2011 on rates of interior live oak seedling establishment. Interior live oak showed widely different degrees of establishment on 4 sites. In Eastwood manzanita-interior live oak chaparral on Mt Tamalpais, interior live oak seedlings and saplings had an average density of 26,980 plants/ha, while interior live oak was absent from plots in Eastwood manzanita-interior live oak chaparral at Northridge. Neither site had burned for at least 56 years [109,110]. For acorns planted in interior live oak's natural elevational ranges, interior live oak showed 18% mortality at seedling emergence on the Santa Lucia Range and 2% to 5% mortality at seedling emergence in the Sierra Nevada [132].

Limited information suggests that interior live oak is reproducing at rates adequate to maintain its populations ([148], review by [182]). Some data suggest that interior live oak is maintaining the expected age-class distributions of more seedlings than saplings and more saplings than mature trees [14], but a few studies suggest rates of interior live oak regeneration may be lower than historical rates. Urban encroachment into oak woodlands poses a serious threat to interior live oak regeneration [74]. Forest Inventory and Analysis data from 2001 to 2005 showed that across California's forestlands, interior live oak numbered about 275 million seedlings (diameter class of 1.0-2.9 inches (2.5-7.5 cm)); 125 million saplings (3.0-4.9 inches (7.6-22.9 cm)), and about 2 million relatively large trees (9.0-10.9 inches (23-27.7 cm)). Compared to California black oak, interior live oak showed higher rates of regeneration but also had higher rates of mortality [14]. Bartolome and others [17,149] reported widespread presence of interior live oak saplings in the late 1980s, but saplings did not outnumber mature trees. Ratios of saplings:mature plants were ≤1:1 in the North Coast Ranges and Klamath-Siskiyou regions and from 1:1 to 1:2 in the Central Coast Ranges and Sierra Nevada [149]. In manzanita chaparral in northern California, scrub interior live oak regeneration averaged ≤1.2 seedlings/m². Most were between 0 and 20 inches (8 cm) tall (Parker unpublished data cited in [153]). Some interior live oaks had apparently grown into the canopy since the last fire [153].

There is evidence that in general, many oak species in the blue oak woodland belt are failing in the pole stage [186], but as of this writing (2011), information of interior live oak in particular was sparse.

On 192 plots in Madera, Fresno, Tulare, and Kern counties, 75% of plots had interior live oak seedlings and 48% had saplings. Interior live oak regeneration was not significantly associated with grazing or elevation. Solar radiation, however, was positively associated with interior live oak seedling presence (P=0.1). The authors predicted that because sclerophyllous interior live oak is more drought-tolerant than deciduous blue oak, it might regenerate more successfully and dominate on drier sites than blue oak [185].

Interior live oak is reported as slow-growing [159]. This is may be due to the dry habitats it typically occupies, but studies exploring interior live oak growth rates on moist vs. dry sites were not available of as 2011.

Heavy mule deer [54] or other browsing can reduce or eliminate interior live oak regeneration. One year following a stand-replacement wildfire on Quail Ridge Reserve near Lake Berryessa, mule deer had browsed 95% of new interior live oak sprouts. The authors suggested that mule deer's preferential selection of interior live oak and blue oak sprouts was hindering postfire regeneration of the oaks [10]. After domestic sheep were removed from Sequoia National Park in the 1890s, there was a flush of oak (*Quercus* spp.) seedling establishment. The authors claim that unlike fire exclusion, which can favor shrubs over trees, density of woody species has increased since cessation of livestock grazing, but this has not resulted in a shift in species composition towards shrubs [174].

Vegetative regeneration: Interior live oak sprouts after top-kill by fire [87,98], cutting [127], or herbicide use [94]. Field experiments in the Santa Lucia Range and the Sierra Nevada showed that damaged interior live oaks may sprout in low numbers (2%-13%) even during stages of epicotyl emergence [131]. Large trees may produce epicormic sprouts after fire [87] or other injury to the bole.

A study in Mendocino County suggests that some interior live oaks may sprout after top-killing disturbances in most seasons. Sprouting responses of cut interior live oak and other oaks were compared throughout the year at the Hopland Field Station. In general, more interior live oaks sprouted after cutting compared to blue oaks; a similar number of interior live oaks and California black oaks sprouted; and fewer interior live oaks sprouted compared to barberry-leaved scrub oaks. Sprouting response of interior live oak was strongest from February through April, with 100% of cut interior live oaks sprouting during that time. Sprouting response was least in July (20%) but increased to 50% in September. Sprouts originated from both the base and the sides of interior live oak stumps. The author concluded that interior live oak was relatively insensitive to season of cutting [127]. This study did not explore sprouting response in late fall. Biswell and Gilman [24] observed that interior live oaks top-killed by fire in late fall sprouted the next spring.

SUCCESSIONAL STATUS:
Interior live oak is more frequent in open or early-seral communities than in late-seral communities. It is moderately shade tolerant; young plants are more tolerant than mature individuals [164]. In the North Coast Ranges of Mendocino County, interior live oak saplings were found in the understory of a mixed-evergreen forest, but they rarely grew over 0.3 foot (1 m) tall [104].

Interior live oak may replace valley oak successionally on valley-foothill interfaces [81]. (See the discussion of Griffin's study [81] in Plant response to fire for more information.) Conversely, Douglas-fir may replace interior live oak on favorable sites in mixed-evergreen communities of Mendocino County [104]. Chaparral and oak woodlands usually remain distinct, with little conversion of one type to another [120].

Fire is important in maintaining interior live oak chaparral and woodlands. Some consider relatively high-elevation interior live oak scrub a fire-maintained community, with ponderosa pine and other conifers replacing interior live oak without frequent fire [98]. See Postfire successional patterns for further information on interior live oak succession.

FIRE EFFECTS AND MANAGEMENT

SPECIES: Quercus wislizeni

FIRE EFFECTS:

Burned interior live oak-manzanita chaparral above pasture in San Diego County 's Daley Ranch Park. Photo courtesy of the San Diego Wildfires Education Project.

Immediate fire effect on plant: Fire top-kills most interior live oaks [78,83,163]. Low-severity fire causes little mortality for age classes, although it may kill some seedlings. Moderate-severity fire may kill small trees [87], and severe fire may kill even large interior live oaks [88]. Fire-scarred interior live oak trees were common on 7 sites across interior live oak's range in California [184].

Interior live oak's thin bark makes young trees susceptible to fire kill. Although the bark of mature trees is still relatively thin and has a high live tissue**:**dead outer bark ratio [164], mature trees may survive fire without top-kill [88,164]. Plumb and Gomez [164] observed that mature interior live oaks with heavily charred bark suffered no scarring and lost little bark to sloughing. They reported that surface fires rarely burned through to the wood, and repeated fires resulted in a hard, fire-cured bark surface [164]. Haggerty [88], however, reports that fire scars large interior live oaks easily.

Fuel mastication in oak-knobcone pine or other communities may result in fires that are more lethal than fires in communities with unmanipulated fuels. In a California black oak-knobcone pine community in Whiskeytown National Recreation Area, sites where fuels were masticated prior to spring burning had higher flame lengths, higher fire temperatures in the litter layer, and greater mortality of overstory and pole-sized oaks—including California black, interior live, and canyon live oaks—than sites where fuels were not manipulated. Mastication was done in November, and the study sites were burned under prescription in April. Interior live oak and canyon live oak were overstory associates [42].

Postfire regeneration strategy [188]:
Tree with adventitious buds and a sprouting root crown
Tall shrub, adventitious buds and a sprouting root crown

Fire adaptations and plant response to fire:
Fire adaptations: Interior live oak has adapted to fire by sprouting from perennating buds on the root crown [88,138,202]. It may sprout even in the seedling stage [88]. Among large-fruited taxa that grow in chaparral, interior live oak is one of the most successful postfire sprouters on north-facing slopes, where it typically shades out most obligate seeders in early postfire years [138]. Plumb and MacDonald [165] summarize the need of interior live oak and other California oaks for frequent fire:

"Although fire is anathema to individual oak trees, it is essential for continuation of oak stands under natural conditions, especially on commercial timber sites where inherently taller conifers are more competitive. By destroying the conifers, the oaks are free to sprout. Because of rapid sprout growth, the oaks capture the area and are perpetuated."

Although the relationship between fire frequency and *Quercus* regeneration is unclear, several studies show that frequent fire favors oak regeneration, reduces ladder fuels in the understory, and helps control acorn predators such as the filbert weevil and filbert worm (review by [183]).

Plant response to fire: Interior live oak sprouts from the root crown after top-kill by fire [24,25,28,69,83,87,98,109,181]. Postfire recovery is usually rapid [98]. Keeley [109] classified interior live oak as an "obligate resprouter" after fire. Biswell and Gilman [24] rated it a "vigorous" sprouter after fire, showing a stronger sprouting response than associated deciduous oaks such as California black oak and blue oak. Interior live oaks often have multiple stems as a result of repeated top-kill by fire and postfire sprouting [157]. Top-killed interior live oaks may sprout soon after winter, spring, or summer fires (see Vegetative regeneration). With summer fires, sprouts may appear as early as postfire week 3, but with late fall fires, sprouting does not usually begin until the next spring [24].

Large, old trees may survive fire without being top-killed [87] but more often, large trees are located in areas that have not burned for 50 to 100 years [157]. Large trees may produce epicormic sprouts after surface fire [87] that scorches the branches.

Fire may kill interior live oak in areas with heavy fuels, particularly in chaparral or communities with a chaparral understory. In a blue oak-interior live oak-gray pine/wedgeleaf ceanothus woodland in Madera County, a prescribed 5 August fire killed 75% of interior live oaks. In postfire year 9, interior live oak comprised 15% of total woody plant species composition. A similar prescribed fire in Madera County resulted in 90% kill of interior live oak. In postfire year 7, interior live oak comprised 15% of total woody plant species composition. Chaparral whitethorn and wedgeleaf ceanothus dominated the community [25]. Prefire composition of these plant communities was not provided.

Interior live oak may establish from acorns after fire, but postfire sprouting is far more important [87]. One year following a stand-replacement wildfire on Quail Ridge Reserve near Lake Berryessa, density of interior live oak seedlings was not significantly different between burned and control plots. It ranged from 7 to 100 seedlings/ha. However, basal sprout regeneration was significantly greater in burned than in control plots ($P<0.05$) [10]. Surveys of 91 interior live oak-dominated plots on the San Bernardino Forest found no interior live oak seedlings in interior live oak chaparral, while interior live oak forests averaged 10 interior live oak seedlings/0.1 ha. The authors suggested that longer fire-return intervals on forest plots allowed formation of the forest stand structure and establishment of interior live oak seedlings [211]. Minnich [138] stated that because chaparral taxa do not rely on off-site seed dispersal onto burned sites, they are not vulnerable to fire size.

Fire scars can be ports of entry for heart-rot fungi. To date (2011), however, little research had been conducted on the relationships between fire, oaks, and heart-rot fungi [165].

Postfire recovery: A qualitative study on the Los Padres National Forest found interior live oak sprouted from the root crown after the Marble-Cone Wildfire of August 1977. The fire burned 178,000 acres (72,000 ha); most of this acreage was mixed chaparral. Scrub interior live oaks "were seldom completely consumed by the chaparral crown fires; they usually remained as charred trunks, perhaps five to ten feet tall, standing above the ashes". Within a month after the wildfire, they were sprouting from the root crowns and by November, the sprouts were "several feet tall". A portion of the higher-elevation, mixed-evergreen canyon live oak-tanoak-interior live oak forest also burned in the Marble-Cone Wildfire, with a mix of surface and crown fire that varied in severity from low to high. Scrub interior live oak also "sprouted readily" from the base after top-kill in this mixed-evergreen forest [83].

No interior live oak mortality was observed in postfire month 10 (July) after severe wildfire in September 1947 on the Tehama Deer Winter Range. All interior live oaks were top-killed, with an average sprout height of 24.9 inches (63.2 cm) in postfire month 10. Mule deer browsed the sprouts heavily the 2nd winter after the wildfire [24].

Prescribed fire and clearcutting may result in similar interior live oak coverage. Eight years after a moderate-severity, prescribed September fire in the Santa Ynez Mountains, interior live oak had similar densities—10 sprouts/900 m^2—on burned plots and on clearcut, unburned fuelbreaks [36].

Although interior live oak sprouts may be dense in early postfire years, stem density usually decreases with succession. Many sprouts of chaparral species do not survive if the site burned when root crowns and roots were water-stressed and/or had low carbohydrate reserves [175]. Heavy postfire browsing may reduce or eliminate interior live oak postfire regeneration [95], especially on small burns. After a 1,100-$foot^2$ (100 m^2) test plot in interior live oak chaparral near Santa Cruz was burned under prescription, mule deer browsed interior live oak and California coffeeberry (*Rhamnus californica*) sprouts so heavily that many plants of both species died, and bigberry manzanita, which was not browsed, became dominant [80].

Two studies, one in Sequoia National Park and the other in Madera County, show a short-term reduction in interior live oak after fire, with interior live oak showing rapid recovery in early postfire years.

In Sequoia National Park, a 26 June 1987 arson fire reduced interior live oak abundance for at least 2 postfire years. Fire conditions were "extreme", with a mean daytime air temperature of 86° F (30° C), relative humidity of 17%, and fine fuel moisture of 3.5%. Slopes ranged from 20° to 39°; mostly, dry annual grasses carried the wildfire [87]. Fire severity was mixed, varying from low to high [88]. Fire severity became moderate after midnight, when relative humidity rose to 50%. Fire effects and postfire responses were measured the fall after the wildfire and in postfire year 2. As measured that fall, postfire mortality of interior live oak was low: only one "very small diameter" stem had been killed. Crown scorch of interior live oaks and blue oaks combined ranged from 18% on west-facing slopes to 61% on ridgetops; bole char height ranged from 8 inches (20 cm) on west-facing slopes to 39 inches (100 cm) on east-facing slopes. Nine interior live oak seedlings were found on study sites; all were determined to have established before the fire. All 9 seedlings sprouted after the fire, but 1 seedling had died by postfire year 2 [87].

In postfire year 2, all large (82.6-133.4 inches (32.5-52.5 cm) diameter), crown-scorched interior live oaks had live crowns and had produced epicormic sprouts, but most smaller trees were dead [87]. Most crown-scorched interior live oaks were <82 inches in diameter, so mortality was highest in smaller size classes [88]. Mortality also increased with degree of crown scorch; overall, all interior live oaks with 100% crown scorch were dead, while none with <51% crown scorch had died [87]. Some surviving crown-scorched individuals grew both epicormic and basal sprouts. Chances of interior live oak stem survival (vs. top-kill) increased with tree size ($P<0.001$), and 86% of large trees bore scars from previous fires. Over half of top-killed interior live oaks (n=154 individuals) had basal sprouts [88].

Mortality was higher for interior live oaks than for blue oaks in postfire year 2: 11% of tagged, burned interior live oaks and 6% of tagged, burned blue oaks were dead. Survival rates of postfire sprouts were higher for interior live oak than for blue oak [87], however, and interior live oak had more sprouts/root crown [88]. More than half of interior live oaks that sprouted the fall after fire had surviving sprouts in postfire year 2, while only 2 top-killed blue oaks still had live sprouts [87].

The author concluded that the wildfire reduced interior live oak density in the short term due to aboveground mortality of small trees, but because most large trees survived, there was little change in interior live oak's basal area [87]. See the Research Paper of this study for further details on fire effects on and postfire responses of interior live oak and blue oak.

Mechanical and prescribed fire treatments reduced interior live oak cover for about 6 years in Madera County. On the Ellis Ranch, a private cattle ranch spanning elevations from 2,500 to 3,250 feet (750-975 m), 600 acres (240 ha) of interior live oak and blue oak woodlands were thinned, then the shrub understory crushed, in July 1986. During thinning, all interior live oaks were cut for firewood but most blue oaks were retained for shade. After mechanical treatments, the site was burned under prescription in August 1986. The goals were to increase browse available for cattle and wildlife, reduce canopy cover of interior live oak, and reduce understory fuels [71,135].On 2 of 5 plots, these treatments significantly reduced interior live oak cover in postfire year 1 compared to pretreatment cover ($P<0.05$) [71].

Interior live oak cover, density, and firewood volume after thinning, crushing, and prescribed fire in Madera Cou calculated from 5 interior live oak-blue oak or blue oak-interior live oak stands [71,135].

Variable	Pretreatment (1986)	After mechanical treatments (1987)	Postfire year 1 (1987)	Postfire year 2 (1988)	Postfir (1989)
Cover (%)	36.6	17	4.4	10	8.2
Density (stems/0.2 acre)	26.6	23.6	0	1.8	not ava
Firewood volume (cords (feet³))	1.17 (149.76)	0.72 (92.16)	0.72 (92.16)	0.17 (21.76)	0.03 (3

In the short term, interior live oak canopy cover and volume were reduced the most on sites where interior live oak was dominant before treatments; this was attributed more to cutting than burning. Crushing and burning successfully reduced shrub density, cover, and height, so more browse was available as forage [135]. Interior live oak was returning to pretreatment density by postfire year 2, particularly on plots where it dominated before treatments. On all sites, wedgeleaf ceanothus and yerba santa comprised about half of the new canopy by postfire year 3 [71,135]. A follow-up prescribed fire in 3 to 4 years was recommended to once again reduce abundance of interior live oak and the shrubs [71]. Repeat burning was not accomplished, however, so by postfire year 8, canopy cover of shrubs was similar to pretreatment levels. Interior live oak regeneration had not regained tree size, so on sites where interior live oak dominated before treatments, stand structure had shifted from an overstory of interior live oak trees to an overstory of shrubs. Blue oak was the sole overstory dominant in former blue oak-interior live oak stands [135].

Postfire successional patterns: Fire generally favors interior live oak [181] successionally. In a survey of 5 blue oak sites in Sequoia National Park, interior live oak was most frequent (15%) on a site that burned 5 years previously. The other 4 sites had not burned for about 40 years, and interior live oak frequency ranged from 5% to 10% on those sites [44]. Minnich [140] noted that interior live oak and other spouting species dominated early postfire succession in Coulter pine-canyon live oak woodlands on the eastern Transverse Ranges. Vegetation from <1-year-old to 37-year-old burns was surveyed. Interior live oak was described as a dominant in early postfire succession. Interior live oak and other sprouting woody vegetation provided up to 9% cover in postfire years 0 to 9; 85% cover in postfire years 10 to 19; 75% cover in postfire years 20 to 29; and 77% cover in postfire years 30 to 37 (Minnich 1978 field data cited in [140]).

Surveys in southern California show that interior live oak chaparral remains stable over time. On a site that burned in a 1919 wildfire on the San Dimas Experimental Forest, Angeles National Forest, crown cover of interior live oak had not changed from that recorded in a survey conducted in postfire year 14 (1933) and in a survey conducted in postfire year 34 (1950). Interior live oak and toyon were the 2 most common species in the mixed chaparral community. Interior live oak showed minimal gains in crown cover on a similar site that had gone 55 years without fire prior to wildfires in 1933 and 1936 [114].

Surveys conducted by Griffin [81] in the Santa Lucia Mountains suggest that fire-return intervals that are longer than those that occurred historically favor interior live oak and other evergreen oaks over valley oak in high-elevation (4,575 feet (1, 525 m)) savannas. He noted that interior live oak, canyon live oak, and tanoak were replacing valley oak successionally on high-elevation sites, while coast live oak was replacing valley oak on lower-elevation sites. He suggested that this successional replacement may be occurring because in the past, frequent, low-severity surface fires favored valley oak over the evergreen oaks [81].

FUELS AND FIRE REGIMES:

- **Fuels**
- **Fire regimes**

Fuels: The chaparral belts in which interior live oak grows contain highly flammable vegetation [105,134]. This, coupled with the hot, dry conditions that occur during the fire season (see Climate and moisture regime), makes chaparral sites easily ignitable [23]. When vegetation is dense, the often interlocking chaparral crowns ensure fire spread due to highly flammable and continuous fuels [161], especially with high winds [23]. In interior live oak chaparral, vegetation may be so dense that it is impenetrable except during the first 5 to 10 years after a fire. Mature interior live oak chaparral stands reach about 12 feet (4 m) tall and are usually denser than adjacent, mature chamise stands [120]. Mixed chaparral stands in Santa Cruz County formed an "almost impenetrable growth" of interior live oak, California coffeeberry, and other sclerophyllous species. Overstory shrubs ranged from 4 to 12 feet (1-4 m) high, with a 0.5- to 3.0-inch (1.3-7.6 cm) litter layer. The author deemed the community "a high fire hazard" [105].

Compared to many sclerophyllous species, however, interior live oak foliage [138] and litter are relatively nonflammable. One comparison of the flammability of chaparral vegetation listed interior live oak as low in flammability relative to manzanita and ceanothus species, tanoak, and California black oak [209]. Interior live oaks did not ignite during a 3 August prescribed fire in wedgeleaf ceanothus chaparral in Kern County. Interior live oaks on the site had a rounded form, with branches extending to the ground. However, the author observed that the fire "failed to affect this species" because fuels beneath interior live oak trees were scant and did not carry the fire [122].

Interior live oak's sclerophyllous leaves may be slow to decay. Latting [120] described the litter layer of interior live oak stands at the ponderosa pine-oak woodland ecotone as "slippery piles of leathery oak leaves that defy decomposition". The interior live oaks were small, with little understory beneath their crowded crowns [120].

Litter accumulation beneath interior live oak can vary depending, in part, on time since the last fire. Plumb and Gomez [164] report that the litter layer of interior live oak is typically thick. In southern California, Halsey [89] found barberry-leaved scrub oak-interior live oak-Muller's scrub oak (*Q. cornelius-mulleri*) chaparral had a "moderate" leaf litter layer (~7 inches (18 cm) thick). These communities typically occur on north-facing slopes below 3,000 feet (900 m) and on all aspects above that elevation. Overstory oaks are 4 to 12 feet (1-4 m) tall [89]. An interior live oak-valley oak community in Tehama County had a mean litter depth of 0.5 inch (1.3 cm) in September; dried annual grasses comprised a far larger proportion of the ground layer (26.3%) than did evergreen leaves (0.6%). The canopy averaged 13.5 feet (4.1 m) tall with 25.2% closure; tree basal area averaged 7.8 m^2/ha [196]. After a fire in chaparral or oak woodlands with interior live oak, the ground layer may accumulate interior live oak debris until the decay rate equals or exceeds the rate of biomass accumulation. In burned, mixed-chaparral sites on the San Dimas Experimental Forest, biomass of interior live oak litter and woody debris increased linearly from postfire years 1 to 11 at an average rate of 0.082 ton/acre/year but then decreased without further fire [114].

From 1991 to 1994, the Forest Inventory and Analysis Program found that the greatest volume of live trees and coarse woody debris (CWD) of interior live oak was in the southern Sierra Nevada region (336.3 million $feet^3$ live trees, 69.0 million $feet^3$ CWD), and the least volume was in the North Coast Ranges (17.1 million $feet^3$ live trees, 7.1 million $feet^3$ CWD) (n=3,316 transects on 495 plots). Interior live oaks were considered tree-size when ≥5 inches (13 cm) DBH [197].

Pillsbury and Kirkley [162] provide equations to estimate total aboveground volume, wood volume, and saw-log volume of interior live oak and other California hardwoods.

With fire exclusion, interior live oak may become a ladder fuel in blue oak, valley oak, and other communities that historically burned less often than interior live oak-dominated communities. In oak woodland/annual grassland, dry herbaceous vegetation is the main fuel that carries fire [28];

however, ingrowth of understory interior live oak and ponderosa pine can increase fuel loads in and flammability of blue oak woodlands [82,154].

Fire regimes: Interior live oak is adapted to stand-replacing fires in chaparral [84] and frequent surface fires in oak and oak-pine woodlands ([98,180,183], review by [49]). Relatively frequent, recurring crown fires help maintain interior live oak chaparral [49]. In both chaparral and oak woodlands, most wildfires historically burned down from higher-elevation conifer ecosystems [70,201]. Lightning ignitions are infrequent in chaparral and oak woodlands; historically, American Indians, miners, and ranchers were probably responsible for most fires in these communities [70]. With a long history of fire use by American Indians and then European settlers, it is difficult to separate natural and anthropogenic fire regimes in oak woodlands [183]. Interior live oak woodlands, and blue oak [180,183] and oak-conifer ([98], review by [49]) woodlands with a substantial interior live oak component, historically experienced mostly short return-interval surface fires, although these woodlands may also experience mixed-severity fires [156].

Chaparral: Chaparral ecosystems have short to moderate intervals between stand-replacement fires [113,211]. Minnich [138] describes a "smolder and run" behavior of chaparral fires. The fire cycle is irregular due to variations in weather and stand configurations of annual grassland-chaparral-oak woodland mosaics, but chaparral remains "remarkably stable under a wide range of fire regimes" that can vary from 20 to 100 years between fires [138]. Fire intensity is generally high but varies with fuels and weather. Most fires occur in summer, although Santa Ana winds can drive large wildfires in autumn [111].

Because fire scar records are rare to lacking in chaparral ecosystems, it is difficult to determine historic fire-return intervals. They may range from 10 [175] to as long as 60 ([113], reviews by [49,70]) or 100 [138] years. Rundel [175] pointed out that chaparral vegetation can burn after only a few years of postfire growth. Kittredge [114] reported that an interior live oak chaparral site on the San Dimas Experimental Forest reburned 3 years after a previous wildfire.

Short fire-return intervals favor sprouting species such as interior live oak, while relatively long fire-return intervals favor a mix of sprouters and obligate seeder species such as wedgeleaf ceanothus [24] and common deerweed (*Lotus scoparius*) [113]. Pioneer accounts of fire patterns in southern California chaparral suggest that before 1919, chaparral fires varied in severity across the landscape, with the low fuel loads of recent burns supporting less severe fires than the higher fuel loads of sites that had not burned in decades [142].

Fire exclusion may have had little effect on either fire frequency or fire size of chaparral, although experts disagree on this. Minnich [141,142] claims that in chaparral, fire size, rate of spread, and severity during extreme fire weather conditions have increased since attempts at fire exclusion. With the more even-aged structure of contemporary chaparral, Santa Ana winds tend to drive fires without the reductions in fire severity historically provided by young chaparral stands [142]. However, Keeley and others [112] contend that neither fire size nor severity have increased with attempts at fire exclusion in chaparral ecosystems. Their analyses of chaparral in southern California found fire frequency increased during the last half of the 20th century, but average fire size decreased. They attributed these changes to increased anthropogenic ignitions—

mostly from arson—and fire suppression. Keeley [111] suggests that the 30- to 40-year fire-return interval typical of California chaparral during the last half of the 20th century is more frequent than fire-return intervals of the past.

Oak woodlands: Oak woodlands, including interior live oak and blue oak-interior live oak communities, have a long history of intentional burning by American Indians and ranchers [187]. Interior live oak woodlands and forests historically experienced mostly frequent understory surface fires [211]. Fire-scar evidence is difficult to obtain from interior live oak and other oaks due to the prevalence of heart rot in old oaks, so fire-scarred conifers growing in oak communities are usually used to obtain fire histories [187]. Fire-scarred ponderosa pines recorded the fire history of an interior live oak-canyon live oak-California black oak/whiteleaf manzanita (*Arctostaphylos viscida*)-toyon woodland in El Dorado County. From 1850 to 1952, fire-return intervals on 3 sites ranged from 2 to 18 years and averaged 7.8 years. Stand structure was likely open during that period. There was no significant difference in mean fire-return intervals among the 3 sites despite large differences in slope (5%, 30%, and 55%). Cattle ranching was the primary land use during the time studied, and the author surmised that fires were set frequently by ranchers to improve cattle forage. Before the mid-1800s, the area had been a community center for the Miwoks; unfortunately, there were no ponderosa pine trees or stumps old enough to record the fire history of that time. By the 1990s, successional changes with fire exclusion had led to a dense stand structure of 1,635 trees/ha; 75% of the basal area was oaks [187]. Roy and Vankat [174] claim that excluding fire from oak woodlands can lead to a shift in species composition, with successional replacement of decadent overstory oaks by understory chaparral shrubs.

California's oak/grass woodlands historically experienced surface fires every 5 to 25 years [183]. These frequent fires burned at low severities, which tended to kill shrub seedlings and keep the shrub layer short [88,202]. Grasses likely fueled these mostly fast-moving fires [88]. Occasional mixed-severity fires also occurred [156]. Because these communities form a mosaic with or lie between chaparral and low-elevation ponderosa pine woodlands, chaparral shrubs or conifers formed pockets where fire crowned, resulting in more lethal effects to vegetation, especially nonsprouting species [202].

Yosemite National Park's fire records from 1930 to 1983 show that lightning ignitions were relatively infrequent in the canyon live oak-interior live oak-chaparral ecosystem, but when fire occurred, it was "very intense". Fire occurrence was disproportionately low in the ecosystem (4.2% of the Park but 1.9% of fires), with a fire-return interval of about 20 to 30 years. Excepting fires <10 acres (4 ha) in size, area burned averaged 177.5 acres (71.8 ha). Because canyon live oak-interior live oak chaparral-woodlands lie outside wilderness areas of the Park, fires in this ecosystem were suppressed during the time under investigation [201].

Oak-conifer woodlands: Frequent fires are needed to maintain the oak component of California's oak-conifer ecosystems (for example, [187]), although as of 2011, information on fire regimes in interior live oak-conifer ecosystems in particular were lacking. Ponderosa pine-oak woodlands with an interior live oak component historically experienced mostly short-interval, low-severity surface fires that favored both pines and oaks (review by [49]). Scrub interior live oak is prominent on new burns in bigcone Douglas-fir woodlands [5]. Little fire history was available on bigcone Douglas-fir communities as of 2011. However, bigcone Douglas-fir communities lie next to California's chaparral belt and burn often. Bigcone Douglas-fir generally survives and sprouts after surface but not after crown fires [139], so surface fires likely help maintain bigcone Douglas-fir communities. Walter and others [208] suggest that fire-return intervals in Coulter pine communities are variable. Areas going 100 or more years without fire may develop into open forests with an overstory of Coulter pine, canyon live oak, and interior live oak and an understory of chaparral whitethorn, Eastwood manzanita, and other chaparral species [208].

Because California's oak-conifer communities usually occur near chaparral or conifer forest ecotones and often have chaparral species in the understory, they may experience mixed or stand-replacement fires. Knobcone pine communities, in which interior live oak and other scrub oaks are often important components of the vegetation [5,12], primarily have stand-replacement fires at intervals long enough that the knobcone pine can establish and produce its serotinous cones before the next fire [98]. Knobcone pines must be at least 10 years old to produce cones [206].

See the Fire Regime Table for further information on fire regimes of vegetation communities in which interior live oak may occur.

FIRE MANAGEMENT CONSIDERATIONS:
Fire is a vital component of chaparral and woodland communities with interior live oak. Frequent fires can encourage new growth of interior live oak and other sprouting species on rangelands [24,24]. Where oak woodland/annual grassland communities form mosaics or blend with chaparral, fires at 20- to 25-year intervals may best balance the regeneration requirements of sprouting species and those that regenerate solely from seed, such as wedgeleaf ceanothus [24].

Chaparral is not usually burned under prescription because of the high flammability of many chaparral species. Green [77] noted that chaparral can rarely be burned successfully under prescribed weather conditions because under the prescription window for weather, the shrubs are usually too moist to burn. Typically, litter and small twigs are consumed but larger stems are not, and the prescribed fire skips over large patches of brush [77]. If prescribed burning is planned and reducing oak cover is a fire management goal, he recommended prefire preparation that top-kills and desiccates the brush, such as crushing or herbicides, with herbicides most effective on oaks and other species with thick, stout stems. See his 1977 publication [77] for detailed instructions on these prefire treatments, and his 1980 publication [78] for recommendations on preparing a prescription for burning in chaparral.

Plumb and MacDonald [165] consider fire an "almost inescapable occurrence" in California oak woodlands and state that trying to exclude fire from these woodlands is not practical. Periodic surface fires in oak woodlands reduce fuel loads, especially the shrub understory, and help prevent severe wildfires that can be lethal to oaks. Hence, they recommend allowing or prescribing frequent, low-severity surface fires in oak woodlands to reduce fuel loads and interference with oak growth from associated shrubs [165].

Fires in oak woodland-chaparral communities can favor mule deer. Near Clear Lake, does averaged higher rates of ovulation on brushlands burned under prescription compared to unburned brushlands, and bucks were heavier. Blue oak-interior live oak-gray pine and chamise chaparral communities formed a mosaic in the area [26].

MANAGEMENT CONSIDERATIONS

SPECIES: Quercus wislizeni

FEDERAL LEGAL STATUS:
None

OTHER STATUS:
Information on state- and province-level protection status of plants in the United States and Canada is available at NatureServe.

IMPORTANCE TO WILDLIFE AND LIVESTOCK:
Use as rangeland: Oak communities with interior live oak are important rangelands [15] for wild and domestic ungulates. Blue oak-interior live oak-foothills pine woodland/annual grasslands of the Sacramento and San Joaquin valleys are particularly prized as productive rangelands [22]. Mule deer [13,20,54] and feral hogs [13] use oak woodlands with interior live oak as their primary habitats. In the Sacramento Valley, mule deer used oak woodlands as often as expected, and wedgeleaf ceanothus chaparral more than expected, based on availability. Feral hogs used interior live oak woodlands more than expected [13].

Interior live oak is an important deer food. In Lake County, mule deer browsed interior live oak year-round, with heaviest use in spring and summer [20]. Use may also be high in winter, when deciduous species have shed their leaves, and in spring, when new shoots are available [24]. A study on the Tehama Winter Deer Range found acorns and dry oak leaves were the primary components (65% of total) of the mule deer diet in October and November. Mule deer used interior live oak as much as expected based on its availability [123].

Oak/annual grassland types are California's primary livestock grazing lands [3,23,63,196]. Cattle [13] and domestic sheep [20] forage in oak woodlands on low foothills. Cattle use flat, open woodlands, while mule deer generally prefer more closed sites with rockier terrain [13]. In Lake County, domestic sheep browsed interior live oak mostly in late spring and summer [20].

Many wildlife species consume interior live oak acorns, including bears [89,189], mule deer [9,24], squirrels [9,81], other rodents [81], acorn woodpeckers [9,116], scrub jays [9], and band-tailed pigeons. Acorns, including those of interior live oak, are a winter staple for band-tailed pigeons [150]. American black bears in the Transverse Ranges consumed large volumes of acorns (canyon live oak and interior live oak, 13%-19% of total diet); behind garbage, acorns were their primary food source [189]. Historically, the California grizzly bear, the largest race of grizzly bears [89], also consumed acorns [81]. Chaparral was a preferred habitat of California grizzly bears [89].

Acorns can be important cattle feed; however, acorns are low in protein and become available after annual herbs have died, so cattle consuming large amounts of acorns require a protein supplement [207].

Habitat use: Oak woodlands, including those with interior live oak, are tremendously important wildlife habitat [183]. A study on the Central Coast Ranges found mule deer generally preferred a mixed-oak woodland habitat over chamise chaparral, but they preferred a chamise community after a prescribed fire. Mule deer used the chamise chaparral burn as primary habitat from about postfire year 2.0 to 2.5, then resumed using the mixed-oak woodland as their primary habitat [115]. On the Sierra Foothill Range Field Station, a 3-year study found wildlife species diversity was directly related to diversity of the mixed-oak woodland. Hutton's vireo, orange-crowned warblers, and Wilson's warblers were positively associated with interior live oak. Over 60 bird species bred and resided year-round in the oak woodland, and many others used the area as winter habitat. Several rodent and herptile species, such as brush mice and western fence lizards, were positively associated with the oak woodlands ($P<0.1$ for all variables). See Block and Morrison [30] for a list of these wildlife species. In a Kern County study, salamanders were positively associated with interior live oak-foothill pine woodlands on north-facing slopes. Except for the ground layer, vegetation cover was higher in salamander habitats than on sites without salamanders ($P<0.05$). Ensatina was the most commonly captured amphibian [31]. Black-bellied, California slender, and yellow-blotched salamanders are also positively associated with interior live oaks [32].

On 2 sites in the Sierra Nevada and 1 in the Tehachapi Mountains, Nuttall's woodpeckers foraged heavily in interior live oak-gray pine woodlands outside the breeding season, but they used blue oak woodlands during the breeding season. Interior live oaks selected for foraging were larger than average, but acorn woodpeckers typically selected large gray pines over large interior live oaks for foraging [29]. Surveys across California's oak woodlands found Nuttall's woodpeckers used live oaks, including interior, canyon, and coast live oaks, for foraging about 19% of the time. They used blue oak (51% use) more than the evergreen oaks but less than other deciduous oaks or gray pine [147].

See these sources for lists of birds using oak woodlands with interior live oak as habitat: [167,172,205].

Interior live oak woodlands are high-quality dusky-footed woodrat habitats [121]; in part, because they provide important food. On the San Dimas Experimental Forest in the San Gabriel Mountains, acorns of scrub interior live oaks were the primary food stored in dusky-footed woodrat nests at high elevations (>4,500 feet (1,400 m)), even though canyon live oak acorns were more plentiful and larger [99].

Many insects use interior live oaks as habitat. Interior live oak hosts Cynipidae gall wasps [52]. The pan-like depressions that are created by scar tissue around branch breaks collect water in spring; these depressions are habitat to maturing insects including mosquitoes, midges, syrphid flies, and moth-flies [215].

Palatability and nutritional value: New spring growth and sprouts arising after fire or other top-killing events are highly palatable to mule deer [24]. Livestock also find interior live oak palatable, and they utilize it increasingly as annual grasses dry and lose nutritional value [129].

Overall nutritive value of interior live oak appears low. In a laboratory experiment using captive mule deer and domestic sheep, total digestible nutrient content of interior live oak was less than that of alfalfa (*Medicago sativa*) or chamise. The authors concluded that interior live oak was of little to no value as a source of protein but overall, it was a fair source of total digestible nutrients [20]. However, interior live oak provides a little protein in late fall and winter months, when deciduous browse species have shed their leaves. Bissell and Strong [19] found interior live oak protein content peaked in June at 8% and was least in December and February at 1%. See these sources for further details on the nutritional value of interior live oak browse: [19,20,176].

Browse of interior live oak and other evergreen oaks is generally less palatable than that of deciduous oaks due to higher concentrations of tannins and lignins in the leaves [155]. However, domestic goats usually find interior live oak moderately to highly palatable [79]. In the Sierra Nevada, they ate interior live oak stems "avidly" (observations by [79]). In mixed chaparral in southern California, domestic goats ate 5-year-old, postfire scrub interior live oak about as much as expected, preferring sprouts of birchleaf mountain-mahogany, redberry buckthorn (*Rhamnus crocea*), and barberry-leaved scrub oak over sprouts of interior live oak [79].

Cover value: Oak woodlands provide vitally important cover for wildlife. Squirrels and cavity-nesting birds often prefer cavities in oak branches or boles for nesting, while rodents, skunks, and foxes dig and den in the roots or in downed interior live oak logs [9].

Many wildlife species may prefer interior live oak and other evergreen oaks as cover in late fall and winter, when deciduous trees lack foliage. Feral hogs in the Sierra Nevada used interior live oak woodlands as bedding and forage sites. Their use increased in winter, when associated blue oaks had lost their leaves and provided less cover [13]. In urban Sacramento, yellow-billed magpies selected interior live oaks as communal roosts over all other tree species during the December through May study period. Evergreen species in general were selected over deciduous species [53].

In a blue oak woodland on the San Joaquin Experimental Range, understory interior live oaks apparently helped protect California towhee nests from predation. On cattle-grazed sites, California towhees preferred interior live oaks for nesting (25% frequency vs. 8% frequency for all other nest-trees), and nesting success was greater in interior live oaks than in other nest-trees.

For cover near the actual nest-tree, successful nests were built on sites with more understory interior live oak cover than occurred on nest-predated sites (*P*=0.003). Western scrub-jays were responsible for most nest predation. On ungrazed sites, California towhees preferred to nest in wedgeleaf ceanothus (18%, 4%, and 12% use for wedgeleaf ceanothus, interior live oak, and other nest-trees, respectively). Nest failure was significantly higher on ungrazed than on grazed sites (*P*=0.008) [168].

VALUE FOR REHABILITATION OF DISTURBED SITES:
Interior live oak provides watershed protection [105] and is recommended for erosion control [99]. See these sources for propagation and planting information: [34,99].

OTHER USES:
Interior live oak produces good-quality firewood [164,173]. Much interior live oak was cut for cordwood around the turn of the 20th century [173]. The wood has little value as lumber [155].

Acorns of interior live oak and other oaks were a staple of California Indians [8,130]. In order to produce new sprouts for basketry, Indian women used fire regularly to top-kill interior live oaks. They preferred 1-year-old sprouts for making baskets [7].

OTHER MANAGEMENT CONSIDERATIONS:
See Plumb and MacDonald [165] for a guidebook on managing California's oaks.

Interior live oak is apparently resistant to sudden oak death disease. As of 2003, it was the only red oak in California in which the disease had not been detected in the field [60].

Possible impacts of climate change on interior live oak are uncertain. Models of McBride and Mossadegh [133] suggest the distributions of most California's oak species, including interior live oak, will not shift with climate change. However, paleobotanical investigations by Davis [55] revealed distributions of California's oak species have shifted in the past with climate change, and he predicts that the distributions of California's oaks will shift with new changes in climate. Large-scale vegetation monitoring (>17,000 plots) across California suggests that the elevational range of interior live oak is extending upslope [195].

Although interior live oak's value for wildlife and livestock is now appreciated, it has been disparaged in the past. In the 1950s and 1960s, some management plans called for removing oaks in general and interior live oak in particular from California's foothills in order to increase herbaceous livestock forage and water yields [21,43,64,94].These efforts greatly increased rates of soil erosion on steep slopes [43,65] and had inconsistent results regarding herbaceous forage yield production after oak removal [183]. Studies have shown decreases [72], no clear trends [169], or increases in forage production [73] after interior live oak removal. In general, oak removal did little to increase water yields on foothill slopes [25,65], although some studies showed increased water yields on valley bottoms after oaks were cut [25].

On the San Joaquin Experimental Range, forage production was greater beneath interior live oak canopies than in the open during 2 drought years. The 1st year of the drought, herbaceous forage biomass peaked in May, at about 700 kg/ha more under interior live oak canopies than in the open. The 2nd year, forage production peaked in May at about 1,000 kg/ha more under interior live oaks than in the open. Herbaceous production early in the growing season (November-January) was similar under interior live oaks and in the open, but it was significantly greater under interior live oaks from March through May (P=0.05) [73]. In general, late-successional annual grasses such as wild oat and ripgut brome were more common under interior live oak than in open areas. Filaree (*Erodium* spp.), clover (*Trifolium* spp.), sixweeks grass (*Vulpia* spp.), and other early-successional species were most common in open areas (review by [183]).

Contrary to expectations, studies at 6 sites in northern and central California did not find a pattern of higher rates of available soil nitrogen beneath deciduous oak compared to evergreen oak species. Available soil nitrogen beneath interior live oak's canopy was similar to that beneath deciduous valley oak and higher than that beneath evergreen blue oak and deciduous California black oak (P=0.1) [152].

APPENDIX: FIRE REGIME TABLE

SPECIES: Quercus wislizeni

The following table provides fire regime information that may be relevant to interior live oak habitats. Follow the links in the table to documents that provide more detailed information on these fire regimes.

Fire regime information on vegetation communities in which interior live oak may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [119], which were developed by local experts using available literature, local data, and/or expert opinion. This table summarizes fire regime characteristics for each plant community listed. The PDF file linked from each plant community name describes the model and synthesizes the knowledge available on vegetation composition, structure, and dynamics in that community. Cells are blank where information is not available in the Rapid Assessment Vegetation Model.

California

- California Grassland
- California Shrubland
- California Woodland
- California Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)

California Grassland					
California grassland	Replacement	100%	2	1	3
California Shrubland					
Coastal sage scrub	Replacement	100%	50	20	150
Coastal sage scrub-coastal prairie	Replacement	8%	40	8	900
	Mixed	31%	10	1	900
	Surface or low	62%	5	1	6
Chaparral	Replacement	100%	50	30	125
Montane chaparral	Replacement	34%	95		
	Mixed	66%	50		
California Woodland					
California oak woodlands	Replacement	8%	120		
	Mixed	2%	500		
	Surface or low	91%	10		
Ponderosa pine	Replacement	5%	200		
	Mixed	17%	60		
	Surface or low	78%	13		
California Forested					
California mixed evergreen	Replacement	10%	140	65	700
	Mixed	58%	25	10	33
	Surface or low	32%	45	7	
Coast redwood	Replacement	2%	≥1,000		
	Surface or low	98%	20		
Mixed conifer (north slopes)	Replacement	5%	250		
	Mixed	7%	200		
	Surface or low	88%	15	10	40
Mixed conifer (south slopes)	Replacement	4%	200		
	Mixed	16%	50		
	Surface or low	80%	10		
Jeffrey pine	Replacement	9%	250		

	Mixed	17%	130		
	Surface or low	74%	30		
Mixed evergreen-bigcone Douglas-fir (southern coastal)	Replacement	29%	250		
	Mixed	71%	100		
Interior white fir (northeastern California)	Replacement	47%	145		
	Mixed	32%	210		
	Surface or low	21%	325		
Red fir-white fir	Replacement	13%	200	125	500
	Mixed	36%	70		
	Surface or low	51%	50	15	50

*Fire Severities—
Replacement: Any fire that causes greater than 75% top removal of a vegetation-fuel type, resulting in general replacement of existing vegetation; may or may not cause a lethal effect on the plants.
Mixed: Any fire burning more than 5% of an area that does not qualify as a replacement, surface, or low-severity fire; includes mosaic and other fires that are intermediate in effects.
Surface or low: Any fire that causes less than 25% upper layer replacement and/or removal in a vegetation-fuel class but burns 5% or more of the area [91,118].

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Attachment #5

Book—116 pages.

Giusti, G.A. et al (editors). 2005. *A planner's guide for oak woodlands*. University of California, Agriculture and Natural Resources, Publication 3491, second edition.

Printout of pages of this book used as the basis for comments in this paper have been included with the hardcopy delivered to EDC's Community Development Agency.

Attachment #6

Oak Woodland Impact Decision Matrix

A Guide for Planner's to Determine Significant Impacts to Oaks
as Required by SB 1334.
(Public Resources Code 21083.4)

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Acknowledgements—The authors wish to express their sincere thanks to all of those individuals who participated in the support and review of this document. Without their help this project would not have achieved the level of quality that is before you. Special thanks to Marilyn Cundiff of the Wildlife Conservation Board for her vision and energy that made this project possible; Dr. James Bartolome, UC Berkeley; Dr. Robert Johnston, UC Davis; for their invaluable insights and suggestions to the manuscript. A special thanks to the nearly 500 planners from both the public and private sector who attended the 5 regional workshops held in 2007 throughout California. Your professionalism and dedication to your craft is an inspiration to us all.

TABLE OF CONTENTS

Introduction

In 2004 the California Environmental Quality Act (CEQA) was amended with the passage of SB 1334, (Chapter 732, and Statutes of 2004). As amended, CEQA now requires a county to determine whether a project within its jurisdiction may result in a conversion of oak woodlands that will have a significant effect on the environment. According to the law (PRC 21083.4) if a county determines that a project will result in a significant effect to oak woodlands, the county shall require one or more oak woodland mitigation alternatives to mitigate for the significant effect associated with the conversion of oak woodlands.

In response to numerous inquiries from county planners, developers and concerned citizens on how to implement this new provision of CEQA, the University of California (UC) Integrated Hardwood Range Management Program (IHRMP) convened a working group comprised of the California Department of Fish and Game, the California Department of Forestry and Fire Protection and the Wildlife Conservation Board (WCB). The purpose of the working group was to develop information to assist county planners with the process of determining project significance including, what types of projects fall under the purview of the law, what constitutes a “significant impact,” compliance standards, effective strategies to conserve oak woodlands and how to determine suitable, appropriate mitigation.

In addition to this report, tools such as a web-based decision key, PowerPoint presentations and visual comparison standards for assessing oak woodland impacts will be made available through the IHRMP web site. This represents an ongoing effort to assist county planners on how to protect and conserve critical oak woodland resources and comply with new regulations.

What Science Tells Us About County Conservation Planning

Given the variety of regional situations that face county planners, it is important to first consider broad, conceptual conservation goals and then develop applicable tools that allow the concepts to be visualized “on the ground.” Forman and Collinge (1997) maintain that in order to conserve biological diversity conservation planning should be done before more than 40 percent of the natural vegetation is altered or removed from the landscape. Conservation planning grounded in science-based information allows for the development of sensitive planning scenarios that if initiated in the early stages of the development process can prevent environmental crises.

The Ecological Society of America (ESA) provides a basis for the conceptual approach to planning that should be included in conservation planning. In their Land Use Committee Guidelines for Land Use Planning and Management (Dale and others 2000) the ESA recommends;

1) Examine the impacts of local decisions in a regional context;
2) Plan for long-term change and unexpected events;
3) Preserve rare landscape elements and associated species;
4) Avoid land uses that deplete natural resources over a broad area;

5) Retain large contiguous or connected areas that contain critical habitats;
6) Minimize the introduction and spread of non-native species;
7) Avoid or compensate for effects of development on ecological processes; and
8) Implement land use and land management practices that are compatible with the natural potential of the area.

Furthermore, it is broadly recognized that a gap exists between conceptual planning designs and pragmatic implementation in the politically charged reality of county planning. Given this reality, it is important that scientifically valid approaches be included in the planning process. Also, well articulated decision-making tools need to be developed that specifically address the idiosyncrasies of oak woodlands. These tools must strive to incorporate the current conventional wisdom pervasive throughout the literature that identifies those elements or characteristics most important for maintaining the integrity of oak woodlands, i.e., old trees/forests, maintaining rare and representative habitats, riparian corridors, water quality and quantity, ecosystem functions and natural connectivity. Additionally, any planning tools should strive to assist planners in promoting compatible land uses to avoid or minimize habitat loss and fragmentation whenever possible.

All current projects should be viewed in context of past events.

In order to address the issue of "*significance*" there needs to be recognition that each project site has a peculiar history and situation. This history of site-specific land use practices may result in sites whose qualities span from relatively undisturbed sites to properties whose oak woodlands have been entirely altered.

We propose a decision matrix, described herein, that uses a process beginning with establishing a baseline site condition from which to initiate decision making process. It relies on the judgment of the resource professional and their ability to objectively determine is likely to have a significant impact.

What is a Woodland?

There are two very different approaches to address what appears to be a relatively straight-forward question.

- The first is to answer this question with a definition of oak woodland;
- The second is to use a *description* of oak woodland.

1. The first is a prescriptive, arbitrary standard or definition that is used to define a woodland, i.e., 10% canopy closure; trees of a certain diameter size class; number of trees per acre, etc.
2. The second option uses other qualitative standards such as soil type, or plant classifications that describe where different types of woodlands are expected to occur, i.e., valley oak woodland soil types. This approach can also be used to describe where woodlands are capable of occurring based on site attributes.

Both options have merit. A jurisdiction has the freedom to decide which option better suits its particular needs.

There are eight major oak species that are generally recognized to occur across California;

- **Blue oak**, **valley oak**, **Oregon white oak** and **Engelmann oak** are all deciduous and members of the white oak group.

- **Coast live oak**, **interior live oak**, and **canyon live oak** are three important evergreen oaks in the red oak group. **California black oak** is a deciduous oak in the red oak group.

Oaks can be found in a wide range of canopy densities depending on site characteristics and landscape characteristics (e.g. aspect, soil type, vegetation community type) as well as historical land use practices (e.g. burning, clearing). Small isolated stands (less than 1 acre) with lower than 10 percent cover are often not considered to be part of a woodland but rather represent remnant trees which can have ecological value but may not be part of a functioning woodland.

It is not unusual for woodlands to have both multiple oak species and other non-oak associates growing in close approximation including madrones, alders, maples, sycamores, and Douglas-fir.

For information on how to identify California's tree oaks, their biology, and the associated plants that are commonly found with them, please see http://danr.ucop.edu/ihrmp/oaks.html.

Step I: Getting Started—Establishing Site Condition

To use this matrix a planner must first establish the condition of the site (*for a review of the CEQA guidelines on establishing site condition see §15125 and §15126*). Site condition should evaluate either the oaks as individual trees, or the condition of the oaks as a component of a larger forest. Significance at both scales can then be determined based on the alterations being proposed and how these alterations might affect the ability of the site to continue providing the ecological goods and services currently in place.

By assessing past, present and future impacts on oak woodlands this matrix is designed to help address potential *Cumulative Impacts* as part of the assessment of significance. Significance criteria for cumulative impacts to biological resources may include:

- The cumulative contribution of other approved and proposed projects that lead to fragmentation of oak woodlands in the project vicinity.

- The net loss of sensitive habitats and species.

- Increased fragmentation of woodlands and loss of habitat connectivity.

- Contribution of the project to urban expansion into natural areas.

- The potential for the proposed project to increase run-off, nutrients and other pollutants into adjacent waterways.

- Isolation of open space within the proposed project by future projects in the vicinity.

To evaluate the quality and ecological condition of a site, we propose that a planner should ascertain if the site represents an oak woodland whose ecological functions are still relatively “intact,” “moderately degraded,” or “severely degraded.” This relative comparison is intended to classify the current state of the site to what would be considered undisturbed oak woodland.

Intact?

The site is currently in a “wild state” being managed for grazing, open space, recreation, etc., where all of the ecological functions are still being provided, i.e., shade, ground water filtration, wildlife/fish habitat, nutrient cycling, wind/noise/dust abatement, carbon sequestration, etc. In this condition roads and buildings are rare across the site. Trees, both dead and alive, dominate the landscape and the site is capable of natural regeneration of oaks and other plant species. The site allows for movement of wildlife and the existing development is localized and limited to a small number of residences with service buildings or barns. The site is relatively undisturbed and is recognized as ***Intact.*** Examples of an ***Intact*** woodland may include large to moderately (even relatively small parcels may qualify) sized private ranches; expansive oak woodlands zoned for agriculture, open space, scenic corridors, etc.

Some latitude is necessary to allow a site to be classified as ***Intact***. There are very few private lands in California that are entirely free from land use and ecological impacts. Virtually all oak woodland-grass communities are dominated by exotic grasses and forbs in the understory. Also, fire exclusion has affected the density and species composition of oak woodlands in many locations. The designation ***Intact*** refers mainly to being free from destructive land use practices that inhibit or limit the oak woodland to naturally sustain itself and its associated flora and fauna.

If a site is classified as ***Intact***, any proposed project that would substantially change its conditions may be determined to have significant impacts. That determination should be based on the findings of an impact assessment process; an example is described in the next section of this matrix.

Moderately Degraded?

In this case, the site has obviously been altered from a “wild” condition but is currently in a state where oak trees are present; natural regeneration is capable of occurring; limited ecological services are still being provided and the site still provides for utilization by wildlife. Roads and stream crossings are present but limited or clustered. Developed areas are centralized and concentrated over a small percentage of the site. The site is recognized as being ***Moderately Degraded***. Examples of ***Moderately Degraded*** oak woodlands may include some golf courses, large ranches that have been subdivided into large parcels, oak woodland subdivisions that share “common grounds” of woodland acres.

A ***Moderately Degraded*** site has been changed in one or more ways that has reduced its potential for providing ecological and socially important services. For example, it may have been partially developed resulting in the net loss of trees; the canopy or understory may have been reduced or eliminated over all or part of the site; past grazing or soil disturbance may have impaired regeneration in some areas or it may be a situation where “ranchettes” dot the landscape.

Severely Degraded?

Here a site has been dramatically altered and is currently in a condition that has no trees or very few remain; it is being managed in such a way that natural regeneration is not possible or practical; the soil is compacted or contaminated; and/or has been used for residential, commercial or industrial purposes. Roads and stream crossings are commonplace and fencing and other obstructions limit wildlife access and movement. This site should be considered ***Severely Degraded***.

> Some isolated rare oak trees, even though found in a severely degraded site, such as valley oak or Englemann oak may warrant special consideration based on their overall distribution within a county. These types of trees or small stands should be evaluated on the basis of regional occurrence and site potential for restoration. Additionally, some jurisdictions may have local statutes that provide additional protection to heritage trees.

Although a site in a severely degraded state may perform limited or no ecological or socially important functions, it may have potential for restoration or enhancement as part of a proposed development. That said, it should not simply be dismissed without considering possibilities for mitigating past damage. Restoring or improving the woodland on the site could provide benefits such as improving connectivity or patch size for locally important wildlife habitat.

Step II: Assessing Thresholds of Significance

> The Guide to CEQA, 11th edition states: “In the absence of an impact necessarily deemed significant, the lead agency has discretion to adopt standards for determining whether an impact is significant. In recent years interest has focused on encouraging agencies to develop standardized “thresholds of significance”, rather than to continue making ad hoc determinations in the context of particular projects…” See CEQA Guidelines § 15064.7 for more on establishing thresholds.

As with the determination of existing conditions, the evaluation of potential impacts of a project should be considered at three scales: (1) landscape, (2) site and (3) individual trees or groves. A project may have significant impacts at one scale but not at another. Or, in some cases, it may have significant impacts at all scales. For example, a project in an oak woodland deemed ***Intact*** that results in the removal of some trees but retention of other woodland qualities such as species composition and canopy cover may only have significant impacts at the tree scale. Another project that creates a barrier, such as a road that interrupts wildlife migrations, may have significant impacts at the landscape scale even if few trees are removed.

The determination of significance in an impact assessment is by no means simple. Any assessment should consider and address more than simply the impacts to the trees; the planner should consider the potential impacts to the other tangible aspects of the woodland.

Many jurisdictions have arbitrarily established thresholds of significance to aid in the determination process. The vast majority of examples to date have focused on the tree scale. [Only a few examples exist of counties developing spatial thresholds, i.e., Lake County's grading ordinance specifies one quarter acre of native vegetation as a threshold.] These include: individual tree diameter limits established in tree ordinances; soil disturbance limits often contained in grading ordinances; heritage tree designations initiating a discretionary permit review process prior to removal.

Here we propose another means of determining thresholds through a process of pre-determining those oak woodlands whose site qualities qualify them to be recognized according to there existing condition. By using spatially derived images (aerial photos, GIS data, etc) a planner can determine contiguous acreages of oak woodlands that may qualify as ***Intact*** woodlands; using other available planning tools areas could be identified as ***Moderately Degraded*** and the same could be done for ***Severely Degraded*** areas. Conceptually, this approach mimics other planning designations identified through zoning.

Developing a System Using Impact Prediction as a Means of Determining Significance

An important consideration dealing with *significance* in wildlands is the assessment and prediction of both the nature and extent of the potential impacts. Predictions can be based on simplified conceptual models of how natural processes function. Models range in complexity from those that are very intuitive to those based on explicit assumptions about environmental processes. We propose a combination of intuition and strict quantitative assessment to help make a determination. Criteria that can be used to describe the nature and duration of an impact may include:

Determination of Impact Magnitude

Spatial Extent

1) At the site scale:

What proportion of the woodland will be removed or changed to the extent that ecological functions or goods and services will be impaired? Metrics that can be evaluated include:

1. Road density pre and post development.
2. Percent canopy cover pre and post development.
3. Oak species present pre and post development.

4. Vegetation composition pre and post development.

2) At the landscape scale:

Would changes at the site cause fragmentation, loss of connectivity or interruption of processes such as wildlife migration, water flow, or increased fire risk over a larger geographic area? Metrics that can be evaluated include:

1. Road density within 1 km of the site,
2. Results in reduced distance between woodlands and urban development.
3. Changes in size and configuration of woodland habitat patches and increased edge habitat.
4. Severe wildlife corridors or habitat linkages thereby impacting animal and plant movement.

Temporal Extent

Does the proposal result in long-term impacts to the structure and ecological services being provided? Metrics that can be evaluated include:

5. What is the duration of the proposed impacts?
6. Are the impacts reversible?
7. Does the project protect oaks and other oak woodland components from future potential impacts to the site?
8. Are exotic and weedy species likely to increase at the site?

Impact Prediction Checklist—Intact Woodlands

If a project is being proposed for ***Intact*** woodland, the following criteria could be considered to determine significance.

- ✓ Net loss of oak woodland acreage.
- ✓ Increase habitat fragmentation.
- ✓ Loss of vertical and horizontal structural complexity.
- ✓ Loss of understory species diversity.
- ✓ Loss of food sources.
- ✓ Loss of nesting, denning, burrowing, hibernating, and roosting structures.
- ✓ Loss of habitats and refugia for sedentary species and those with special habitat requirements, i.e., mosses, lichens, rocks, native grasses and fungi.
- ✓ Net loss of oak woodland acreage.
- ✓ Road construction, grading, trenching, activities affecting changes in grade, other road-related impacts.
- ✓ Stream crossings, culverts, and road associated erosion and sediment inputs.

Although mitigation measures may help to diminish some of the negative aspects of a project, they can not ensure that the cumulative effects would not result in long-term changes affecting the ecological processes associated with an ***Intact*** woodland. Therefore, cumulative impacts may have to be considered when predicting the affect of a project proposed for designated ***Intact*** woodland.

Impact Prediction Checklist—Moderately Degraded Woodlands

Moderately Degraded woodlands may be the most frequently encountered oak woodland condition found in California. When a site is determined to be moderately degraded, the baseline conditions may be such that further perturbations will have a significant impact. Conversely, a proposed development may present opportunities for improving or enhancing site conditions.

If a project is being proposed for woodland you determine to be Moderately Degraded, the following criteria could be considered to determine significance:

- ✓ Net loss of oak woodland acreage.
- ✓ Increase habitat fragmentation.
- ✓ Loss of vertical and horizontal structural complexity.
- ✓ Loss of understory species diversity.
- ✓ Loss of food sources.
- ✓ Loss of nesting, denning, burrowing, hibernating, and roosting structures.
- ✓ Loss of habitats and refugia for sedentary species and those with special habitat requirements i.e. mosses, lichens, rocks, native grasses and fungi.
- ✓ Net loss of oak woodland acreage.
- ✓ Road construction, grading, trenching, activities affecting changes in grade, other road-related impacts.
- ✓ Stream crossings, culverts, and road associated erosion and sediment inputs.
- ✓ Road building activities that aggravate existing conditions.
- ✓ Changes in environmental conditions that prevent existing residual trees the ability to naturally regenerate.
- ✓ Proposed project designs that result in the construction of obstacles that pose as barriers to wildlife or fish passage.
- ✓ Proposed project designs that result in the probable introduction of invasive plants and animals.

Impact Prediction Checklist—Severely Degraded Woodlands

If the project is being proposed for a ***Severely Degraded*** woodland, consideration of the following impacts should be recognized to determine potential significance. In order for a site to be initially classified as ***Severely Degraded*** it should be highly altered, fragmented or in such a state as to make it virtually unrecognizable as ever having been an oak woodland. These sites may be urban, suburban or agricultural sites whose only link to its past natural heritage is found in the name of the community. In these sites, the oaks remain only as a relic of the past and the reality of oak regeneration is highly unlikely and constrained.

Take note that these sites may have significance if the relic trees represent a resource protected by local ordinance or statute. Additionally, the site may have significance if the relic trees are considered in a spatial context of what may have been found throughout the county prior to development, and though mitigation may never fully recover the lost biological attributes of a forest, it may serve as a strong source of civic pride that should be considered as part of the determination of significance.

The conversion of these resources may not lead directly to the loss or reduction of sensitive habitat or species but in a cumulative sense may be significant. Thus, impacts to ***Severely Degraded*** *sites may be less than significant* when dealing with individual trees on a small scale, but some projects, depending on specific attributes, may in fact be significant.

Scenarios where the loss of trees may be considered significant in a ***Severely Degraded*** oak woodland:

- ✓ Loss of individual heritage tress that are recognized and/or protected by ordinance or statute.
- ✓ Loss of appropriate recruitment sites for recognized and/or protected heritage tree species.
- ✓ Loss of individual trees in a county where the natural range and occurrence of the species has been dramatically reduced and/or altered thereby affecting the recruitment/restoration potential for the species.
- ✓ The removal of even a few individual trees, taken in spatial context of the county and species being considered, may represent a significant portion of the existing population of that species.

Scenarios that may be **less than** significant under this classification may include:

- ✓ Removal of a small number of immature trees for a road-widening project.
- ✓ Removal of a single tree(s) from a residential property associated with a remodeling project.
- ✓ Actions associated with tree care, maintenance and health, i.e., pruning, shaping, etc..
- ✓ Removal and replacement of street trees.
- ✓ Removal and replacement of landscape trees associated with existing developments.
- ✓ Removal of hazard trees where the threat of a tree failure could injure people or property.

Designing an Oak Woodland Decision Matrix

As has been previously stated, the matrix being proposed here relies on the planner making an assessment of the proposed project based on:

1. the site condition of the oak woodlands at the project site; and
2. the degree to which the initial site condition will be changed as a result of the project.

When developing your matrix start by using a set of broadly defined criteria as a means to identify rudimentary thresholds of significance in simple terms. These criteria apply subjective reasoning to determine the level of impact being proposed (Table 1).

Conceptually, your matrix should compare the site condition (Step I) to the relative impacts being proposed (Step II) thus, the matrix will provide both the planner and the applicant a relatively straight-forward and economically cost effective assessment of environmental impacts and their potential significance.

Table 1. Conceptual sample of how the decision matrix is intended to demonstrate the determination of ***significance*** by comparing the initial condition of the site with the proposed impacts of the project.

	Site Condition		
Degree of Impact	Undisturbed (Intact)	Moderately Degraded	Severely Degraded
Low	Moderately Significant	Least likely significant	Least likely significant
Moderate	Highly likely significant	Moderately likely significant	Less likely significant
High	Significant	Highly likely Significant	Most likely significant

If a county has pre-determined designated lands that are assigned a condition rating of ***Intact***, ***Moderately Degraded*** or ***Severely Degraded***, it will facilitate the process.

Table 2 provides example criteria that can be considered when trying to qualify impacts at a project level (Table 3). Supporting documents to consider should include maps, aerial photos, landsat imagery or areas/trees with special designation (rare, threatened or endangered habitats, heritage trees, zoning overlays, etc.)

Table 2. Criteria for consideration when rating of impact magnitude and significance. (Adapted from Rossouw 2003).

Impact Magnitude and Significance Rating	Examples
HIGH Of the highest order possible within the bounds of impacts that could occur. In the case of adverse impacts, there is no possible mitigation that could offset the impact, or mitigation is difficult, expensive, time consuming or some combination of these. Site scale—Typically on a small scale (less than 3 acres) a high impact would result in the removal of a majority of the existing trees. Landscape scale—Does the loss of trees result in habitat fragmentation because the site is located within a larger continuous patch of woodland. Existing threshold limits delineating significant impacts currently in use in California range from ¼ acre to 3 acres.	Examples include alterations/conversion of oak woodlands resulting in: ✓ Loss of vertical and horizontal structural complexity. ✓ Loss of understory species diversity. ✓ Loss of food sources. ✓ Loss of nesting, denning, burrowing, hibernating, and roosting structures. ✓ Loss of habitats and refugia for sedentary species and those with special habitat requirements, i.e., mosses, lichens, rocks, native grasses and fungi. ✓ Net loss of oak woodland acreage. ✓ Road construction, culverts, grading and other road-related impacts. ✓ Stream crossings, culverts, and road associated erosion and sediment inputs.
MODERATE A second order or tier impact. In the case of adverse impacts, mitigation or minimization of impacts is sometimes possible to offset overall alterations. Site scale—Both tree and non-tree components of the oak woodland are being considered for removal or alteration. Removal of trees will result in the creation of more edge impacts. Landscape scale—Increased edge habitat but less than 1 kilometer. Complete loss of habitat resulting in a disturbance envelops less than 3 acres. Existing threshold limits delineating significant impacts currently in use in California range from ¼ acre to 3 acres.	Examples of moderate impacts at a site scale may include: ✓ Understory removal. ✓ Thinning of existing trees. ✓ Removal of snags and other wildlife elements. Examples of moderate impacts at a landscape scale may include: ✓ Right of way clearing. ✓ Road alignments. ✓ Road expansion.
LOW A third tier or order of proposed impacts. In the case of adverse impacts, minimal disturbance is anticipated or can easily be avoided, minimized or mitigated.	Examples of low impacts at a site scale – Less than 10 trees: Large scale—No change to the stand structure and immeasurable impacts on canopy cover.

Table 3. This illustrates an example matrix and how it might be used to help determine significance.

	Initial Site Condition		
Impact Level	**Intact Woodland**	**Moderately Degraded Woodland**	**Highly Degraded Woodland**
Low Impact	Minimal disturbance to stand structure and composition and habitat features resulting in no increased edge habitat or fragmentation; road and stream crossings are not being considered; activities will not result in the introduction of exotic or invasive species. [Minimal site or spatial disturbance may still result in significant impacts to an intact or core woodland.]	Regeneration potential is being maintained across the site; expansion of developed areas are maintained and centralized; new road and stream crossings are not being considered. [In the absence of special circumstances, statutes or ordinances this may represent a non-significant impact.]	Majority of remnant trees are retained; understory removal or road widening protects existing tree health; individual tree removal on a residential, commercial or industrial site. [In the absence of special circumstances, statutes or ordinances this may represent a non-significant impact.]
Moderate Impact	Detectable change or reduction in canopy, structure or composition; loss of some habitat features, subtle impacts increasing fragmentation, edge creation or loss of connectivity (roads, fences, other introduced artificial barriers or buffers). [These impacts are considered significant.]	Regeneration potential is being marginalized; develop areas are expanding into previously undeveloped sites; new roads or stream crossing are being proposed; habitat features are being lost; activities being proposed will add to the existence of exotic and invasive species. [These impacts are considered significant.]	Loss of a majority of existing trees; activities will inhibit or harm residual tree health and vigor; barriers are constructed that increase fragmentation and connectivity; [These impacts may be significant.]
High Impact	Obvious change or reduction or loss in canopy, structure or composition loss of most of the existing habitat features and services; fragmentation and or parcelization of contiguous ownerships; introduction of roads or stream crossings; creation of edge habitats previously absent; construction of barriers (fences). [These impacts are considered significant.]	Large scale impacts including loss of habitat resulting in habitat fragmentation and increased edge. Loss of woodland structure and changes in composition occurring in large continuous patch of woodland. [These impacts are considered significant.]	Loss of remnant trees or stand increases fragmentation across the landscape through the loss of connectivity. [In the absence of special circumstances, statutes or ordinances this may represent a non-significant impact to oak woodlands.]

Step III: Identifying Potential Mitigatory or Remedial Actions

CEQA does not mandate similar mitigation for all similar projects. Nothing in CEQA requires a local legislative body to enact legislation which uniformly applies a certain level or standard of mitigation to all similar project submitted for environmental review within its jurisdiction. Guidelines § 15130.

Projects predicted to have significant impacts at the individual tree, site (or stand) and/or landscape scale should include mitigation measures designed to avoid, minimize or compensate the impacts. If that is not feasible, a project with residual significant impacts cannot be approved without a finding of overriding considerations by the approving jurisdiction. Mitigation measures may be proposed to reduce the level of impacts, restore impacted resources or enhance degraded resources. In some cases, on-site mitigation will not be practical and so provisions must be made for off-site mitigation or even compensation. Off-site compensation may include both direct measures at other suitable locations or contribution of in-lieu fees. To some extent, the existing conditions at a site, whether ***Intact, Moderately Degraded*** or ***Severely Degraded***, will determine the nature and feasibility of on-site mitigation. For example, although on-site mitigation is always preferred, a project within ***Severely Degraded*** oak woodland may have few options. Consequently, only off-site compensation may be feasible.

Appropriate Mitigation measures may include:

- ✓ Old trees with irreplaceable characteristics are retained.
- ✓ Snags are maintained or recruited where safe and feasible.
- ✓ Snags are well represented by size, specie, and decay class.
- ✓ Measures are initiated to minimize storm water runoff and other sources of non-point source pollution.
- ✓ Stream crossings include measures to minimize water quality degradation and facilitate fish passage.
- ✓ Hydrologically disconnect effects of impervious surfaces from waterways.
- ✓ Areas are designated to serve as seedling/sampling receptor sites or are designed to facilitate natural oak recruitment.
- ✓ Appropriate sites for long-term oak recruitment should be identified within the project impact area, e.g., roadside right-of-ways, utility easements, publicly owned open space, etc.
- ✓ Replacement of like-species of trees.
- ✓ Use of like-species of trees in off-site planting sites.
- ✓ A county-wide policy stipulating a percentage of native oaks be planted in all projects requiring landscape design approval.

- ✓ In-lieu fees, or the Wildlife Conservation Board or County department in order to provide a funding source to expand the impact of oak restorative actions across a larger spatial context on publicly maintained sites and roadways.

The matrix you develop for your particular jurisdiction should be fluid and elastic over time. As information becomes available, the decision matrix you use should be adaptable to address the challenges of your county.

Appendix I: Mitigation Considerations

The following recommended process was developed to help estimate a compensation fee listed as a mitigation option in California Public Resources Code 21083.4. This text will be incorporated into the implementation Section III of the overall decision-support document.

1. The WCB or Counties themselves are the only entities that can receive funds under option 3 of California Public Resources Code 21083.4[1].

2. Consider where in the County oak woodlands should be conserved to protect the natural communities they harbor and associated natural resource values. Ultimately, these are areas where funds will be required to protect privately-owned oak woodlands in the county. Existing regional land conservation plans developed by the county, stakeholders, or conservation organizations can be used. If no such plan exists, large continuous areas of mixed oak woodlands that are in need of protection from land conversion should be identified through a planning process (see Planners Guidelines – link to order).

3. Acquire all recent sales (1-3 years) data from woodland properties that are a priority for land conservation identified in step 2. Using this data, determine median value per acre for purchasing land in its entirety and the price range for acquiring a conservation easement from properties in these areas. If the project area falls within the area of interest for conservation then these values should also be determined based on the area impacted by the project. We encourage you to use a qualified property appraiser who has met the educational requirements for General Certification pursuant to the Appraisal Qualifications Board of the Appraisal Foundation and who holds a designation from a recognized professional appraisal organization. The appraiser should be familiar with conservation easement valuation and should follow best practice guidelines (web link here to SCAOSD guidelines).

4. Calculate the impact area of the project and include; the building envelope, new roads, landscaping, all areas enclosed by a fence that prohibits animal movement, and include a border surrounding the building envelope which will likely be impacted by activities associated with development such as pets and invasive weeds. Development results in human-created woodland edges where the natural habitat

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[1] (3) Contribute funds to the Oak Woodlands Conservation Fund, as established under subdivision (a) of Section 1363 of the Fish and Game Code, for the purpose of purchasing oak woodlands conservation easements, as specified under paragraph (1) of subdivision (d) of that section and the guidelines and criteria of the Wildlife Conservation Board. A project applicant that contributes funds under this paragraph shall not receive a grant from the Oak Woodlands Conservation Fund as part of the mitigation for the project.

ends and abuts the human-altered parts of the landscape. These edges can result in strong negative physical and biological impacts detectable as far as 1,640 feet into forested systems (Laurance 1995); therefore woodlands immediately adjacent to development will be impacted and should be considered as part of the impact area of the project.

5. Determine an appropriate mitigation ratio to determine the amount of in-kind (i.e. same type of woodland such as blue, valley or mixed) area that should be protected to compensate for the likely impacts associated with the proposed project.
   a. If you go with a 1:1 replacement this means that 50% of the woodland resources could ultimately be lost to development over the long-run.
   b. A 2:1 replacement will more fully compensate for the land impacted by the proposed development.

6. Calculate fee based on the cost of purchasing protected land in its entirety or through a conservation easement in the area identified as a priority for woodland conservation. The amount of protected land to base the fee on can be based on the number of acres impacted by the proposed (see #4) project times the mitigation ratio.

7. If the development being proposed is simply an addition to an existing structure or an outbuilding adjacent to an existing structure that will require the removal of a few trees; then compensation may best be approached through estimating the costs of replacing the trees removed. These estimates can be provided by a certified arborist or consult the International Society of Arboriculture standards for valuing trees of different sizes.

8. Sending this fee to the WCB satisfies the CEQA mitigation requirement detailed in California Public Resources Code 21083.4. The funds will remain with the WCB for future land conservation projects within that county. This allows for a transparent public process for reallocation of these funds to protect public trust benefits.

9. If the County is going to receive the money for compensation rather than the WCB they should consider:
   a. Collecting a fee for stewardship including compliance and resource monitoring. These fees often range from 5-10% of the total.
   b. The county should develop and continually update (every 5 years at least) a land acquisition plan that is approved by the county.
   c. The county should establish an independent spending authority to provide checks and balances to protect the public interest.
   d. County legal counsel will be responsible for ensuring that the public trust interests are protected through CEQA and for every negotiated conservation easement.
   e. The county will be responsible for compliance and resource monitoring of any conservation easements that they hold.

f. The funds collected as mitigation should not be transferred to a private company or non-profit without public oversight.
g. The time lag between collecting the fee and purchasing land as compensation should be minimized, while still allowing for enough funds to be accumulated to implement a beneficial acquisition.
h. If funds are held for a period of time, interest should be accrued in order to offset expected increases in land values.

Appendix II: PRC 12220

PUBLIC RESOURCES CODE SECTION 12220

12220. Unless the context otherwise requires, the definitions in this article govern the construction of this division.

(a) "Applicant" means a landowner who is eligible for cost-sharing grants pursuant to the federal Forest Legacy Program (16 U.S.C. Sec. 2103 et seq.) or who is eligible to participate in the California Forest Legacy Program and the operation of the program, with regard to that applicant, does not rely on federal funding.

(b) "Biodiversity" is a component and measure of ecosystem health and function. It is the number and genetic richness of different individuals found within the population of a species, of populations found within a species range, of different species found within a natural community or ecosystem, and of different communities and ecosystems found within a region.

(c) "Board" means the State Board of Forestry and Fire Protection.

(d) "Conservation easement" has the same meaning as found in Chapter 4 (commencing with Section 815) of Title 2 of Part 2 of Division 2 of the Civil Code.

(e) "Conversions" is a generic term for situations in which forest lands become used for nonforest uses, particularly those uses that alter the landscape in a relatively permanent fashion.

(f) "Department" means the Department of Forestry and Fire Protection and "Director" means the Director of Forestry and Fire Prevention.

(g) "Forest land" is land that can support 10-percent native tree cover of any species, including hardwoods, under natural conditions, and that allows for management of one or more forest resources, including timber, aesthetics, fish and wildlife, biodiversity, water quality, recreation, and other public benefits.

(h) "Landowner" means an individual, partnership, private, public, or municipal corporation, Indian tribe, state agency, county, or local government entity, educational institution, or association of individuals of whatever nature that own private forest lands or woodlands.

(i) "Local government" means a city, county, district, or city and county.

(j) "Nonprofit organization" means any qualified land trust organization, as defined in Section 170(h)(3) of Title 26 of the United States Code, that is organized for one of the purposes of Section 170(b)(1)(A)(vi) or 170(h)(3) of Title 26 of the United States Code, and that has, among its purposes, the conservation of forest lands.

(k) "Program" means the California Forest Legacy Program established under this division.

(l) "Woodlands" are forest lands composed mostly of hardwood species such as oak.

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Attachment #7

Senate Bill 1334 (Kuehl) – Synopsis of the Main Points

SB 1334 would require that timberland conversions (that take place outside of a Timber Harvest Plan) be mitigated by making a monetary contribution to the California Forest Legacy Program.

SB 1334 would require oak woodlands conversions to be subject to CEQA and to be mitigated. It would do so by requiring all 58 counties in California to adopt oak woodlands management plans and ordinances that require a discretionary permit for oak woodland conversions and set a minimum mitigation standard.

SB 1334 would only apply to counties. It would not apply to incorporated cities or other local jurisdictions. A county may impose a fee to cover administrative costs and the costs of monitoring and enforcing mitigation activities.

SB 1334 offers a "menu" of mitigation options. Mitigation options double the acreage of the land converted and provide for equivalent biological value. The planting option requires replacement trees at a five to one ratio. For projects located within an existing urbanized area, Urban Reserve Line, Urban Services Line, or within a city's sphere of influence as approved by LAFCO, mitigation could be reduced to one to one.

Mitigation options in SB 1334 options include:

- A monetary contribution to the Oak Woodlands Conservation Fund for the purpose of purchasing oak woodlands conservation easements.

- Onsite mitigation which requires the dedication in perpetuity of a conservation easement on mitigation lands that are contiguous to the project and that will provide for a biologically functional

- Offsite mitigation which requires the procurement of oak woodland habitat of equivalent biological value. Those mitigation lands shall be purchased in fee or by a conservation easement and conserved in perpetuity.

- Planting of replacement trees at a five to one ratio, on up to 10 acres , for each oak woodlands conversion project. Monitoring and replacement of dead and diseased trees would be required. The planting mitigation alternative may be used in conjunction with the other mitigation alternatives.

- If the Department of Fish and Game establishes a mitigation bank, the mitigation bank could be used to fulfill the offsite mitigation requirements of an oak woodlands conversion project, but no landowner may be compelled to use the mitigation bank.

For the purposes of SB 1334, the following terms have the following meanings:

- "Conversion" means cutting or removing 30 percent or more of the canopy from an oak woodland and changing the land use so that the converted acreage will not sustain oak species functioning as a biological unit in the future, or undertaking an activity within the dripline of an oak tree in order to convert the land into another use.

- "Oak" means a native tree species in the genus Quercus that is five inches or greater in diameter at breast height (dbh).

- "Oak woodland" means a tree habitat with five or more oak trees per acre, except for valley oaks (Quercus lobata) that include one or more trees per acre.

- "Equivalent biological value" means that the mitigation shall provide for the biological relationships between the affected oak woodland and the needs of affected plant and wildlife species in order to accommodate the normal life cycle of those species, including migration corridors, food availability, denning, spawning, nesting, and other functions necessary to complete a life cycle. The habitat components shall be in sufficient quantities and arranged to support the diverse plant and animal species that are normally found on or use the affected oak woodlands.

The oak woodlands management plan or county ordinance may exempt the following activities:

- Affordable housing projects for low and very low income (as defined HCD) located within an existing urbanized area, Urban Reserve Line, Urban Services Line, or within a city's sphere of influence as approved by LAFCO.

- The conversion of three acres or less of oak woodlands. A person or other legal entity may not use this exemption more than once in a five-year period.

- The harvesting of fuelwood for (non-commercial) use on the parcel from which it is harvested.

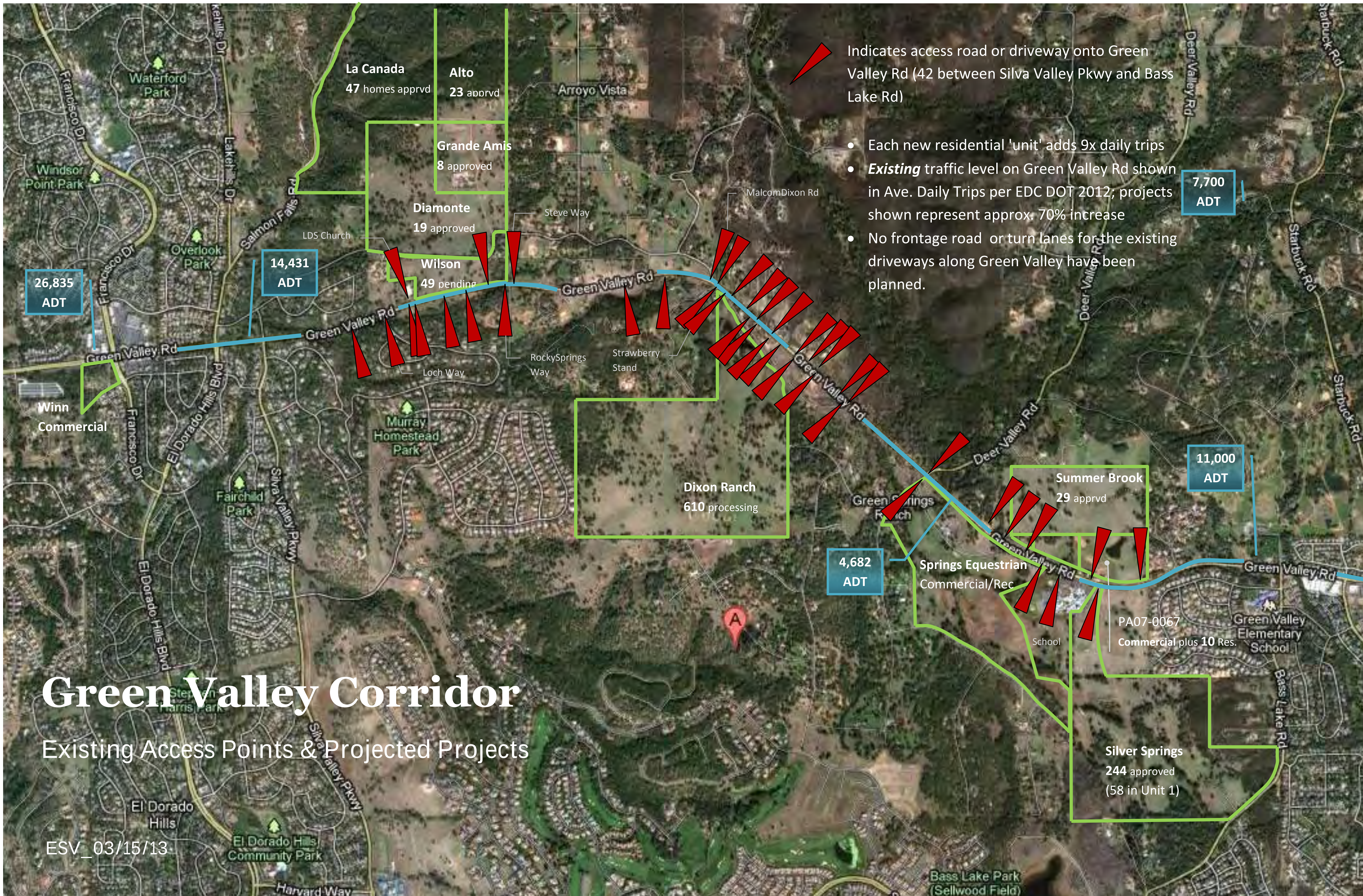
- An approved Natural Community Conservation Plan or approved subarea plan within an approved Natural Community Conservation Plan that includes oaks as a covered species.

- The removal of dead and diseased trees that pose significant risks to life, property, or to healthy trees.

- Projects within oak woodlands in which no oak trees greater than five inches in diameter at breast height are to be removed or projects that do not encroach upon the dripline of oak trees greater than five inches at breast height.

Nothing in SB 1334 prohibits a county from adopting a plan or ordinance that is more protective of oak trees or oak woodlands than provided for in the bill.

Attachment #8



Indicates access road or driveway onto Green Valley Rd (42 between Silva Valley Pkwy and Bass Lake Rd)
• Each new residential 'unit' adds 9x daily trips
• *Existing* traffic level on Green Valley Rd shown in Ave. Daily Trips per EDC DOT 2012; projects shown represent approx. 70% increase
• No frontage road or turn lanes for the existing driveways along Green Valley have been planned.
La Canada
47 homes apprvd
Alto
23 apprvd
Grande Amis
8 approved
Diamonte
19 approved
Wilson
49 pending
Dixon Ranch
610 processing
Summer Brook
29 apprvd
Springs Equestrian
Commercial/Rec
PA07-0067
Commercial plus 10 Res.
Silver Springs
244 approved
(58 in Unit 1)
Winn
Commercial
26,835
ADT
14,431
ADT
7,700
ADT
11,000
ADT
4,682
ADT
Green Valley Rd
Arroyo Vista
MalcomDixon Rd
Steve Way
LDS Church
RockySprings
Way
Strawberry
Stand
Loch Way
Deer Valley Rd
School
Green Valley
Elementary
School
Bass Lake Rd
Green Valley Corridor
Existing Access Points & Projected Projects
ESV_03/15/13

Attachment #9

Dam emissions rise
Low water levels at Folsom Lake are causing an increase in air pollution from the spillway project. Page B8

Opinion
MARCOS BRETON

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Hansen's got guts to defy KJ

Steve Hansen is showing some real daring in standing up to Mayor Kevin Johnson – the kind of political guts we don't often see in Sacramento.

KJ is easily the most popular politician in town. He is riding high after saving the Kings, cultivating a national profile and going after what he's always wanted: more hiring power, firing power and veto power for the mayor's office.

Influential people helped KJ put a strong-mayor proposal on the November ballot, and it appeared there

Friends mourn animal rescuer

THEY TIE HEALTH DECLINE TO RECENT DOG NEGLECT CASE

By Cynthia Hubert
chubert@sacbee.com

For decades, it was just Elaine Greenberg and her rescue dogs.

On her farm off a country road outside Davis, Greenberg took in dogs that had been burned and beaten, injured in dog fights, destined for death row. She fed, sheltered and trained them, paid for their veterinary care and found many of them new homes through her nonprofit group, Second Chance Rottweiler Rescue.

But something happened to Greenberg in the final months of her life that left her unable to care for her animals and herself, friends and acquaintances said. Earlier this month, authorities converged on her home and found a horrifying scene, with dead and malnourished animals living in squalor. They seized 11 surviving dogs, placed Greenberg on a "mental health hold" for a few hours and began investigating her for neglect.

Two weeks later, sheriff's deputies found Greenberg's dead body in her home. She was 74 years old.

The chain of events shocked longtime friends who knew Greenberg as an intensely private, somewhat cantankerous former biochemist who during the past two decades dedicated her life to saving dogs that otherwise likely would have been killed at animal shelters.

"She took dogs that no one else would take, and she gave them meticulous care, and she saved hun-

RESCUER | Page B2

Second Chance Rottweiler Rescue

Elaine Greenberg, 74, a longtime dog rescuer, was found dead in her Davis-area home over the weekend.

Water is way below allotments

TOTAL OF 'JUNIOR RIGHTS' IS 5 TIMES THE SUPPLY

By Matt Weiser
mweiser@sacbee.com

The state of California has handed out five times more water rights than nature can deliver, a new study by University of California researchers shows.

California's total freshwater runoff in an average year is about 70 million acre-feet, according to the study. But the state has handed out junior water rights totaling 370 million acre-feet. One acre-foot is enough to meet the needs of two average households for a year.

The rivers under the most strain, the research indicates, are virtually all that drain into the Central Valley, including the Sacramento, Feather, Yuba, American, Mokelumne, Stanislaus, Tuolumne, Merced, Kings and San Joaquin rivers. Others near the top include the Salinas, Santa Clara,

WATER | Page B3

FROM THE COVER

Water

FROM PAGE B1

Santa Ana and Santa Ynez rivers.

"It seems clear that in a lot of these cases, we've promised a lot more water than what's available," said Ted Grantham, the study's lead author, who conducted the research as part of postdoctoral studies at UC Davis. "There's never going to be enough water to meet all of these demands."

The study confirms prior estimates of the disparity but goes further by describing the degree of over-allocation in individual watersheds across California. It also reveals that the problem may be much larger since the researchers looked at only a subset of California water rights – those allocated after 1914 and considered "junior" rights.

California's system of water rights, overseen by the State Water Resources Control Board, is the primary means by which the state distributes natural runoff to provide water for cities, farms and industry. In most cases, a property owner or government agency applies to the state for a water right or permit. If granted, it allows them to divert a certain amount of water directly from a river or stream.

Such rights, for example, account for all the water stored behind dams in the state, which is the primary source of drinking water for many Californians and irrigation water for crops.

The study was published in the current issue of the journal Environmental Research Letters. It was conducted by analyzing more than 12,000 water rights issued after 1914, the year California adopted its system of water diversion rules. Only those rights had sufficient data available for analysis, Grantham said.

"It seems clear that in a lot of these cases, we've promised a lot more water than what's available. There's never going to be enough water to meet all of these demands."

TED GRANTHAM, *study's lead author*

The researchers then used streamflow data collected by the U.S. Geological Survey to establish baseline natural runoff volumes for about 4,500 sub-watersheds across the state. These data were compared to the water rights. In many cases, the results showed that diverters are allowed to withdraw far more water than the stream can produce in an average weather year.

"In so doing, they give these rights-holders a false sense of water security," said Joshua Viers, a co-author of the study and an engineering professor at UC Merced. "It's an entitlement that may never be filled. That is unfortunate, because we continue to allocate water rights to this day."

In dry years like this one, the disparity grows worse, because there is less snowmelt to feed streams. The consequences can be dire: This summer, the state water board imposed curtailments on about 10,000 water rights, requiring diversions to be halted completely because there isn't enough water to go around.

Craig Wilson, Delta water master for the state board, has a different view of the situation. He said the excess allocation of water is "overblown" because many water-rights holders actually divert less water than their permits allow. And very often, much of that diverted water returns to the same stream as runoff from farm fields, where it can be used again by someone downstream.

"It's very true, the board has issued water rights for more water than is available," said Wilson, who oversees water rights in the Sacramento-San Joaquin Delta. "I don't think it's nearly as big an issue as some people believe."

But Grantham said it is difficult to know for sure, because the state has no idea how much water is being diverted at any moment. Diverters are not required to report their water use in real time. Instead, they report water usage annually, and these reports are not verified for accuracy.

"Particularly in times of drought, I think there is just so much uncertainty in how these water rights are being exercised that it's practically impossible to try and manage these systems," said Grantham, who now works for the U.S. Geological Survey in Colorado.

It has long been assumed that correcting the excess allocation would be complicated because there are so many water rights, each with unique historical and legal complications. But Grantham said the study revealed that might not be so, because 80 percent of the water volume is held by 1 percent of the water rights, and mostly by government agencies.

"We don't really need to deal with thousands and thousands of water-rights holders," he said. "We might just need to deal with a couple hundred that hold 90 percent of the water."

Call The Bee's Matt Weiser at (916) 321-1264. Follow him on Twitter @matt_weiser.

Attachment #10

El Dorado Irrigation District

SB 610 Water Supply Assessment for the Village of Marble Valley Specific Plan

SB 610 Water Supply Assessment

Prepared for the
Village of Marble Valley Specific Plan

Final

August 2013

Prepared by:

Tully & Young
Comprehensive Water Planning

Prepared for:

El Dorado Irrigation District

Approved by Eldorado Irrigation District Board of Directors
on August 26, 2013 as action item #8

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Table of Contents

SECTION 1 – PROJECT INTRODUCTION

1.1 INTRODUCTION

In December 2012, the El Dorado Irrigation District (EID) received a letter from the El Dorado County Planning Department (County) requesting the completion of a Water Supply Assessment (WSA) for the Village of Marble Valley Specific Plan (hereafter referred to as the "Proposed Project"). As the proposed water supply purveyor for the Proposed Project, EID has prepared this WSA to assess the availability and sufficiency of EID's water supplies to meet the Proposed Project's estimated water demands. This document provides the necessary information to comply with the assessment of sufficiency as required by statute.

Statutory Background

Enacted in 2001, Senate Bill 610 added section 21151.9 to the Public Resources Code requiring that any proposed "project," as defined in section 10912 of the Water Code, comply with Water Code section 10910, et seq. Commonly referred to as a "SB 610 Water Supply Assessment," Water Code section 10910 outlines the necessary information and analysis that must be included in an environmental analysis of the project (e.g. CEQA compliance) to ensure that proposed land developments have a sufficient water supply to meet existing and planned water demands over a 20-year projection.

Proposed "projects" requiring the preparation of a SB 610 water supply assessment include, among others, residential developments of more than 500 dwelling units, shopping centers or business establishments employing more than 1,000 persons or having more than 500,000 square feet of floor space, commercial office buildings employing more than 1,000 persons or having more than 250,000 square feet of floor space and projects that would demand an amount of water equivalent to, or greater than, the amount of water required by a 500 dwelling unit project.[1]

The Proposed Project requires a WSA because it contemplates more than 500 new dwelling units as detailed in Section 1.2.

Document Organization

This WSA supports the Proposed Project's environmental review process and analyzes the sufficiency of water supplies to meet projected water demands of the Proposed Project through the required planning horizon. The WSA is organized according to the following sections:

- **Section 1: Project Introduction**. This section provides an overview of WSA requirements, and a detailed description of the Proposed Project, especially the land-use elements that will require water service.

[1] Water Code § 10912, subdivision (a).

- **Section 2: Proposed Project Estimated Water Demands**. This section describes the methodology used to estimate water demands of the Proposed Project and details the estimated water demands at build-out of the Proposed Project.

- **Section 3: Other Estimated Water Demands**. This section details the other water demands currently served by EID and anticipated to be served based on information in the El Dorado County's (County) General Plan as well as known and potential planned modifications since the County's adoption of the General Plan.

- **Section 4: Water Supply Characterization**. This section characterizes the EID water supply portfolio that will serve the Proposed Project along with other current and future water demands. Water rights, along with water service contracts and agreements are characterized for normal, single dry, and multiple dry year conditions.

- **Section 5: Sufficiency Analysis**. This section assesses whether sufficient water will be available to meet the Proposed Project water demands, while recognizing existing and other potential planned water demands within the EID service area. To provide the necessary conclusions required by statute, the analysis integrates the demand detailed in Section 2 and Section 3 with the characterization of EID's water supply portfolio detailed in Section 4.

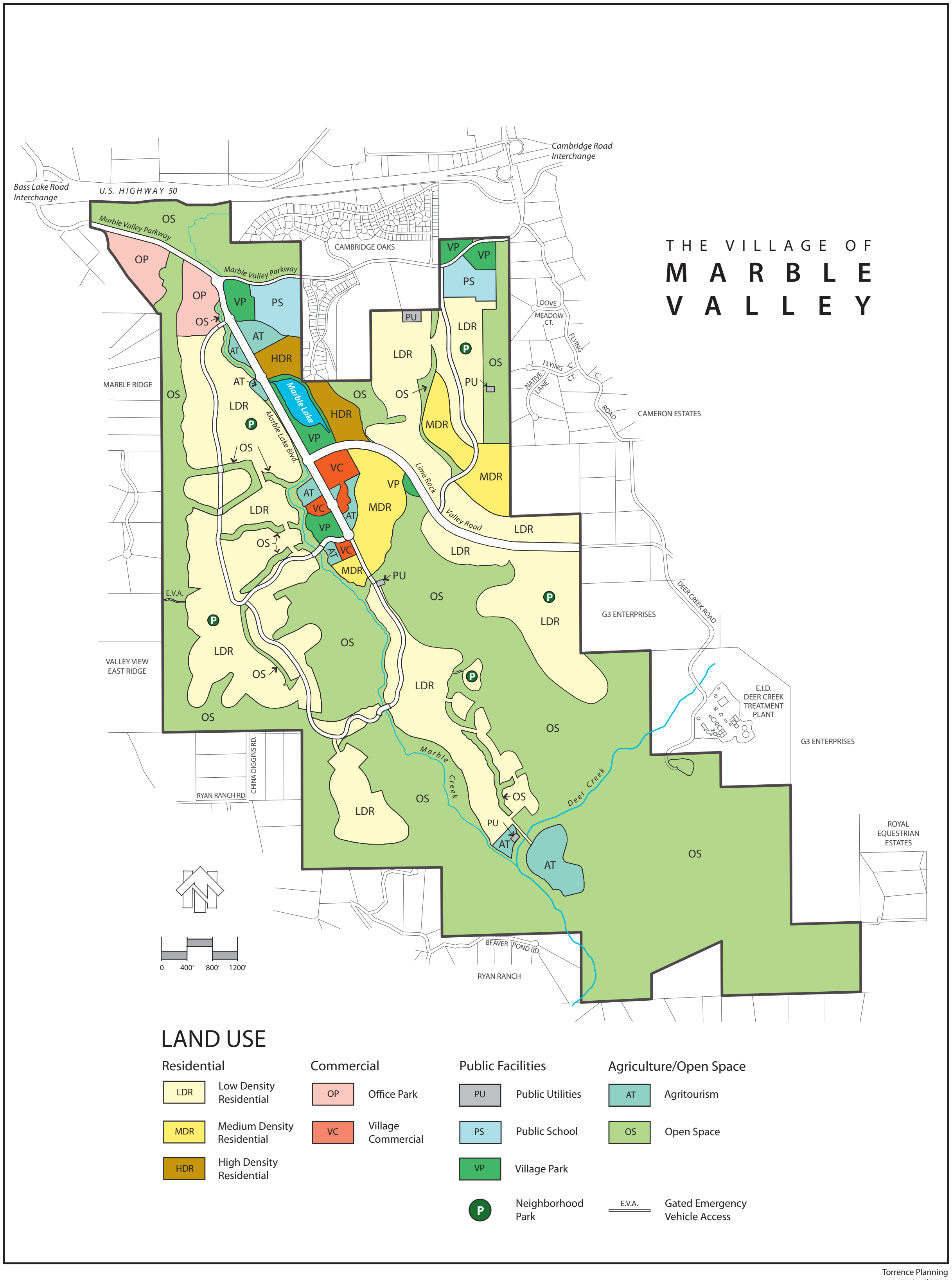
1.2 PROPOSED PROJECT DESCRIPTION

The Proposed Project is a planned development between Bass Lake and Cambridge Roads, south of Highway 50 encompassing approximately 2,340 acres in the unincorporated community of El Dorado Hills (see **Figure 1-1**).

The Proposed Project includes 3,236 residences, commercial space, village and neighborhood parks, agricultural uses, two schools, and open space. Proposed residential dwelling units include 193 custom lots on approximately 1 acre, 125 custom homes on approximately 1/2 acre-lots, 982 production lots with densities of 3 to 4 dwelling units per acre (designated "medium density-low"), 663 production lots with densities of 4 to 5 dwelling units per acre (designated "medium density-high"), 981 lots with densities of 7 to 12 dwelling units per acre (designated "Condo/Duplex"), and 292 high-density units (designated "multi-family"). Parks are spread throughout the project and include private parks in the gated areas, joint use parks along side the schools, village parks for non gated areas, a large park around the lake, and a historic park. The project includes about 475,000 square feet of commercial, retail, office, and other non-residential space residing on about 58 acres on the project site. Both a K5 and K8 school are planned for about 35 acres. About 55 acres of vineyards are to be planted on site both in designated lots and in some medians for aesthetics.

Table 1-1 summarizes the proposed land use acreages.

Figure 1-1 – Proposed Project Location and Land Uses



1.2.2 Projected Land Uses

Table 1-1 – Summary of Proposed Build-Out Land Uses and Acreages[2]

Land Use	Description	Acres	Units
1 Acre Custom Homes	1 DU/Ac	198	193
1/2 Acre Custom Homes	2 DU/Ac	62	125
3-4 per Acre Production Homes	3-4 DU/Ac	277	982
4-5 per Acre Production Homes	4-5 DU/Ac	148	663
Condominiums/Town Homes	5-12 DU/Ac	85	772
High Density Residential	12-24 DU/Ac	28	501
Office Park/Commercial	--	60	--
Schools	--	35	--
Parks	--	47	--
Open Space	--	1,282	--
ROW and Landscaping	--	73	--
Vineyards	--	55	--
	Total	**2,350**	**3,236**

1.3 PROPOSED PROJECT PHASING

Table 1-2 describes the Proposed Project's four construction phases. Each phase represents a portion of the development, focusing on particular land-use classifications. Before constructing homes, commercial space, or other parts of the development, the proponents will begin site grading and project-wide infrastructure development. Some infrastructure and site grading will continue throughout all phases of the Proposed Project, as necessary. These activities include installing facilities for potable water, recycled water (as appropriate for the Proposed Project), sewer, electric, telecommunications, gas, stormwater, and roads. During these activities, a small water demand will exist – referred to in this WSA as "construction water." This demand is included in the yearly water demands presented in Section 2.

The initial phase will result in approximately one quarter of the Proposed Project demanding water service by 2020, with the three subsequent phases each adding an additional quarter as they are completed. All construction is planned to be completed by 2035, within the 20-year planning horizon of this WSA.

[2] Specific Plan Land Use Summary was provided by El Dorado County of Development Services Department.

Table 1-2 – Proposed Project Schedule

Land Use	Phase 1 By 2020	Phase 2 2021-2025	Phase 3 2026-2030	Phase 4 2031-2035	Total
1 Acre Custom Homes	25	20	100	48	193
1/2 Acre Custom Homes	25	25	--	75	125
3-4 per Acre Production Homes	215	378	--	389	982
4-5 per Acre Production Homes	--	--	663	--	663
Condominiums/Town Homes	75	522	175	--	772
High Density Residential	209	50	228	14	501
Total	549	995	1,166	526	**3,236**

SECTION 2 – PROPOSED PROJECT ESTIMATED WATER DEMANDS

2.1 INTRODUCTION

This section describes the methodology, provides the supporting evidence, and presents the estimated water demands for the Proposed Project. For the purpose of estimating water demand, the Proposed Project is planned to develop according to the phasing in **Table 1-2**.

2.2 DETERMINING UNIT WATER DEMAND FACTORS

As detailed in Section 1, the Proposed Project has specific residential and non-residential land-uses with defined residential lot-sizes, types of commercial uses and other characteristics. As these attributes vary among the types of proposed land-uses, so too will the water needs. To understand the water needs of the entire Proposed Project, unique demand factors that correspond with each unique land use are necessary. This subsection presents the methodology for determining the baseline unit water use demand factors that become the basis of the Proposed Project water demand estimates. Two distinct groups of demand factors are presented: (1) residential, and (2) non-residential.

2.3 PRIMARY SOURCE OF BASELINE WATER USE DATA

Because the Proposed Project is very similar in nature to particular elements built as part of the Serrano and El Dorado Hills developments over the past few decades, recent water use data for comparable products in these neighborhoods provides a reliable foundation for EID to establish new project-specific water demands. Through comparison of Proposed Project land-use elements to existing land uses, EID determined appropriate existing, established neighborhoods and commercial facilities that best aligned with each unique residential and non-residential project element. For each comparable neighborhood, EID gathered and assessed total annual water use for the years 2008 through 2012. This selected period of water use best represents 1) the highest build-out percentage within each selected area (including established back-yard landscapes), and 2) varied water use over a range of climatic conditions reflecting various rainfall amounts and timing. Average annual uses were derived from the data and are discussed under the respective land-use categories.

2.4 BASELINE RESIDENTIAL WATER USE DEMAND FACTORS

The Proposed Project anticipates specific residential products that fall within general lot-size designations. The size of the lot will have the largest impact on the annual per-lot demand for water. Indoor demands remain relatively consistent regardless of lot size, with the exception of apartments, which tend to have fewer people living in each unit and thus a slightly lower indoor use.

For purposes of this WSA, the per-lot demand for residential lots will be described as "the acre-feet of water use annually per dwelling unit" – or simply put, acre-feet/dwelling unit (af/du). This value will reflect indoor and outdoor uses expected for a typical dwelling unit for each of the following classifications:[3]

- 1-acre custom lots
- ½-acre custom lots
- 8,000 to 10,000 square-foot production lots
- 5,000 to 7,000 square-foot production lots
- Condominiums/townhouses
- Multi-family housing with community facilities including pool and/or clubhouse

The method and basis for determining the baseline unit water demand factor for each of these classifications is detailed in the following subsections.

1-Acre Custom Home Lots

Water demand factors for the proposed large lots are based on recent water use data records for residential lots in the Serrano development – specifically existing residential lots located on Greenview Drive, Errante Drive, and others. The proposed lots in this category average at about 1 acre. However, not all land on these lots will be landscaped. For instance, a lot may include hillside and/or areas of oak woodland that must be protected, resulting in a diminished area for the home's footprint, outdoor hardscapes and landscaping. Generally, the house itself is large, with extensive outdoor features including pools, hardscapes, water features, and significant landscaping with well-maintained turf areas.

Based on available historic meter data for similar developments served by EID, the baseline unit water demand factor for this land-use category is approximately 1.16 af/du.

½-Acre Custom Home Lots

Water demand factors for the proposed large lots are based on recent water use data records for residential lots in the Serrano development – specifically existing residential lots located on Renaissance Way and Renaissance Place. The proposed lots in this category average at about 1/2-acre though have a project minimum of 15,000 square feet. Landscaping on the lot may be based on a predetermined landscaping package for a production home. Generally, the house itself is large, with extensive outdoor features including pools, hardscapes, water features, and significant landscaping with well-maintained turf areas.

Based on available historic meter data for similar developments served by EID, the baseline unit water demand factor for this land-use category is approximately 0.87 af/du.

[3] These classifications reflect EID's defined water demand factor categories as EID believes they best relate to the Proposed Project's land-use classifications as shown in the Table 1-1.

8,000 to 10,000 Square-foot Production Lots

The proposed project will include a large number of lots reserved for production homes on lots typically described as “large” for a residential community. For these lots, ranging up to ¼-acre or more, water demands will be based on recent water use data records for similar lots in the Serrano development – specifically Village D2 and portions of Village E, which includes numerous similar-sized lots. In contrast to the smaller lot production homes described in the next classification, these lots will retain adequate area on the lot for well-maintained turf and other landscaping. As much as one-half, but not less than about one-quarter, of the lot may still remain for landscaping, after accounting for the home’s footprint and hardscape areas – equating to a few thousand to several thousand square-feet. Though less landscaped area than the custom home lots, the landscaped area will drive water use on these lots.

Based on the available historic meter data for similar developments served by EID, the baseline unit water demand factor for this land-use category is 0.55 af/du.

5,000 to 7,000 Square-foot Production Lots

The Proposed Project includes numerous proposed lots with average of 4 to 5 dwelling units per acre. As a result of the limited outdoor area, many of these lots are limited to front-yard landscaping with well-maintained turf, and back yards often only including hardscapes, pools or other amenities, and lower water using landscapes. Unit water demands are based on recent water use data records for similar lots in the Serrano development – specifically Village D1A, portions of Village E and Euer Ranch, which include numerous similar-sized lots.

Based on the available historic meter data for similar developments served by EID, the baseline unit water demand factor for this land-use category is 0.50 af/du.

Condominiums/Townhouses

The Proposed Project includes numerous proposed lots characterized as being condominiums or townhomes (7 to 12 units per acre). These proposed lots are anticipated to be similar to projects in the El Dorado Hills area, most notable the Regalo Project in Serrano. The Proposed Project includes large attached housing units, with large individual landscape yards and common areas.

Based on the available historic meter data for similar developments served by EID, the baseline unit water demand factor for this land-use category is 0.40 af/du.

Multi-Family Housing

The Proposed Project includes numerous multi-family housing elements characterized as multi-family housing. These lots will include community landscaping, multi-story housing structures, community pools and other amenities. These projects are anticipated to be similar to the existing indoor and outdoor demands of the Sterling Apartment and Vineyard Apartment properties currently served by EID. Although both of these properties differ in their layouts and landscape types and coverage, both use approximately the same quantity of water on a per-dwelling unit basis.

Based on the available historic meter data for similar developments served by EID, the baseline unit water demand factor for this land-use category is 0.16 af/du – inclusive of both indoor and outdoor demands.

Residential Indoor Water Use

Based on EID meter data for the past several years, indoor water use for typical single-family homes averages about 0.18 af/du.[4]. The value drops for apartments as a result of less people on average living in each apartment unit.[5] This value can be used to derive separation of residential demands that could be served with non-potable supplies, such as recycled water from the Deer Creek and/or El Dorado Hills wastewater treatment facilities (see Section 2.7.2).

2.5 MODIFYING BASELINE VALUES

All of the above-developed water demand factors for the residential classifications are based on similar existing developments in the El Dorado Hills area. However, since construction of the existing houses, a few changes have occurred that will reduce the Proposed Project's water demands from the baseline unit water demands derived from existing meter data. These include:

- CAL Green Code
- California Model Water Efficient Landscape Ordinance

CAL Green Code

In January 2010, the California Building Standards Commission adopted the statewide mandatory Green Building Standards Code (CAL Green Code) that requires the installation of water-efficient indoor infrastructure for all new projects beginning January 1, 2011. CAL Green Code was incorporated as Part 11 into Title 24 of the California Code of Regulations.[6] The CAL Green Code applies to the planning, design, operation, construction, use and occupancy of every newly constructed building or structure. All proposed land uses must satisfy the indoor water use infrastructure standards necessary to meet the CAL Green Code. The CAL Green Code requires residential and nonresidential water efficiency and conservation measures for new buildings and structures that will reduce the overall potable water use inside the building by 20 percent. The 20 percent water savings can be achieved in one of the following ways: (1) installation of plumbing fixtures and fittings that meet the 20 percent reduced flow rate specified in the CAL Green Code, or (2) by demonstrating a 20 percent reduction in water use from the building

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[4] This value is a subset of the total usage estimated for a dwelling unit under each land-use category. Data from 2012 Water Resources and Service Reliability Report, EID, August 13, 2012, Appendix Table A, p.42
[5] El Dorado County indicates the average household size is 2.63 persons per occupied unit. (El Dorado County General Plan, 2008 Housing Element, August 2008 (Amended April 2009), p. 4-7).
[6] The CAL Green Code is Part 11 in Title 24.

"water use baseline."[7] The Proposed Project will satisfy one of these two requirements through the use of appliances and fixtures such as high-efficiency toilets, faucet aerators, on-demand water heaters, as well as Energy Star and California Energy Commission-approved appliances.

California Model Water Efficient Landscape Ordinance

In 2006, the Water Conservation in Landscaping Act was enacted, which required the Department of Water Resources to update the Model Water Efficient Landscape Ordinance (MWELO).[8] In fall of 2009, the Office of Administrative Law (OAL) approved the updated MWELO, which required that a retail water supplier adopt the provisions of the MWELO by January 1, 2010 or enact its own provisions equal to or more restrictive than the MWELO provisions.

The provisions of the MWELO are applicable to new construction with a landscape area greater than 2,500 square feet.[9] The MWELO provides a methodology to calculate total water use based upon a given plant factor and irrigation efficiency. Finally, MWELO requires the landscape design plan to delineate hydrozones (based upon plant factors) and then assign a unique valve for each hydrozone (low, medium, high water use).[10] The design of landscape irrigation systems is anticipated to better match the needs of grouped plant-types and thus result in more efficient outdoor irrigation.

Applying Conservation to Baseline Demand Factors

Collectively, these and other factors will put downward pressure on the baseline residential unit water demand factors – potentially dropping each unit demand by up to 10 percent for the larger lots. **Table 2-1** provides a summary of the baseline demand factor for each residential land-use category, the anticipated savings from the conservation mandates, and the resulting unit demand factor used to estimate the Proposed Project's water use.

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[7] See CAL Green Code.
[8] Gov. Code §§ 65591-65599
[9] CCR Tit. 23, Div. 2, Ch. 27, Sec. 490.1.
[10] CCR Tit. 23, Div. 2, Ch. 27, Secs. 492.3(a)(2)(A) and 492.7(a)(2).

Table 2-1 – Summary of Residential Baseline and Proposed Project Demand Factors

EID Water Demand Category (Relates to Table 1-1 Land Use)	Density Range	Current Factor (af/du)	Conservation Applied	Factor Used (af/du)
1 Acre Custom Homes	1 DU/Ac	1.16	10%	1.04
1/2 Acre Custom Homes	2 DU/Ac	0.87	8%	0.80
8,000-10,000 sf Lots	3 - 4 DU/Ac	0.55	5%	0.52
5,000-7,000 sf Lots	4 - 5 DU/Ac	0.50	5%	0.48
Condominiums/Town Homes	7 - 12 DU/Ac	0.40	4%	0.38
Multi-Family Housing[1]	15 - 24 DU/Ac	0.16	2%	0.16

1. The Multi-family Housing values remain constant due to rounding. The "current factor" was determined to be 0.165 af/du.

2.6 Baseline Non-Residential Water Use Demand Factors

Similar to the residential water demand factors, non-residential factors are based upon recent water use trends for similar types of land classifications.

For purposes of this WSA, the per-lot demand for non-residential lots is described as "the acre-feet of water use annually per acre of land" – or simply put, acre-feet/acre (af/ac). This value reflects indoor and outdoor water needs expected for a typical non-residential use for each of the following classifications:

- Office Park/Village Commercial
- Public and Neighborhood Parks
- Schools
- Other miscellaneous uses, including street medians, recreational lake, vineyards, and environmental mitigation

The method and basis for determining the baseline unit water demand factor for each of these classifications is detailed in the following subsections.

Office Park/Village Commercial

The proposed office park/village commercial facilities are anticipated to be "office space" as well as "retail and entertainment" in nature. Analysis of recent meter data for both the La Borgata retail facility on El Dorado Hills Boulevard and the Village Green office/public facility at the corner of Silva Valley and Serrano Parkways indicates that water use on a per-acre basis is nearly consistent, with the retail space using about 2.15 af/ac and the office facility using 1.95 af/ac. Although the Village Green indoor facilities have lower use, the area has more turf landscaped area (not including Village Green park), which matches, on a gross acre-by-acre comparison with the higher indoor retail demands and limited landscaping of the restaurants at La Borgata.

Based on the available historic meter data for similar facilities served by EID, the unit water demand factor is 2.0 af/ac.

Public and Neighborhood Parks

The Proposed Project includes five neighborhood parks, two village joint-use parks, and two special use parks. Neighborhood parks will include expansive turf areas, playfields, and other park amenities. Village joint-use parks will be adjacent to the school facilities and consist of similar features as the neighborhood parks. The special use parks, that surround the lake and historical site, differ from the other parks and are analyzed on a net landscaped acreage to match the water use estimates. Based upon recent water meter data for similar park facilities in the El Dorado Hills area – namely Bella Terra Park, Allan Lindsey Park, and the Village A, C, L3, and L4 parks – a representative water demand factor was identified. A “smart meter” controls the irrigation system at each existing park. These devices adjust water use to actual climate data, including precipitation events. Thus, the recent meter data is very indicative of expected demands for the new parks, which will also be outfitted with similar technology.

Based on the available historic meter data for similar facilities served by EID, the unit water demand factor is 2.77 af/ac.

Schools

The Proposed Project includes two schools: a Kindergarten through 5th grade, and a Kindergarten through 8th grade. The schools will use adjacent village parks for school-related recreational activities, and will include turf playfields. As an example, the water use at Oak Meadows Elementary on Silva Valley Parkway provides a useful representation of the expectations for the two proposed school facilities. Oak Meadows, operational by 2004, has an average water use of 1.70 af/ac – representing a use of about 0.019 af/student. For comparison, other schools in the area were analyzed and had very comparable per-student water use rates for similar facilities. But, the range in school use varied from as much as 2.5 af/ac to 0.8 af/ac – depending on factors like total school footprint, number of students and amenities. The average among seven schools analyzed was 1.43 af/ac. For purposes of this WSA, the average value would be an appropriate estimation for the future school sites.

Based on the available historic meter data for similar facilities served by EID, the unit water demand factor will use a baseline value of approximately 1.43 af/ac.

Other Miscellaneous Uses

The Proposed Project has additional miscellaneous uses including landscaped street medians, environmental mitigation requirements, a recreational lake, vineyards, gate houses at entrances to private streets, sewer lift stations, and construction water. These uses have minimal impacts to the overall per-project total water use due to their limited size and water needs, and some are temporary in nature.

Landscape Street Medians and Community Entrances

The Proposed Project includes proposed landscaping along street corridors and at entrances to particular residential areas, as is common in El Dorado Hills. Since comparable data is not available due to the variety of landscapes used in existing street medians around El Dorado Hills, unit water demands for this category is derived from the MWELO (see prior discussion under "residential land-uses"). To provide flexibility to the Proposed Project to landscape as needed, the entire width of the landscaped area was assumed to demand the maximum use allowed by MWELO.[11] This maximum is determined as 70 percent of the reference evapotranspiration for the area. Using available maps from the California Department of Water Resources, the reference evapotranspiration for the Proposed Project area is approximately 57 inches per year.[12] The resulting demand factor is 3.3 af/ac.

Oak Woodlands Management

As of the preparation of this WSA, the mitigation requirements for impacts to oak woodlands resulting from the Proposed Project are as detailed in the County's Policy 7.4.4.4.[13] For purposes of estimating the water demands of this Proposed Project element, the WSA assumes mitigation will include establishing new trees, likely with associated irrigation water to assure seedlings are established. As defined in the County's Oak Woodland Management Plan Monitoring Program:

> *"Replacement of removed tree canopy . . . is subject to intensive to moderate management and 10 to 15 years of monitoring, respectively. The survival rate shall be 90 percent as specified in the approved monitoring plan for the project, prepared by a qualified professional. Acorns may be used instead of saplings or one gallon trees."*

> *"Management intensity assumes that 10 years after planting 1 year old saplings that trees that have been nurtured with high management intensity will be on average 2 inches DBH with 90 percent survival; moderate management intensity will result in trees that are on average 1.5 inches DBH with 85 percent survival."*

More precisely, an intensive management program is required to obtain 90 percent survival. The management includes10 years of monitoring for one-gallon/one year old saplings and 15 years of

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[11] Although this may be higher than seen by EID for current street medians and community entrances, this conservative assumption allows the Proposed Project with flexibility to landscape these areas up to the full demands of MWELO.

[12] Reference Evapotranspiration is obtained from the map available at http://wwwcimis.water.ca.gov/cimis/cimiSatEtoZones.jsp

[13] The County Board of Supervisors has an Oak Woodland Management Plan (OWMP) codified as Chapter 17.73 of the County Code (Ord. 4771. May 6, 2008.). The primary purpose of this plan is to implement the Option B provisions of Policy 7.4.4.4. On September 24, 2012, the Board of Supervisors directed the Development Services Department to prepare a General Plan amendment to amend Policies 7.4.2.8, 7.4.2.9, 7.4.4.4, 7.4.4.5, 7.4.5.1, and 7.4.5.2 and their related implementation measures to clarify and refine the County's policies regarding oak tree protection and habitat preservation. (This excerpt was copied from the following El Dorado County web site: http://www.edcgov.us/Government/Planning/General_Plan_Oak_Woodlands.aspx on May 4, 2013.)

monitoring if acorns are planted. Any trees/acorns that do not survive within the monitoring periods are to be replaced within that time, so that 90 percent survival is achieved at the end of the monitoring period.

Because establishment of new trees is highly dependent on site conditions (soil depth and composition, depth to water table, slope, aspect, existing vegetation), planting conditions (water year, starting from acorns or saplings, weed mats, mulch, density of plantings and other adjacent veg, etc.), establishment and maintenance practices (manual or installed irrigation systems, and irrigation intervals), and the required success criteria (target % survival), the estimated water demands are difficult to predict.[14] However, in order to be reasonably conservative, this WSA assumes that each acre of habitat mitigation will require 1 acre-foot per acre of annual irrigation for a period of 15 years.[15] For instance, if the Proposed Project must mitigate with 10 acres of woodland, the demand would be 10 acre-feet annually. All oak woodland will be established prior to build-out and require no on-going irrigation.

Recreational Lake

The recreational lake is expected to need augmentation water to maintain desired lake elevations. Currently, the lake fills from adjacent groundwater seepage and stormwater runoff. Based on characterizations of this seepage from Proposed Project representatives, the water elevation often lowers during the summer and fall as surface evaporation outpaces seepage. To maintain water level elevations in the 10-acre lake, and estimated 6 to 10 acre-feet per surface acre of the lake will be assumed. For the entire lake, this equates to between 60 and 100 acre-feet. For purposes of the WSA, an assumed annual demand of 85 acre-feet will be used.

Vineyards

The Proposed Project will include approximately 55 acres of vineyards spread throughout the project. These vineyards serve as both an aesthetic feature and a business function – actively producing wine grapes. The majority of the planting is located on lots spread between differing housing types. Vineyards are also used in medians and other ornamental type plantings where appropriate. The use of vineyards in this fashion results in lower water use than fully landscaped medians. The vineyard water use estimates is based on a collection of documents from the University of California – Cooperative Extension combined with input for a local producer and winemaker. Reviewing water use data from *Wine Grape Cost and Return Studies, El Dorado and Amador Counties*, as well as other areas with similar climates and elevations, water demand range from 5 to 12 inches per year for established vines. In the interest of being conservative,

[14] A qualified professional will likely develop the project specific oak management plan. More detailed water use will be available in this plan. Review of information from oak mitigation projects in the area revealed a range of planting types, irrigation methods, and management time frames. Overall, irrigation demands were all low as would be expected for a native species.

[15] A conservative water demand number and a long management window were assumed to provide the Proposed Project applicants flexibility in meeting the oak woodland mitigation requirements.

the 12-inch annual value is used.[16] To account for any additional water demands while establishing the vines, this WSA assumes that twice the water will be needed in the first few years following planting. As shown in **Table 2-3**, the initial demand upon planning (included for the first 5-year increment for each vineyard planning phase) is 2 acre-feet/acre. This value drops to 1 acre-foot/acre for the remainder of the analysis period for a particular planting phase.

Gate Houses at Private Entrances

No usable comparison exists in the EID water use history to represent the demand of a gate house. A gate house consists of a small building with a single bathroom. The average country club employee per shift uses 50 Liters per day, or just over 13.2 gallons.[17] Assuming two employees per shift and 3 shifts per day, the resulting water use comes out to about 0.09 acre-feet per year. To be conservative, the demand used is rounded up to 0.1 acre-feet per year.

Sewer Lift Stations

Lift station demand comes in form of maintenance of the stations. Operational flushing at these lift stations is the primary water use. Based on EID records for such operations, each lift station is assumed to demand 2.5 acre-feet of water annually.

Construction Water

As stated in Section 1, early phases of the Proposed Project will include site grading and infrastructure installation. These and other construction elements will require dust suppression and other incidental water uses. These are estimated to be nominal, and do not continue beyond the construction phases of the Proposed Project. For purposes of identifying incremental water demands, construction water is assumed within this WSA to be 11 acre-feet per year (this is well over 3.5 million gallons – or nearly 900 fill-ups of a 4,000 gallon water truck annually).

Modifications to Reflect Additional Water Use Reductions

Similar to the residential demand factors, the above-developed water demand factors for the non-residential classifications are based on similar existing developments in the El Dorado Hills area. Considerations to reduce these baseline values for conservation factors, however, are not required, since demand factors for many of the landscaped features, such as parks, will not change from the existing values – with the exception of commercial land-uses. The landscape-dominant demand factors are affected primarily by climatic conditions that drive plant evapotranspiration. In other words, an acre of turf at a park will still use the same amount of water in the new parks as the existing parks. Commercial land-uses, however, are adjusted downward slightly to reflect the CAL Green Code and likely modifications to landscape designs (compared to existing establishments) to limit outdoor water use. Schools are kept consistent

[16] *The water demand is one dimensional and total demand is dependent on area. For the purposes of this WSA, acres are used for the second dimension. Therefore, one acre-foot of water is multiplied by each acre of vineyard. The result is 1 acre-foot/acre which is used in this documents calculations*

[17] Tchobanoglous, George, and Edward Schroeder. *Water Quality*. Menlo Park: Addison Wesley Longman, 1987

with the existing demand factor, since the data is based on the average of several schools and the exact configuration and number of students at the proposed schools is not fully defined. **Table 2-2** summarizes the non-residential demand factors used in this WSA.

Table 2-2 – Summary of Non-Residential Demand Factors

Land Use	Current Factor (af/ac)	Conservation % Applied	Factor Used (af/ac)
Office Park/Commercial	2.00	3%	1.94
Parks	2.77	0%	2.77
Schools	1.43	0%	1.43
ROW Landscaping	3.30	0%	3.30
Open Space	0.00	0%	0.00

2.7 Proposed Project Water Demand Projection

Combining the Proposed Project's land-use details and phasing as summarized in **Table 1-1** and **Table 1-2** with the demand factors presented in **Table 2-1** and **Table 2-2**, the water demands for the project from initiation to build-out are estimated. At completion, the Proposed Project is estimated to need 1,927 acre-feet of water annually (prior to considerations of non-revenue water, described in the next subsection) as shown in **Table 2-3**.

2.7.1 Non-Revenue Water Demands

The demand factors presented earlier in this section represent the demand for water at the customer's meter for each category. To fully represent the demand on EID's water resources, non-revenue water also needs to be included. Non-revenue water represents all of the water necessary to deliver to the customer accounts and reflects distribution system leaks, water demands from potentially un-metered uses such as fire protection, hydrant flushing, and unauthorized connections, and inescapable inaccuracies in meter readings.[18] In most instances, the predominant source of non-revenue water is from system leaks – the loss from fittings and connections from EID's water sources through treatment plants, tanks, pumping plants, major delivery system back-bone pipelines, and community distribution systems. Because a significant portion of the delivery system used to bring water to the Proposed Project already exists, the benefits of new piping within the Proposed Project has limited effect on the overall percentage of non-revenue water necessary to operate the system.

[18] The American Water Works Association and the California Urban Water Conservation Council recognize the inherent non-revenue water that is either lost or mis-accounted in urban treated water distribution systems and suggest purveyors strive for a value of 10% of all delivered water. Obtaining this value is dependent on numerous factors including the age and extent of distribution system infrastructure, meter rehabilitation programs, and how a purveyor accounts for actions such as fire flows and hydrant flushing.

Although EID has an established program for identifying and accounting for most unbilled and other system losses, there are still pipeline leaks, unmetered uses, unauthorized connections, meter inaccuracies, and other losses that are difficult to specifically quantify. Consistent with the District's methodology for calculating future water meter availability, as defined in the *2012 Water Resources and Service Reliability Report*, non-revenue water is projected at a fixed rate of 13 percent. Non-revenue demand is estimated to add 250 acre-feet per year at build-out to the Proposed Project's land-use demands, bringing the estimated build-out water demand attributed to the Proposed Project to 2,177 acre-feet annually (see **Table 2-3**).

2.7.2 Recycled Water Demand

A portion of the Proposed Project's demands (see Figure 1-1) could be met with recycled water provided by EID (see Section 4.3). As previously noted, other than the high-density multi-family units, residential potable demands require about 0.18 acre-feet annually per household. The remaining portion of the unit demand factor for each type of residential lot could be met with recycled water (see **Table 2.1** for unit demand factors). For the high-density residential units, the potable water requirement is lower due to fewer customers per unit on average when compared to other housing types. Using these unit water demand assumptions, coupled with the number of residential units, the Proposed Project could meet approximately 937 acre-feet of the 1,510 acre-feet of residential water demand with recycled water – prior to consideration of non-revenue water demands.

Non-residential components of the Proposed Project could also be met with recycled water, especially the parks, vineyards and lake supplementation. Removing the small potable demands for parks and the limited commercial properties, the Proposed Project could meet 355 acre-feet of the 417 acre-feet of total non-residential demand with recycled water – prior to the consideration of non-revenue water demands. Combined, recycled water could serve approximately 1,292 acre-feet of the Proposed Project's demand (see **Table 2-4**).

Table 2-4 – Estimated Demand Met with Recycled Water

	Demand (af/yr)		
	Residential	Non-Res	Total
Potable	572	62	635
Recycled	937	355	1,292
Total Demand	**1,510**	**417**	**1,927**

Table 2-3 – Estimated Proposed Project Water Demands from Start-up to Build-out

	Unit Count or Acreage						Demand Factor (af/du or af/ac)						Demand (af/yr)					
Category	Current	2015	2020	2025	2030	2035	Current	2015	2020	2025	2030	2035	Current	2015	2020	2025	2030	2035
Residential																		
1 Acre Custom Homes	0	0	25	45	145	193	1.16	1.04	1.04	1.04	1.04	1.04	0	0	26	47	152	202
1/2 Acre Custom Homes	0	0	25	50	50	125	0.87	0.80	0.80	0.80	0.80	0.80	0	0	20	40	40	100
8,000-10,000 sf Lots	0	0	215	593	593	982	0.55	0.53	0.53	0.53	0.53	0.53	0	0	113	312	312	517
5,000-7,000 sf Lots	0	0	0	0	663	663	0.50	0.48	0.48	0.48	0.48	0.48	0	0	0	0	315	315
Condominiums/Town Homes	0	0	75	597	772	772	0.40	0.38	0.38	0.38	0.38	0.38	0	0	29	228	295	295
Multi-Family Housing	0	0	209	259	487	501	0.16	0.16	0.16	0.16	0.16	0.16	0	0	34	42	79	81
												Subtotal	0	0	222	669	1,192	1,510
Commercial																		
Office Park/Commercial	0	0	0	12	27	58	2.00	1.94	1.94	1.94	1.94	1.94	0	0	0	22	52	112
Schools	0	0	0	0	19	35	1.43	1.43	1.43	1.43	1.43	1.43	0	0	0	0	28	50
Gate House	0	0	1	1	1	1	0.10	0.10	0.10	0.10	0.10	0.10	0	0	0	0	0	0
												Subtotal	0	0	0	23	80	162
Public																		
Parks	0	5	13	14	22	22	2.77	2.77	2.77	2.77	2.77	2.77	0	14	37	40	60	60
Open Space	0	1,282	1,282	1,282	1,282	1,282	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0
Lake	0	0	1	1	1	1	85.00	85.00	85.00	85.00	85.00	85.00	0	0	85	85	85	85
Vineyards Phase 1	0	0	18	18	18	18	0.00	0.00	2.00	1.00	1.00	1.00	0	0	35	18	18	18
Vineyards Phase 2	0	0	0	13	13	13	0.00	0.00	0.00	2.00	1.00	1.00	0	0	0	26	13	13
Vineyards Phase 3	0	0	0	0	10	10	0.00	0.00	0.00	0.00	2.00	1.00	0	0	0	0	20	10
Vineyards Phase 4	0	0	0	0	0	14	0.00	0.00	0.00	0.00	0.00	2.00	0	0	0	0	0	28
Lift Stations	0	0	2	2	2	2	2.50	2.50	2.50	2.50	2.50	2.50	0	0	5	5	5	5
												Subtotal	0	14	162	173	201	219
Other																		
ROW & landscape lots	0	0	6	11	11	11	3.30	3.30	3.30	3.30	3.30	3.30	0	0	18	36	36	36
Mitigation Demands	0	100	225	225	125	0	1.00	1.00	1.00	1.00	1.00	1.00	0	100	225	225	125	0
Construction Water	0	2	2	2	2	0	5.50	5.50	5.50	5.50	5.50	5.50	0	11	11	11	11	0
												Subtotal	0	111	254	272	172	36
												Total Water Demand	**0**	**125**	**638**	**1,137**	**1,646**	**1,927**
											Non-Revenue Demand at	13%	0	16	83	148	214	250
												Total Proposed Project Demand	**0**	**141**	**721**	**1,285**	**1,860**	**2,177**

SECTION 3 – OTHER ESTIMATED WATER DEMANDS

3.1 INTRODUCTION

As stated in this excerpt from Water Code Section 10910(b)(3): *"[T]he water supply assessment for the project shall include a discussion with regard to whether the public water system's total projected water supplies available…will meet the projected water demand associated with the proposed project, in addition to the public water system's existing and planned future uses…"* This section details EID's other "existing and planned future uses." For purposes of this WSA, existing and planned future uses are subdivided into the following:

- **Other Currently Proposed Projects –** in addition to the Proposed Project, El Dorado County (County) is the Lead Agency (pursuant to CEQA) for four additional proposed development projects. As Lead Agency, the County has requested separate WSAs from EID for each of these other projects. Because detailed land-use information is available for three of the four projects and separate WSAs are being developed for these three in parallel to this WSA, each of these three projects have unique water demand estimates that are included in this WSA.[19]

- **All Other Existing and Planned Future Uses –** in addition to the Proposed Project and the Other Currently Proposed Projects, existing customers and anticipated growth in the County must be quantified. The subdivisions of this category are:

    - **Current Customers and Uses –** using 2012 as a baseline condition, this category reflects the current range of EID's potable and recycled water customers. Because these customers and uses already exist, keeping them separate from planned future uses allows an analysis to reflect anticipated reductions in use over time as EID continues to implement its urban water conservation programs targeted at many of the existing customers.[20]

    - **Adjusted General Plan Update Land Use Growth –** in addition to the identified development projects currently undergoing County CEQA review, the County's 2004 General Plan Update (GPU) anticipates continued urban growth throughout the EID service area. This growth is accounted for in the EID 2013 *Integrated*

[19] EID understands the fourth project, San Stino, to be undergoing changes to its land-use plans at the time of drafting this WSA. Lacking the details needed to determine water demands similar to the other WSAs currently being completed, the San Stino project is reflected in the next subgroup of demands (see Section 3.3).

[20] New customers added to EID's system will have lower demand factors, as discussed in Section 2, and will be less likely to implement additional conservation or see much reduction when changes are made. For instance, many existing customers may still have 3 gallon per flush toilets or even 1.6 gallon per flush toilets, which when replaced, will likely only use 1.28 gallons. New houses will be constructed, per the CAL Green Code, with 1.28 gallon per flush toilets. EID has had conservation and incentives programs for more than 20 years.

Water Resources Master Plan (2013 IWRMP) and serves as the primary water demand driver into the future. Adjustments to anticipated GPU growth to reflect the "Other Currently Proposed Projects" and other proposed land-use changes, however, must be made. The adjustments discussed under this category include: (1) potential changes in the 2004 General Plan land use designations as identified in Facility Improvement Letters received and analyzed by EID; and (2) the removal of the Proposed Project and other proposed project uses being developed under concurrent WSAs.

  - **Other Authorized Uses –** EID does not anticipate increases above 2012 levels in other authorized potable water uses such as fire flows, meter testing, water quality flushing, and ditch system operations. Demands for this category of water use is removed from the general plan growth and included separately.

- **Non-Revenue Water –** As discussed in Section 2.7.1, an additional demand is seen by EID to treat and deliver water to all customers. Referred to as non-revenue water, this water demand represents a 13 percent increase added to estimated customer demands. This value represents a long-term average experienced by EID.

3.2 OTHER CURRENTLY PROPOSED PROJECTS

As mentioned in the previous section, El Dorado County is the Lead CEQA Agency for four additional proposed development projects and has requested EID to prepare WSA's for each development concurrent with this Proposed Project WSA. EID is currently drafting three of these four WSAs.[21] The estimate of water demand for each WSA follows the same methods used in Section 2 of this WSA, with specific unit demand factors applied to each unique land use element. The other projects are:

- Central El Dorado Hills – located along El Dorado Hills Blvd north of Hwy 50, this projects is a planned infill mixed development with primarily residential units and some commercial space.
- Lime Rock Valley Specific Plan – located adjacent to the Village of Marble Valley, this development is a planned residential community with a variety of lot sizes and housing types.
- Dixon Ranch Residential Project – located northeast of the Proposed Project, this development is a planned residential community with a range of lot sizes and housing types, including a number of "age-restricted" units, accompanied by a community club house, parks, ponds, and trails.

[21] EID understands that the San Stino development project is undergoing changes to the land-use plans previously submitted to the County. Therefore, EID has not begun the WSA for that project.

Based on the detailed analysis completed in the other WSAs, these "Other Currently Proposed Projects" represent approximately 1,330 acre-feet per year of new demand by 2035. **Table 3-1**, presented later in this section, summarizes the estimated water demands as determined and detailed in the concurrent WSAs for each unique project. The values shown are the estimated customer and use demands and do not include the additional water associated with non-revenue percentages attributable to the treatment and distribution for each project (see Section 3.5).

3.3 All Other Existing and Planned Future Uses

In simple terms, this category of use would typically reflect all the other water demands anticipated by EID that are in addition to the Proposed Project. However, because of the unique circumstance that other WSAs are concurrently being drafted by EID, this category must be adjusted to remove those other well-defined water demands. Furthermore, because other potential changes to the 2004 GPU have been brought to EID's attention, and EID anticipates changes to current customer uses, a more detailed assessment of future demands is warranted. This subsection describes:

- Current Customers and Uses
- Adjusted GPU Land Use Growth
- Other Authorized Uses

3.3.1 Current Customers and Uses

Current customers and uses in the contiguous EID service area provide a baseline from which to assess additional demand from the Proposed Project and other potential planned uses. For purposes of the WSA, the deliveries to current customers in 2012 were used to define this baseline. Based on the 2012 EID *Water Diversion Report*, EID diverted 36,580 acre-feet into its potable water system. In addition to the potable water, EID served 2,404 acre-feet of recycled water to meet customer demands.[22] Combined, the current water demand is represented as 38,984 acre-feet. This value includes the non-revenue water (see Section 2.7.1), including system losses, necessary to deliver these supplies from their respective treatment plants to the customer meter. This value also includes 1,269 acre-feet sold to the City of Placerville.[23]

Since the WSA uses 2012 as a baseline, the "current" demand varies from that used in the recently adopted 2013 IWRMP, which used the year 2008 for its baseline.[24] Given on-going conservation efforts, adoption of new rate structures, and other drivers, EID has seen an overall decrease in the annual customer use since the IWRMP selected its baseline. Therefore the 2012

[22] See EID 2013 Water Resources and Reliability Report (Table 14)
[23] See EID Consumption Report: Reporting Year 2012 (Table on p. 7)
[24] The IWRMP, adopted by the EID Board in March 2013, began several years ago and at the time used 2008 as a baseline. Since that time, EID's annual diversions have dropped from a high in 2008 of about 45,000 acre-feet to 35,678, 33,453, and 36,580 in 2010, 2011, and 2012, respectively. Combined with recycled water deliveries, the 2012 demand is lower than that used for the 2013 IWRMP, but greater than 2010 and 2011.

baseline used for this WSA is more representative of the baseline use expected into the future from these existing customers and uses.

A slight adjustment to this baseline is necessary, however, to project it into the future. Although this demand will remain relatively constant since it does not add any new uses (additional uses are discussed in the next subsections), a slight decrease is assumed that reflects on-going implementation of conservation and installation of new water-using fixtures by existing customers. EID's continued leadership in conservation will enable existing customers to retrofit toilets, receive appliance rebates for new household items such as dishwashers, water heaters and clothes washers, and implement irrigation efficiency improvements through various incentives. Additional reductions in existing customer demands will also occur simply as a result of the natural replacement of old fixtures and appliances with lower water-use devices. For purposes of the WSA, EID estimates the reduction in current customer demand will be approximately 2% by 2020 and an additional 1% by 2035. This is consistent with EID's expectations necessary to meet its per-capita water use targets as detailed in the 2010 Urban Water Management Plan.[25]

3.3.2 Adjusted GPU Land Use Growth

In the 2004 GPU, the County made growth projections using land-use zoning throughout the County. Within the contiguous EID water service area, the GPU land-use zoning correlates to EID defined unit water demand factors. During preparation of the recently adopted 2013 IWRMP, EID used GIS-based land-use designations, combined with the water demand factors, to develop estimated growth in water demand. Absent any changes to the 2004 GPU land-use designations, the 2013 IWRMP demand projections would provide a valid representation of future water needs. However, because several proposed changes to the GPU land-use designations have been submitted – both through the County's formal process, such as is the situation with the Proposed Project and Other Planned Projects, and through an EID process explained below – the 2013 IWRMP demand projections require refinement. The steps to adjust these demands included:

- Removal of Proposed Project and Other Planned Projects water demands
- Modifying land-use zoning based on Facility Improvement Letters
- Determining Growth to Year 2035

Once these steps were completed, the analysis reassessed the water demand using the water demand factors applied in the 2013 IWRMP.

Step 1: Removal of Proposed Project and Other Planned Project Water Demands

The first step in adjusting the water demands was to remove the detailed water demands estimated in this WSA for the Proposed Project and for the Other Planned Projects (see

[25] See Section 3 of the 2010 UWMP available here: http://www.eid.org/modules/showdocument.aspx?documentid=338

Section 2 and Section 3.2). This step involved removing the specific acreage and water demand factors from the 2013 IWRMP analysis. The 2004 GPU included land-use zoning for the lands underlying the Proposed Project as well as the Other Planned Projects. In the 2013 IWRMP, water demands were estimated using the existing zoning. Removing these land uses eliminates the potential to double-count the associated acreage when assessing the remaining GPU expected growth.

Step 2: Modifying Land-use Zoning based on FILs

When investigating water service from EID for development projects (e.g. lot splits, land use changes, and new service to existing parcels), existing landowners submit a Facilities Improvement Letter (FIL). This document allows EID to assess whether infrastructure or supplies are available to serve the proposed project. In some instances, the FILs include proposed land-use zoning changes not previously incorporated into EID water demand projections. By using GIS to map the locations of the FILs requesting a change in land-use zoning, EID was able to identify where changes to the 2013 IWRMP demand estimates would occur. About 25 specific FILs were identified as having land-use designation changes. These identified parcels were removed from the prior analysis to eliminate potential double counting of demands.

In a separate analysis, the water demand for this subset of parcels was recalculated using the appropriate water demand factor for the new proposed land-use classification (e.g. water needs for these parcels may have previously been calculated based on very-low density housing, but is requesting a change to higher density housing). Through the analysis, an increased demand of approximately 3,000 acre-feet over the 2013 IWRMP projections was identified.

Step 3: Determining Growth to 2035

The GPU identifies anticipated build-out conditions for the County and, as a subset, for the EID contiguous water service area. Since this WSA assesses water demands in 5-year increments only to 2035 – well short of the anticipated timing of the County's build-out – the amount of build-out growth occurring by 2035 must be determined. This was done for both the parcels identified with new land-use zoning through the FIL analysis, and for the remaining parcels with original GPU land-use designations.

Because there is little detail about planned development rates for the FIL-related parcels, this WSA assumed that these parcels would have full water demand usage by 2035.[26] This is a conservative estimate, since some of these lands may not develop by 2035 or may never

[26] This assumption also considers that a landowner would likely only submit a FIL to EID if they are seriously contemplating the development activity. Thus, there is a higher likelihood that these parcels will develop at a faster rate than other generally anticipated growth for the remaining parcels in the GPU.

develop. Thus, the estimated increase in demand of approximately 3,000 acre-feet was assumed to occur by 2035 with the 2013 IWRMP growth rate applied.

For the remaining parcels, growth rates used to determine the degree of development were based on EID's 2013 IWRMP. In the 2013 IWRMP, growth rates for the El Dorado Hills, and Western/Eastern water service areas were identified for specific year-ranges.[27] This WSA uses those growth rates for the remaining parcels. Using the 2013 IWRMP growth rates, the analysis determined build-out for the El Dorado and Western/Eastern service areas occurs after 2035.

During this adjustment, special attention was provided to the City of Placerville. The City purchases potable water from EID for distribution to its residents. The 2013 IWRMP projected future water demands for the City based on the City's existing General Plan. This WSA assumes the same rate of growth and build-out demand as the 2013 IWRMP for the City.

Upon completion of these steps, the adjusted demand for the GPU land uses was determined. **Table 3-1** summarizes the anticipated increase in water demand during each 5-year increment as a result of these adjustments to the GPU land-uses.

3.3.3 Other Authorized Uses

In addition to the sale of water to metered customers, EID has a set of water demands it refers to as "Other Authorized Uses." This designation is for the following existing uses:

- Knolls Reservoir Assessment District
- Private Fire Services
- Temporary Water Use Permit
- Bulk Water Stations - Permanent
- Bulk Water Stations - Temporary
- Lift Stations
- Collection System Flushing
- Spills, Overflows, and Flushing
- Clear Creek Aesthetics Flow Maintenance District

Of these, the Clear Creek aesthetic flows comprise over 80 percent of the annual authorized uses. Lift stations and temporary use permits comprise another 10 percent. The current demand of approximately 2,200 acre-feet is already reflected in the "Current Customers and Uses." EID anticipates no growth in these authorized water uses, with the total demand to remain constant at 2,200 acre-feet through 2035.

[27] EID Integrated Water Resources Master Plan, adopted March 2013 (Table 9-2).

3.4 NON-REVENUE WATER DEMANDS

The subtotal values in **Table 3-1** represent the demand for water at the customer's meter for each category. To fully represent the demand placed on EID's water resources, non-revenue water also needs to be included. Non-revenue water represents all of the water necessary to deliver to the meter and reflects distribution system leaks, water demands from potentially un-metered uses of fire protection, fire hydrant flushing, and unauthorized connections, and inescapable inaccuracies in meter readings.[28] In most instances, the predominant source of non-revenue water is from system losses – the loss from fittings and connections from the District's water sources through treatment plants, tanks, pumping plants, major delivery system back-bone pipelines, and community distribution systems.

Although the District has an established program for identifying and accounting for most unbilled and other system losses, there are still pipeline leaks, unmetered uses, unauthorized connections, meter inaccuracies, and other losses that are difficult to specifically quantify. Consistent with the District's methodology for calculating future water meter availability, as defined in the *2012 Water Resources and Service Reliability Report*, non-revenue water is projected at a fixed rate of 13 percent.

As shown in **Table 3-1**, non-revenue demand for Existing and Planned Future Uses is estimated to be about 7,500 acre-feet per year by 2035.

3.5 ESTIMATED EXISTING AND PLANNED FUTURE USES

Combining the estimated water demand for Other Currently Planned Projects (see Section 3.2 with the All Other Existing and Planned Future Uses demand (Current Customers and Uses plus the Adjusted GPU Land Use values), the total estimated demand during each 5-year increment to 2035 is derived (see subtotal water demand in **Table 3-1)**.

[28] See footnote 14

Table 3-1 – All Other Existing and Planned Future Uses

Category	Estimated Demand (af/yr)					
	Current	2015	2020	2025	2030	2035
Other Currently Proposed Projects	0	163	696	1,052	1,272	1,332
Current Customers and Uses [1]	38,984	34,154	33,809	33,694	33,579	33,464
Adjusted GPU Land Use [2]	0	514	2,853	7,975	14,718	22,830
Subtotal Water Demand	**38,984**	**34,831**	**37,359**	**42,721**	**49,570**	**57,627**
	Current	2015	2020	2025	2030	2035
Non-Revenue Water at 13%	--	4,528	4,857	5,554	6,444	7,491
Total Water Demand	**38,984**	**39,359**	**42,216**	**48,275**	**56,014**	**65,117**

1. The "Current Customers and Uses" demand value includes the "Other Authorized Uses." The Value is greater under the "Current" condition because "Non-Revenue Water" is included in the current year. All other years will have "non-revenue water" added on a separate line. A 3% conservation decrease occurs by 2035.
2. "Adjusted GPU Land Use" reflects changes to the 2004 GPU as determined by FILs submitted to EID. This value also does NOT include the other proposed projects currently undergoing County CEQA review.

3.6 TOTAL ESTIMATED DEMAND

The other existing and planned future water demands described in this section represent the total demands anticipated *in addition to* the water demands of the Proposed Project. Combining the estimated Proposed Project water demands of 2,177 acre-feet annually (see **Table 2-3**) with the estimated Existing and Planned Future water demands of approximately 65,000 acre-feet annually (see **Table 3-1**), a total estimated demand for EID water supplies by 2035 is determined. Estimated existing and planned future water demands, inclusive of non-revenue water needs, for each 5-year increment to 2035 are presented in **Table 3-2**. The estimated demand for EID Water supplies is 67,295 acre-feet annually.

Table 3-2 – Total Estimated Water Demands

Category	Estimated Demand (af/yr)					
	Current	2015	2020	2025	2030	2035
Proposed Project	0	141	721	1,285	1,860	2,177
Existing and Planned Future Uses	38,984	39,359	42,216	48,275	56,014	65,117
Total Water Demand	**38,984**	**39,500**	**42,937**	**49,560**	**57,874**	**67,295**

Of note is that the estimated water demand for 2035 presented in **Table 3-2** fits within the range of total demands presented in Table 9-1 of the 2013 IWRMP (estimated to be between 61,262 acre-feet and 77,315 acre-feet). The primary differences is that the 2013 IWRMP used 2008 as a baseline demand, which is substantially higher than EID has seen in the last several years. This WSA uses 2012 as a baseline. The 2008 value was approximately 45,000 acre-feet, while the 2012 value is 38,984 – or about 39,000 acre-feet. This represents a difference of about 6,000 acre-feet. Starting from a different baseline quantity and year, and then applying the 2013 IWRMP growth rates, results in a different estimated total demand when reaching 2035.

SECTION 4 – WATER SUPPLY CHARACTERIZATION

4.1 INTRODUCTION

This section explains the intended water supply that EID will use to serve the Proposed Project.[29] EID will meet the Proposed Project's water demands by utilizing water assets derived from its existing sources as well as through future asset acquisition efforts with El Dorado County Water Agency. This section details the Proposed Project's available water supplies and entitlements as well as its planned water supplies and entitlements in both normal water years and dry water years. The Proposed Project exists completely in El Dorado Irrigation District's contiguous water service area (see **Figure 4-1**) and may be served with both treated water and recycled water.[30]

El Dorado Irrigation District maintains two primary interconnected water systems in its contiguous service area: the El Dorado Hills system and the Western/Eastern system, along with a separate recycled water system. The El Dorado Hills water system obtains its primary supplies under rights and entitlements from Folsom Reservoir. The Western/Eastern system derives its supplies from sources under rights and entitlements emanating from further up the American River watershed and the Cosumnes River watershed. The recycled water system serves treated wastewater from the El Dorado Hills wastewater treatment plant and the Deer Creek wastewater treatment plant.

The water assets can be further categorized by the service area they primarily serve and the treatment plant they flow through. Water derived from Folsom Reservoir is delivered to the El Dorado Hills water treatment plant and serves the El Dorado Hills area. Water derived from upstream American River watershed diversions and storage reservoirs generally use the Reservoir 1 Water Treatment Plant while the Cosumnes River diversions use Reservoir A Water Treatment Plant to serve the Western/Eastern area. Water assets from these upstream diversions can be delivered by gravity feed to the El Dorado Hills area, but assets from Folsom Reservoir are not delivered outside the El Dorado Hills area due to infrastructure limitations. The following subsections describe these water supplies and delivery mechanics in more detail.

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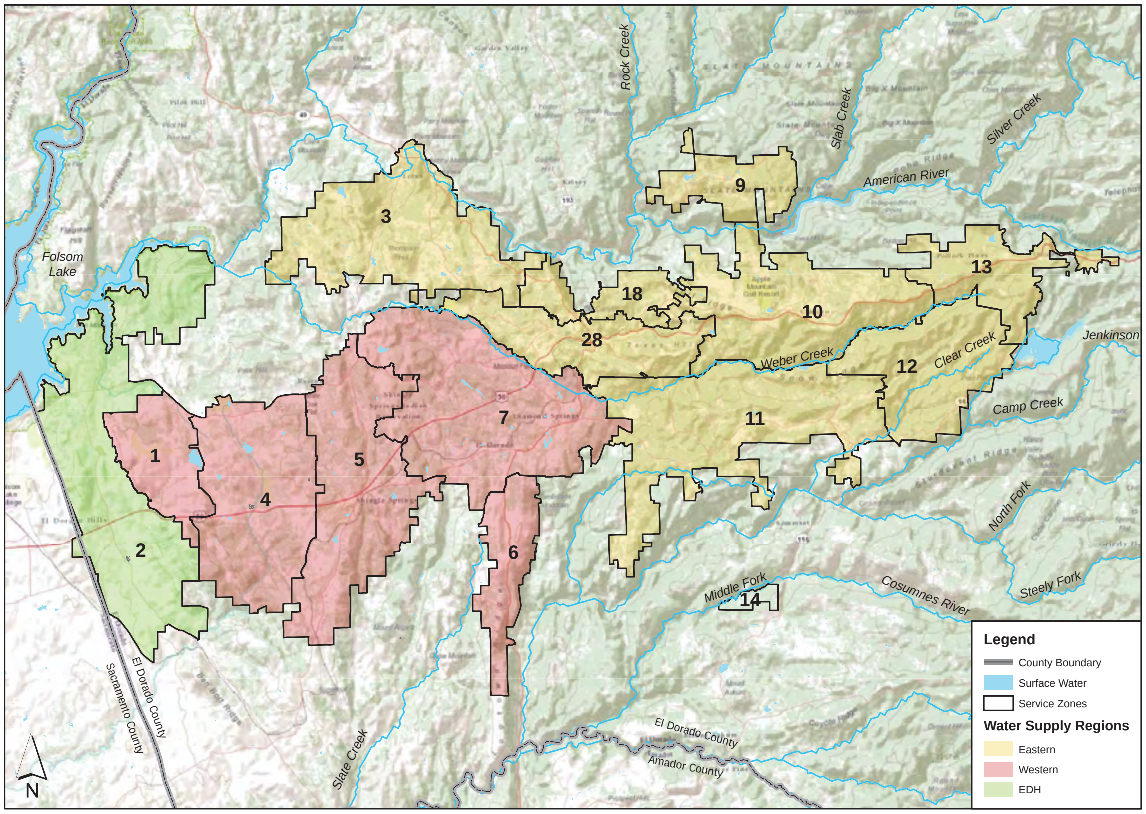
[29] CWC § 10910(d)(1) requires that "The assessment… include an identification of any existing water supply entitlements, water rights, or water service contracts relevant to the identified water supply for the proposed project, and a description of the quantities of water received in prior years by the public water system…under existing water supply entitlements, water rights, or water service contracts. (2) An identification of existing water supply entitlements, water rights, or water service contracts held by the public water system…shall be demonstrated by providing information related to all of the following: (A) Written contracts or other proof of entitlement to an identified water supply. (B) Copies of a capital outlay program for financing the delivery of a water supply that has been adopted by the public water system. (C) Federal, state, and local permits for construction of necessary infrastructure associated with delivering the water supply. (D) Any necessary regulatory approvals that are required in order to be able to convey or deliver the water supply."

[30] EID also has surface water assets that it serves to two non-contiguous areas as well as raw water assets that are used for agricultural purposes. These water assets are irrelevant to the Proposed Project contemplated in this Water Supply Assessment and are, therefore, not analyzed.

Figure 4-1 – El Dorado Irrigation District Service Area

(from Figure 8-7, Integrated Water Resources Master Plan, EID, March 2013)



4.2 Treated Water Supplies

EID's treated water supplies identified for the Proposed Project are derived from a number of water rights and entitlements as detailed in **Table 4-1**. The maximum available water assets column in **Table 4-1** does not account for other hydrological, technical, regulatory, and contractual limitations that apply to the water assets for normal year and dry year deliveries. These issues are addressed in the other two columns in the table. EID's water assets available for the Proposed Project include water rights and entitlements that EID currently has in its possession and planned water rights and entitlements that it will control in the future.

4.2.1 Water Rights and Entitlements Description

Generally, EID's water assets are derived from pre-1914 appropriative water rights, licensed and permitted appropriative water rights, Central Valley Project (CVP) contracts, Warren Act contracts (that allow non-federal water assets to be wheeled through the federal storage and conveyance facilities), and recycled water generated from the effluent treated at the District's two wastewater treatment plants. The District's counsel has recently confirmed all of these water rights and entitlements. Pertinent information regarding these water assets is included in **Appendix A** of this document as required by Water Code section 10910(d).

Water for the Proposed Project will be derived from both Folsom Reservoir and upstream American River and Cosumnes River diversions. As shown in **Table 4-1**, the primary water assets for diversion at Folsom Reservoir are: CVP Contract 14-06-200-1375A-LTR1, and License 2184 and several pre-1914 water rights incorporated into Warren Act contract 06-WC-20-3315. EID is seeking to finalize its Warren Act contract for diversions of Permit 21112 at Folsom Reservoir. EID also has additional water assets under the El Dorado – SMUD Cooperation Agreement and a Central Valley Project water entitlement derived from El Dorado County Water Agency's Fazio water supply. These water assets will be described in **Section 4.2.2**.

Table 4-1 – Water Rights, Entitlements, and Supply Availability

Water Right or Entitlement	Maximum Water Assets Available (Ac-ft)	Normal Year Planned Supply Availability (Ac-ft)	Dry-Year Planned Supply Availability (Ac-ft)
License 2184 and pre-1914 ditch rights including Warren Act Contract 06-WC-20-3315	4,560	4,560	3,000
Licenses 11835 and 11836	33,400	23,000	20,920[A]
CVP Contract 14-06-200-1375A-LTR1	7,550	7,550	5,660
Pre-1914 American River diversion and storage rights	15,080	15,080	15,080
Permit 21112	17,000	17,000	17,000
Subtotal Existing	**77,590**	**67,190**	**61,660**
Central Valley Project Fazio water entitlement (PL 101-514 (1990) Fazio) [D]	7,500	7,500	5,625
Applications 5645X12, 5644X02 and partial assignment of Applications 5645, 5644 with El Dorado-SMUD Cooperation Agreement [E]	40,000[B]	30,000	5,000[C]
Subtotal Planned	**47,500**	**37,500**	**10,625**
Recycled Water	5,600	5,600	5,600
Total	**130,690**	**110,290**	**77,885**

[A] This is the modeled safe-yield of this water right during a single dry-year. For planning purposes, the second and third dry years of a three-year dry period are assumed to be 17,000 acre-feet, and 15,500 acre-feet, respectfully

[B] Section 5.1.1 of the El-Dorado SMUD Cooperation Agreement indicates that 40,000 acre-feet of SMUD water will be available after 2025. For conservative Normal Year planning purposes, the District uses 30,000 acre-feet of available supply.

[C] Available supply is 15,000 acre-feet in a single dry year but in preparing for multiple dry years EID anticipates using only 5,000 acre-feet per year for a three year period.

[D] Available starting in 2015

[E] Available starting in 2025

License 2184 and Pre-1914 Water Rights

Water rights associated with Weber Dam, Weber Creek (Farmer's Free Ditch), Slab Creek (Summerfield Ditch), and Hangtown Creek (Gold Hill Ditch) are available to be diverted at Folsom Reservoir under a long-term Warren Act Contract, with approximately 4,560 acre-feet available each year from these sources. A Warren Act Contract allows the use of federal facilities to take non-CVP water such as these supplies. The 40-year contract commenced on March 1, 2011 and has a maximum net contract amount of 4,560 acre-feet per year. The contract total also assumes a 15% conveyance loss between the former points of diversion and Folsom Reservoir, which can be adjusted at a later date by mutual agreement without amending the contract. The annual water diversion season is limited to April through November 15 and the water must be used for municipal and industrial purposes in the El Dorado Hills and Cameron Park areas.

Licenses 11835 and 11836

Licenses 11835 and 11836 allow for 33,400 acre-feet of diversion in EID's upstream system in the Cosumnes River watershed. These diversions are stored in Jenkinson Lake, the largest storage reservoir in EID, formed by two earth and rock dams across Sly Park Creek near Pollock Pines with a maximum capacity of 41,033 acre-feet. The dam was constructed as a portion of the United States Bureau of Reclamation (USBR) CVP in 1955. With the transfer of ownership from the USBR of the Sly Park dam and associated lands and facilities in 2003, EID not only operates and maintains the Jenkinson Lake and Sly Park Dam facilities, including recreational aspects, but also holds the water rights. The average annual use from this facility is approximately 23,000 acre-feet, though EID's annual water right is for 33,400 acre-feet of total beneficial use. This water supply is used entirely within EID's contiguous service area. Under average flow conditions, Jenkinson Lake is operated to maintain 14,000 to 18,000 acre-feet of carryover storage each year. The outlet works at Sly Park Dam have a maximum capacity of 125 cfs. Water is released to the Reservoir A Water Treatment Plant for subsequent treatment, transmission, and distribution.

Jenkinson Lake contributes approximately 20,920 acre-feet per year to EID's system firm yield. Over the past five years, EID's annual diversions from Jenkinson Lake have averaged approximately 22,600 acre-feet per year. EID's maximum and minimum diversions from this particular water source during this five-year period were 25,745 and 20,800 acre-feet per year, respectively.

USBR CVP Contract 14-06-200-1375A-LTR1

Surface water from Folsom Reservoir is provided to the El Dorado Hills area. By contract with the USBR for Folsom Reservoir water, EID is entitled to 7,550 acre-feet per year. The contract includes provisions for use in a particular area that generally encompasses the El Dorado Hills and Cameron Park areas. Folsom Reservoir is operated by the USBR as part of the CVP, a multipurpose project that provides flood control, hydroelectricity, drinking water, and water for irrigation.

The El Dorado Hills County Water District entered into a USBR Contract in 1964 for water supply from Folsom Reservoir. The contract had a not-to-exceed limit of 37,600 acre-feet per year. When EID annexed the El Dorado Hills County Water District in 1973, the contract was assigned to EID, and subsequently, in 1979, an amendatory contract replaced the original 1964 contract and reduced the maximum annual supply quantity of Folsom Reservoir water to 6,500 acre-feet per year. In 1983, the USBR increased the maximum annual supply quantity from 6,500 to 7,500 acre-feet per year. EID also annexed and succeeded to a USBR Contract for 50 acre-feet per year to supply the Lakehills area in El Dorado Hills. In 2006, these two contracts were consolidated into a single 40-year USBR Contract with a maximum quantity of 7,550 acre-feet per year.

Pre-1914 South Fork American River and Project 184

EID acquired Project 184 from Pacific Gas and Electric (PG&E) in 1999. Project 184 includes reservoirs and associated dams, 22 miles of canals, a 21 Mw powerhouse, and other ancillary facilities. Prior to the transfer of ownership and water rights, EID held a contract to purchase water from PG&E and its predecessor, Western States Gas and Electric Co. The original water rights claims date back to 1856, with additional claims being filed in the 1860s and 1870s. The water rights for diversions from Echo Lake were established in 1880 in a California Supreme Court decision. Then, in 1918, the California Railroad Commission (predecessor to the California Public Utilities Commission) recognized the use of water from the El Dorado Canal for irrigation and domestic purposes.

The sources of this water supply include natural flows in the South Fork American River and its tributaries, and stored water in Silver, Aloha, Echo, and Caples Lakes. The supply is diverted from the South Fork American River at Kyburz and is conveyed via the El Dorado Canal to the El Dorado Forebay. Some additional water is obtained by diversions into the El Dorado Canal from streams tributary to the South Fork American River. EID takes consumptive use of the water supply at the Main Ditch Intake, located at the El Dorado Forebay. This particular supply contributes 15,080 acre-feet per year to EID's system firm yield.

Water diversions of up to 156 cfs can be made from the South Fork American River at the diversion dam. In addition to these direct diversion rights, EID also has pre-1914 diversion and storage rights associated with portions of the waters stored in Silver Lake, Caples Lake, and Lake Aloha and all of the waters stored in Echo Lake.

El Dorado Forebay is filled by the surface water supply from the Project 184 facilities upstream in the South Fork American River basin and at Echo Lake. EID has a consumptive water entitlement of 15,080 acre-feet per year delivery at the Forebay. The entitlement is a pre-1914 water right, and diversions are made in compliance with the 40-year Federal Energy Regulatory Commission Project 184 operating license issued to EID in October 2006. Because the full entitlement can be provided in all years including the most severe historic single dry year of 1977, this source of water is considered assured, and not subject to shortage from hydrologic droughts.

Permit 21112 and Warren Act Contract

The State Water Resources Control Board (SWRCB) issued EID a water right permit in 2001 for an additional 17,000 acre-feet per year of water supply associated with Project 184 facilities and power operations to be taken at Folsom Reservoir. This water supply was authorized under Permit 21112 for diversion and consumptive use anywhere within EID's contiguous service area. There are no cutback provisions on this supply.

The El Dorado County Water Agency (EDCWA) and EID applied to the SWRCB to obtain water rights for consumptive use of waters previously stored and released for power generation from Caples, Silver, and Aloha Lakes, as well as certain direct diversions from the South Fork American River, all of which have been used by Project 184 for hydroelectric power generation or instream flows. The EDCWA later assigned all of its rights under this application to EID. The SWRCB granted the right to appropriate 17,000 acre-feet per year of water. Permit 21112 allows EID to make direct diversions from the South Fork American River at Folsom Reservoir; to store in Caples, Silver, and Aloha Lakes; and to redivert the water released from storage. The sole approved point of take for consumptive purposes is Folsom Reservoir.

A diversion from Folsom Reservoir requires acquiescence from the USBR and issuance of a Warren Act Contract. EID has diverted water under this right under a temporary urgency basis and the Warren Act Contract is pending.

Recycled Water Supplies

EID produces recycled water at both the El Dorado Hills and Deer Creek wastewater treatment plants which is then used by EID's customers for irrigation of residential landscape and commercial landscape. The availability of recycled water is currently limited to the El Dorado Hills and Cameron Park areas. EID anticipates a 2035 recycled water supply totaling 5,600 acre-feet per year (see Section 4.3 for further details).

4.2.2 Planned Water Supplies

EID has plans to acquire and use two additional water supplies from EDCWA for use within its service area to make available for the Proposed Project – water under the El Dorado-SMUD Cooperation Agreement and water under EDCWA's Fazio CVP supply. This section describes these supplies.

El Dorado-SMUD Cooperation Agreement

As shown in **Table 4-1**, the additional supplies include a grouping of water right applications and assignment of existing water right applications totaling approximately 40,000 acre-feet of water. This supply is being developed by the El Dorado Water and Power Authority (EDWPA). EDWPA is a Joint Powers Authority consisting of El Dorado County, El Dorado County Water Agency and El Dorado Irrigation District (collectively, El Dorado Parties). EDWPA was formed to pursue additional water supplies for the western slope of El Dorado County as determined by the El Dorado County General Plan. This need is identified in the El Dorado County Water Agency Water Resources Development and Management Plan (Water Plan).[31] The Water Plan is

[31] http://www.edcgov.us/water/final_water_resources_plan.html

designed to coordinate water resource planning activities within El Dorado County and identifies water supply needs for the western slope of El Dorado County of approximately 34,000 acre-feet per year (AFA) at the 2025 demand level.

In 2005, the El Dorado Parties signed the "El Dorado – SMUD Cooperation Agreement" (included with **Appendix A**), which would help meet the Water Plan's identified water supply needs. This Agreement requires SMUD to make annual deliveries of up to 30,000 acre-feet of water through 2025 and 40,000 acre-feet thereafter from SMUD's Upper American River Project (UARP) to the El Dorado Parties. In 2008, EDWPA petitioned the SWRCB for partial assignment of two applications for diversion and storage to obtain water supplies necessary to trigger SMUD's obligations. A Draft Environmental Impact Report has been prepared in support of the water rights application and was circulated in July 2010. EDWPA is currently in the protest settlement phase and the CEQA process is anticipated to be completed in 2014 with award of water rights shortly thereafter.

The El Dorado-SMUD Cooperation Agreement also obliges SMUD to provide carryover storage and delivery to EID of up to 15,000 acre-feet of drought protection water supplies to be obtained by EDWPA. Based on demand projections, EID anticipates that only 30,000 acre-feet of the 40,000 acre-feet identified in the water right applications and the El Dorado – SMUD Cooperative Agreement will be available to EID in normal years. Moreover, EID has planned that a mere 5,000 acre-feet of the water supply will be available for EID's uses in each dry year. This number is derived from Appendix H of the El Dorado – SMUD Cooperation Agreement describing deliveries available from carryover storage. Both of these conservative assumptions are shown in **Table 4-1**. EID has planned this supply to be available starting in 2025.

Fazio CVP Supply

EID is also in the final stages of securing 7,500 acre-feet of CVP water supplies in conjunction with EDCWA. In 1990, Congress directed the Secretary of the Interior, through the USBR, to enter into a new CVP Municipal and Industrial (M&I) water service contract with EDCWA for up to 15,000 acre-feet of water annually (Section 206 of P.L. 101-514). The CVP water service contract requires requisite compliance by EDCWA and the USBR with CEQA, NEPA, and ESA statutes.

In 2009, a draft EIS/EIR was released for public review and comment for the CVP M&I water rights contract. In 2010, USBR advised EDCWA that it would take another 5 years before the CVP-Operations Criteria and Plan (OCAP) related litigation would allow the EIS to move forward. As a result, EDCWA made the decision to detach the EIR from the EIS – essentially separating the CEQA and NEPA processes. EDCWA certified the Final EIR and approved the project in January 2011. EDCWA then prepared and submitted to USBR a draft Biological Assessment (BA) in September 2011 and a draft Final EIS in October 2011. USBR submitted the draft Final EIS to NOAA Fisheries in December 2011. Final EIS completion and contract execution is pending completion of ESA consultation with NOAA Fisheries.

The CVP contract seeks to acquire 15,000 acre-feet of CVP project water, of which at least 7,500 acre-feet would be made available to EID by subcontracts with EDCWA.[32] Diversions by EID would occur at its existing intake in Folsom Reservoir, conveyed to the El Dorado Hills Water Treatment Plant, and delivered to a specific place of use location in El Dorado Hills and Cameron Park areas as shown in Figure ES-2 of EDCWA's EIR.

The contract negotiations and environmental compliance efforts are ongoing. These actions allow EID to use this water supply in this WSA as a planned supply that will be available to EID in the future to serve the Proposed Project. The approval of the contract terms as well as finalization of the environmental documents will allow EID to apply the water supplies under this contract entitlement to municipal and industrial beneficial uses. EID has planned this water supply to be available starting in 2015.

4.2.3 Normal Year Water Supply Availability

As shown in **Table 4-1**, EID's total water entitlements under its existing and planned supplies does not equate to the amount of water available in normal years in the future. The normal year water supplies will be described in this section.

Excluding recycled supplies, EID's secured water rights and entitlements available for the Proposed Project total 67,190 acre-feet. As shown in the sufficiency analysis in Section 5, this amount is insufficient to serve EID's future demand incorporating the Proposed Project and all planned future projects. Accordingly, this section assesses both EID's secured supplies and additional planned supplies. EID's water supplies associated with the entire secured and planned water assets totals 110,290 acre-feet per year.

The 67,190 acre-feet of secured supplies include appropriative water right license 2184 and pre-1914 appropriative water rights associated with Slab Creek, Hangtown Creek and Weber Creek. As described above, these rights are collectively combined for conveyance purposes in a Warren Act Contract, No. 06-WC-20-3315, that allows for storage in and diversion from Folsom Reservoir. The total volume is 4,560, net of a negotiated 15% conveyance loss under the terms of the Warren Act contract. For purposes of serving the Proposed Project, EID assumes full diversion at 4,560 in normal years under these water assets.

Appropriative water right licenses 11835 and 11836 are also secured supplies. These supplies can be diverted from several creeks in the Cosumnes River watershed (Camp, Hazel, and Sly

[32] Central Valley Project Water Supply Contracts Under Public Law 101-514 (Section 206): Proposed Contract Between the U.S. Bureau of Reclamation and the El Dorado County Water Agency, and Proposed Subcontracts Between the El Dorado County Water Agency and the El Dorado Irrigation District, and Between the El Dorado County Water Agency and the Georgetown Divide Public Utility District Final Environmental Impact Report at ES-1, January 2011.

Park) and are typically stored in Jenkinson Lake. The maximum rate of diversion is 500 cfs for a total possible diversion volume of 33,400. However, due to limitations in storage availability in Jenkinson Lake assessed through OASIS hydrologic modeling, the maximum available normal year supply for the Proposed Project is 23,000 acre-feet.[33] Although EID has diverted as much as 25,745 acre-feet from this reservoir, EID does not anticipate using more than 23,000 acre-feet under this right for its normal year diversions in the future.

Central Valley Project Contract 14-06-200-1375A-LTR1 is a secured supply available for immediate use for the Proposed Project. This CVP contract entitlement requires the USBR to deliver up to 7,550 acre-feet of water from its SWRCB water right permits on the American River to EID.

As described in Section 4.2.1, EID also has a number of pre-1914 appropriative water rights on the American River with storage components in Silver Lake, Lake Aloha, Caples Lake, and Echo Lake. For purposes of this document, these are collectively called the pre-1914 American River water rights.[34] The total volume of water available under the pre-1914 American River water rights is 15,080 acre-feet in normal years.

Appropriative water right permit 21112 is a secured supply for purposes of this WSA. Permit 21112 allows EID to divert up to 17,000 acre-feet of water per year from Folsom Reservoir to be used in EID's service area. EID has diverted water under this permit as part of a temporary urgency in 2008. EID must finalize its Warren Act Contract to divert this water at Folsom Reservoir. However, based upon the availability of the supply in Permit 21112, the ability to store the water in Caples, Silver, and Aloha lakes, and the pending conveyance agreement with USBR, the normal-year availability of this supply is 17,000 acre-feet.[35]

As described in Section 4.2.2, EID's planned water supplies include the CVP Fazio supply of 7,500 acre-feet as authorized under federal law. Once secured, EID should receive normal-year deliveries of the full entitlement just as USBR promises to other CVP M&I contract holders on the American River system. There is no reason to believe that this contract entitlement will be different than other CVP contract entitlements on the American River system.

Last, as described in Section 4.2.2, EID's planned water supplies derived from the EDWPA appropriative water right applications filings and assignments, as well as the El Dorado – SMUD Cooperation Agreement, indicate that EID should receive normal-year water deliveries of 30,000 acre-feet per year starting in 2025 and then as much as 40,000 acre-feet of deliveries thereafter.

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[33] 2013 Water Resources Report

[34] California Water Code section 10910(d)(2)(A) requires "proof of entitlement" of each individual water right that is combined into this pre-1914 American River water rights grouping. These documents are contained in **Appendix A** of this Water Supply Assessment.

[35] EID Urban Water Management Plan 2010 Update, July 2011 at page 4-7 of 22. Follow-up discussion with EID Counsel on water availability on April 23, 2013.

Based on demand projections, the District uses 30,000 acre-feet of normal-year deliveries under these collective applications and the El Dorado-SMUD Cooperation Agreement.

4.2.4 Dry-Year Water Supply Availability

As shown in **Table 4-1**, EID anticipates less water being available in dry years than is otherwise available in normal years as described in Section 4.2.3. Dry-year supplies include supply reductions attributable to hydrologic droughts and regulatory curtailments. The dry-year water supplies are described in this section.

EID's entire normal-year secured and planned water assets total 110,290 acre-feet per year. In dry years, EID's total water assets equal 77,885 acre-feet. Of this total supply, 61,660 acre-feet are secured water assets and 16,225 acre-feet are planned water assets.

As described in Section 4.2.3, the secured water assets include License 2184 and the additional pre-1914 appropriative rights that are included in Warren Act contract 06-WC-20-3315, Licenses 11835 and 11836, CVP Contract 14-06-200-1375A-LTR1, the pre-1914 American River water rights grouping, and Permit 21112. All of these water rights are subject to different regulatory and hydrological restrictions that could result, in some instances, in reduction of the water supplies available under the right or entitlement in dry years.

The water rights contained in the Warren Act Contract 06-WC-20-3315 have some level of regulatory restrictions and hydrological uncertainty. EID's 2010 UWMP indicates that the estimated dry-year yield associated with this water asset is 3,000 acre-feet per year based upon regional hydrologic conditions.[36] Accordingly, based upon the presumed hydrologic conditions, the dry-year reliability for this supply in three consecutive dry years is 3,000 acre-feet per year.

Licenses 11835 and 11836 have a full diversion entitlement of 33,400 acre-feet per year. Of that amount, carryover storage in Jenkinson Lake and diminished inflow reduce that entitlement to a normal-year supply of 23,000 acre-feet per year. In dry years, this amount is further reduced based upon hydrologic conditions as well as carryover storage needs for future years from Jenkinson Lake. Accordingly, based upon the OASIS hydrologic modeling report, EID reduces this supply's availability to 20,920 acre-feet in a single dry year. Thus, 20,920 acre-feet per year is used in this WSA as the dry-year safe yield number for a single dry year. To be conservative, EID plans for this supply to be further reduced during year two and again in year three of and three consecutive dry years. This WSA uses 17,000 acre-feet and 15,500 acre-feet as the available supply in year two and year three of a multi-year drought, respectfully.

CVP Contract 14-06-200-1375A-LTR1 has a normal-year entitlement of 7,500 acre-feet per year. The USBR, however, assesses the dry-year supply availability of its CVP M&I contracts

[36] EID Urban Water Management Plan 2010 Update, July 2011 at page 4-6 of 22. Follow-up discussion with EID Counsel on water availability on April 23, 2013.

through the CVP M&I Shortage Policy. Based on inflow and storage criteria developed at the joint operations center, USBR can reduce contract water supplies under the CVP M&I Shortage Policy by up to 25% of historic use with various adjustments made for population, use of non-CVP water and extraordinary conservation actions.[37] With these adjustments in mind, USBR calculates the reduced CVP M&I delivery essentially based upon the average of the three previous normal years of use under the CVP contract. Under the strictest interpretation of this policy, if the water under the CVP contract was not used, then the dry year water is not available. But, USBR has considered that use of non-CVP supplies in lieu of CVP water use may be used to calculate use under this shortage policy. For purposes of this analysis, however, we have determined that based upon normal growth in demand in EID's service area, EID's customers would utilize the entire contract entitlement in normal years in the future. As such, EID calculates its dry-year reduction for this Proposed Project based upon three years of full use of its contract allocation. Accordingly, the dry year supply under this water contract entitlement is 5,660 acre-feet per year.

EID's pre-1914 American River water rights-grouping has a normal-year reliability of 15,080 acre-feet per year. Based upon the early priority date of these water assets and the storage capability within EID's system associated with these water assets, they are not reduced at all in a single dry year or three consecutive dry years.

Permit 21112 is another secure dry-year water asset. EID's 2010 UWMP states "there are no cutback provisions on this supply."[38] As such, the dry year reliability of Permit 21112 is 17,000 acre-feet per year.

As described in Section 4.2.2, EID's planned supplies include the CVP Fazio supply, and the several rights and contract that make up the UARP SMUD water. All of these assets combined have a three consecutive dry year supply reliability of 10,625 acre-feet per year.

The CVP Fazio supply is another CVP M&I contract supply that is subject to the same Municipal and Industrial shortage provisions described above for EID's other CVP contract entitlement. EID's expected portion of the Fazio supply has a normal-year contract allocation of 7,500 acre-feet per year. Assuming under the rules described above that EID is able to use its entire contract entitlement in the future, a 25% reduction from the contract entitlement reduces the delivery by 1,875 acre-feet per year. As such, the single dry year reliability and three consecutive dry year reliability under this contract is 5,625 acre-feet per year.

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[37] Reclamation has the authority to reduce the supply volumes even further under extreme conditions – Health and Safety criteria – but this sort of supply reduction would only occur in extreme drought and would be offset by reductions in demand in EID's service area, as needed, to maintain basic Health and Safety conditions. The District's drought contingency plans address these situations.

[38] This assertion was confirmed in a telephone conversation with the District's Counsel on April 23, 2013.

Last, the UARP SMUD water that is derived from the numerous water right applications and assignments as well as the El Dorado-SMUD Cooperative Agreement indicates that the water available under these components in dry years could be severely curtailed. Appendix H of the Agreement states that annual deliveries can be superseded and deliveries from carryover drought storage can be reduced to as little as 5,000 acre-feet in a declared Critically Dry year if SMUD reservoir storage drops below 100,000 acre-feet (approximately 25%). Out of an abundance of caution, EID anticipates only 5,000 acre-feet of carryover drought-supply water would be available each year over the course of a three-year drought.

4.3 RECYCLED WATER SUPPLIES

EID uses recycled water to meet some current non-potable demands within its service area. EID may expand its development and use of recycled water in the future to meet a portion of the non-potable demands associated with the Proposed Project and other anticipated new demands. EID's current recycled water use is about 2,200 acre-feet per year. This use will expand incrementally over time. By 2035, EID anticipates a supply of 5,600 acre-feet of recycled water per year within its service area.[39]

EID's recycled water system consists of supply from the El Dorado Hills wastewater treatment plant and the Deer Creek wastewater treatment plant. These treatment plants have an interconnected network of transmission and distribution pipelines, pump stations, storage tanks, pressure reducing stations, and appurtenant facilities located within the communities of El Dorado Hills and Cameron Park.[40] EID mandates the use of recycled water through Board Policy 7010, wherever economically and physically feasible as determined by the Board, for non-domestic purposes.[41] At this time, non-domestic use includes commercial landscape irrigation, residential or multi-family dual-plumbed landscape irrigation, construction water, and recreational impoundments.

Recycled water availability is an outcome of increased municipal and domestic demand and wastewater production as a byproduct of this demand. In other words, annual recycled water production capabilities are based on the total wastewater flows to the treatment plants. With the population and industrial demands growing in this region, as described in Section 3, the availability of recycled water will increase. EID is taking a conservative view of the growth in recycled water based upon its current production levels, estimated regional population growth, facility expansion identified in its 2013 IWRMP and WWFMP, treated water discharge requirements, and its ability to capture and store recycled water supplies in the future. The total recycled water available for use in 2035 is estimated to be 5,600 acre-feet per year.[42]

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39 EID Integrated Water Resources Master Plan, March 31, 2013
40 EID Urban Water Management Plan 2010 Update, July 2011 at page 4-10 of 22.
41 EID Urban Water Management Plan 2010 Update, July 2011 at page 4-6 of 22.
42 EID Integrated Water Resources Master Plan, March 31, 2013 at page 221.

Accordingly, Table 4-2 shows the incremental recycled water assets that would be available over time for the District's non-potable water uses.

Table 4-2 – Timing of Recycled Water and Quantities

Year	Recycled Water Supply (acre-feet)
Current	2,200
2015	2,400
2020	2,600
2025	3,100
2030	4,200
2035	5,600

4.4 Facility Costs and Financing

EID's recently completed 2013 IWRMP and WWFMP identify and allocate the future costs of capital expansion and replacement needs, and addresses financing mechanisms for EID's water assets. These costs and financing mechanisms are hereby incorporated by reference.

The District establishes and periodically updates its Facility Capacity Charges (FCCs) to recover the cost of those portions of existing District facilities that will be used by future customers and to fund needed expansion, or additional capacity, of District facilities to serve new users. The District periodically reviews its FCCs to ensure they accurately reflect the costs of providing service to new customers. Currently the District is updating the FCCs to incorporate projects identified in the adopted 2013 IWRMP. The FCC update is currently under review by the Board and a developer committee, and the District anticipates adoption of the updated FCCs in August 2013.

4.5 Regulatory Approvals and Permits

As described in Section 4.2.2, EID has water assets that require further regulatory approvals, permit compliance, and contract approvals. Each water asset has its own set of regulatory requirements that are assessed in this section.

Appropriative water right Permit 21112 issued by the SWRCB has not been perfected. In order to perfect an appropriative water right, EID must put all of the water assets under that permit to beneficial use. Upon putting the water to beneficial uses and meeting all of the other conditions in the water right permit, EID will be eligible to obtain a water right license for this appropriative water right. Attaining a water right license further fortifies the legitimacy of the water right for EID's continual use in the future. There is no indication that EID will have difficulty in obtaining a water right license for Permit 21112.

Permit 21112 also requires a Warren Act Contract to be negotiated and approved by the USBR. The Warren Act Contract will allow EID to divert water from Folsom Reservoir for delivery to the El Dorado Hills Water Treatment Plant. Although the District may choose to divert some of the water upstream of Folsom Reservoir through other SWRCB regulatory processes, a Warren Act Contract is essential for any diversions emanating from Folsom Reservoir. EID is currently in negotiations with USBR to obtain a long-term contract. While those negotiations continue, short-term Warren Act Contracts are also obtainable, if needed. There are no foreseeable reasons that these negotiations will not succeed. Both EID's Board of Directors and USBR officials will need to execute the contract once the terms have been drafted, and EID will need to obtain judgment in a judicial action to validate the contract.

The Fazio water supply also has additional regulatory approvals and permits pending. This CVP contract entitlement is authorized by Public Law 101-514. The 15,000 acre-feet of water supply is contemplated to be split equally between Georgetown Divide Public Utilities District and EID. As described in Section 4.2.2, EDCWA is negotiating with USBR on behalf of EID to secure the CVP contract entitlement authorized by this federal statute and finalize the EIS. Accordingly, EID will continue to work with EDCWA and USBR to finalize acquisition of this water supply. Upon completion of the EIS, the EDCWA's designee and USBR officials will need to execute the CVP water supply contract, and EDCWA may need to obtain judgment in a judicial action validating the contract.

The pending water right applications and application assignments before the SWRCB as well as the El Dorado – SMUD Cooperation Agreement constitute the last water supply that is pending further regulatory approvals. As described in Section 4.2.2, EDWPA is awaiting approvals from SWRCB for these water assets. Upon SWRCB approval, EID will obtain 30,000 acre-feet of water under the El Dorado – SMUD Cooperation Agreement.

The SWRCB water right process requires the SWRCB to conduct an internal project review of the applicable technical and hydrological information as well as consider the broader effects on other legal users of water throughout the watershed before issuing a permit. This regulatory process may eventually necessitate a SWRCB hearing where testimony from proponents and opponents of the water right permit is heard and weighed by the SWRCB Board Members before issuing the conditioned permits. Once permits have been issued, then the District must comply with the permit terms and perfect application of the water supplies to beneficial use in order to acquire water right licenses associated with the appropriative water rights.

The El Dorado – SMUD Cooperation Agreement is an agreement among the various parties to cooperate in facilitating the storage and delivery of these water assets to the identified purveyors. As such, through the processing of the water right applications and the furtherance of compliance with the terms of those agreements, the water assets considered there are likely to be available to

EID. The regulatory approvals and permits needed to finalize EID's control over these water assets are moving forward.

4.6 SUPPLY SUMMARY

EID has two broad categories of water assets that are available for the Proposed Project – the secured water assets and planned water assets. Collectively, these supplies total 110,290 acre-feet in normal water years and 77,885 acre-feet in a single dry water year. In year two and year three of a multi-year drought, supplies are further reduced to 73,965 acre-feet and 72,465 acre-feet, respectfully.

As described above, the secured water assets include appropriative water right License 2184 and the accompanying pre-1914 appropriative water rights held under Warren Act Contract 06-WC-20-3315, appropriative water right Licenses 11835 and 11836, CVP Contract 14-060200-1375A-LTR1, the pre-1914 American River storage and diversion appropriative water rights, and Permit 21112. The normal year water supplies available to EID under the secured assets total 67,190 acre-feet per year. In dry years, the water supplies available to EID under the secured assets totals 61,660 acre-feet per year.

The planned water assets, although partially secured, are not yet fully available for EID's use to serve the Proposed Project contemplated in this WSA. As described above, these assets are sufficiently secure to be considered planned supplies for the Proposed Project in 2035. In normal years, the water supplies under these assets total 37,500 acre-feet. In dry years, the water supplies under these assets total 10,625 acre-feet.

Finally, the recycled water assets in both normal and dry years, derived from planned growth and continual indoor water usage regardless of year type, total 5,600 acre-feet in 2035.

SECTION 5 – SUFFICIENCY ANALYSIS

5.1 INTRODUCTION

The analysis detailed in this section provides a basis for determining whether sufficient water supplies exist to meet the estimated water demand of the Proposed Project.[43]

This section includes:

- Analysis of sufficiency, considering variations in supply and demand characteristics under normal, single-dry and multi-dry hydrologic conditions,
- Analysis conclusions

5.2 SUFFICIENCY ANALYSIS

The sufficiency analysis integrates the water demands detailed in Section 2 and Section 3 with the water supplies characterized in Section 4. The results are presented in **Table 5-1** beginning with "current" conditions (recognized as 2012) and continuing with 5-year increments from 2015 through 2035. While the analysis at various intervals before build-out is important, the most critical projection for the sufficiency analysis occurs in 2035. This analysis assumes that the Proposed Project, along with the other projects simultaneously undergoing a WSA analysis (see Section 3.3), are fully constructed by 2035, and other anticipated growth continues as described in Section 3.4.

Table 5-1 incorporates the Proposed Project water demand projection in **Table 2-3**, assuming the Proposed Project develops as detailed in Section 1, and the estimated water demands for all other existing and planned future uses through 2035 as detailed in **Table 3-2**. **Table 5-1** also presents the available water supplies for the contiguous EID service area during normal, single-dry and multiple-dry years, as detailed in Section 4. The water demands and available supplies in a single dry-year and multiple dry-year condition are discussed in the following subsections.

[43] CWC § 10910 (c)(4) provides that "If the city or county is required to comply with this part pursuant to subdivision (b), the water supply assessment for the project shall include a discussion with regard to whether the total projected water supplies, determined to be available by the city or county for the project during normal, single dry, and multiple dry water years during a 20-year projection, will meet the projected water demand associated with the proposed project, in addition to existing and planned future uses, including agricultural and manufacturing uses."

Table 5-1 – Comparable Analysis of Supply and Demand

Year	Project Water Demand (af/yr)	All Other EID Water Demands (af/yr)	Total Water Demands (af/yr)	Non-Revenue Water @ 13%	Demands with Loss	EID Water Supplies							
						Surface Water							
						Hydrologic Year Type		EDH Service Area (af/yr)	West/East Service Area (af/yr)	Total (af/yr)	Recycled Water (af/yr)	Total Available Water Supply (af/yr)	Projected Surplus/ (Shortfall) (af/yr)
Current	0	38,984	38,984	N/A	38,984	**Normal**		29,110	38,080	67,190	2,200	69,390	30,406
	0	40,933	40,933	N/A	40,933	**Single Dry**		25,660	36,000	61,660		63,860	22,927
	0	40,933	40,933	N/A	40,933	**Multiple Dry**	Year 1	25,660	36,000	61,660		63,860	22,927
	0	38,068	38,068	N/A	38,068		Year 2	25,660	32,080	57,740		59,940	21,872
	0	34,793	34,793	N/A	34,793		Year 3	25,660	30,580	56,240		58,440	23,647
2015	125	34,831	34,956	4,544	39,500	**Normal**		36,610	38,080	74,690	2,400	77,090	37,590
	131	36,573	36,704	4,771	41,475	**Single Dry**		31,285	36,000	67,285		69,685	28,210
	131	36,573	36,704	4,771	41,475	**Multiple Dry**	Year 1	31,285	36,000	67,285		69,685	28,210
	122	34,012	34,134	4,437	38,572		Year 2	31,285	32,080	63,365		65,765	27,193
	111	31,087	31,198	4,056	35,254		Year 3	31,285	30,580	61,865		64,265	29,011
2020	638	37,359	37,997	4,940	42,937	**Normal**		36,610	38,080	74,690	2,600	77,290	34,353
	670	39,227	39,897	5,187	45,084	**Single Dry**		31,285	36,000	67,285		69,885	24,801
	670	39,227	39,897	5,187	45,084	**Multiple Dry**	Year 1	31,285	36,000	67,285		69,885	24,801
	623	36,481	37,104	4,824	41,928		Year 2	31,285	32,080	63,365		65,965	24,037
	569	33,343	33,912	4,409	38,321		Year 3	31,285	30,580	61,865		64,465	26,144
2025	1,137	42,721	43,859	5,702	49,561	**Normal**		19,610	85,080	104,690	3,200	107,890	58,329
	1,194	44,858	46,052	5,987	52,039	**Single Dry**		14,285	58,000	72,285		75,485	23,446
	1,194	44,858	46,052	5,987	52,039	**Multiple Dry**	Year 1	14,285	58,000	72,285		75,485	23,446
	1,111	41,718	42,828	5,568	48,396		Year 2	14,285	54,080	68,365		71,565	23,169
	1,015	38,129	39,144	5,089	44,233		Year 3	14,285	52,580	66,865		70,065	25,832
2030	1,646	49,570	51,216	6,658	57,874	**Normal**		19,610	85,080	104,690	4,100	108,790	50,916
	1,728	52,048	53,777	6,991	60,768	**Single Dry**		14,285	58,000	72,285		76,385	15,617
	1,728	52,048	53,777	6,991	60,768	**Multiple Dry**	Year 1	14,285	58,000	72,285		76,385	15,617
	1,607	48,405	50,012	6,502	56,514		Year 2	14,285	54,080	68,365		72,465	15,951
	1,469	44,241	45,710	5,942	51,652		Year 3	14,285	52,580	66,865		70,965	19,313
2035	1,927	57,627	59,554	7,742	67,295	**Normal**		19,610	85,080	104,690	5,600	110,290	42,995
	2,023	60,508	62,531	8,129	70,660	**Single Dry**		14,285	58,000	72,285		77,885	7,225
	2,023	60,508	62,531	8,129	70,660	**Multiple Dry**	Year 1	14,285	58,000	72,285		77,885	7,225
	1,881	56,273	58,154	7,560	65,714		Year 2	14,285	54,080	68,365		73,965	8,251
	1,720	51,432	53,152	6,910	60,061		Year 3	14,285	52,580	66,865		72,465	12,404

5.2.1 Single Dry Year Supply and Demand Conditions

Under this condition, EID would anticipate a variance from the normal-year analysis, including: (1) shortage in full availability of supplies as detailed in **Section 4**, and (2) an increase in water demand. The increase in demand is based on the following:

- Landscape irrigation demands will increase to reflect the generalized earlier start of the landscape irrigation season due to limited rainfall in the single driest year. Since this increase only applies to the outdoor portion of a customer's demand, an adjustment factor of 5 percent is applied to the total normal-year water demand values.
- Historically, during single dry year circumstances, EID does not implement its shortage contingency plan,[44] since the extent of the dry conditions into future years is unknown. EID follows adopted policies and its 2008 *Drought Preparedness Plan* when implementing any voluntary or mandatory demand reduction measures.

As a result of these factors, the Proposed Project water demand and those of the other existing and planned uses is expected to increase in a single dry year above the demand expected under normal hydrologic circumstances. Additionally, as detailed in Section 4, EID anticipates a decrease in available water supplies. These changes are shown in **Table 5-1**.

5.2.2 Multi-Dry Year Supply and Demand Conditions

When a single dry year expands into a series of dry years, water supply and demand conditions will continue to evolve. Under such a multi-dry year, EID would anticipate many similar conditions that were assumed for the single-dry year, including: (1) shortage in full availability of supplies as detailed in Section 4, and (2) increases in projected demands. However, when entering the second and third year of a sequence of dry-years, EID would implement necessary policies to manage limited water supplies.[45] Demands over a series of three dry years are adjusted as follows:

- Year 1 – the first year mimics a "single-dry year" condition, where demands increase approximately 5 percent and EID shortage policies are not yet invoked (see Section 5.2.1).
- Year 2 – The demands again mimic a "single-dry year" and would be expected to increase by 5 percent above normal year conditions. However, when recognizing a second dry-year, EID would invoke the first stage of the Drought Preparedness Plan. This stage states: "*The objective of Stage 1 is to initiate public awareness of predicted water shortage conditions, and encourage voluntary water conservation to decrease*

[44] See EID Board Policy AR 5011-Water Supply Management Conditions (available at http://www.eid.org/modules/showdocument.aspx?documentid=2687).
[45] See EID Board Policy AR 5011-Water Supply Management Conditions (available at http://www.eid.org/modules/showdocument.aspx?documentid=2687).

normal demand up to 15%."[46] As part of this stage, EID implements drought water rates among other specified activities to encourage conservation. For purposes of this WSA, the demand reduction achieved under Stage 1 is estimated to be 7 percent of the already higher single dry-year demand.

- Year 3 – Upon entering the third dry year, EID would invoke the second stage of the Drought Preparedness Plan. This stage states: "*The objective of Stage 2 is to increase public understanding of worsening water supply conditions, encourage voluntary water conservation measures, and then if necessary, enforce mandatory conservation measures in order to decrease normal demand up to 30%*."[47] Under this Stage, EID increases efforts to reduce demand. For purposes of this WSA, the savings achieved under Stage 2 is estimated to be 15 percent of the already higher single dry-year demand.

As a result of these factors, the Proposed Project water demand and those of the Other Existing and Planned Uses is expected to increase in the first year of a multi dry-year condition above that estimated during normal hydrologic circumstances. In subsequent years, the demand will drop as elements of EID's Drought Preparedness Plan are implemented. These changes are shown in **Table 5-1**.

5.2.3 Analysis

As shown in **Table 5-1**, the demand and supply are compared under each hydrologic condition for each 5-year increment out to 2035. The resulting "supply surplus" or "supply shortfall" is shown in the final column. Based on the analyses, EID anticipates it will have sufficient water under all hydrologic conditions in each of the 5-year increments through 2035. Notably, the "surplus" supply is lowest during the second year of a multi-dry year condition, since this is the circumstance where demand is only slightly constrained, while supplies are the most constrained. Yet, even under such circumstances, sufficient water should be available.

5.3 SUFFICIENCY ANALYSIS CONCLUSIONS

As detailed in **Section 2**, this WSA estimates water demands for the Proposed Project of 2,177 acre-feet per year at build-out (including non-revenue water demands). The annual water demand estimate for all existing and planned projects in the contiguous EID service area, as detailed in **Section 3**, is approximately 67,300 acre-feet per year by 2035. After accounting for these demand projections for the next twenty years, EID should have sufficient water to meet the demands of the Proposed Project and its other service area demands for at least the next 20 years.

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[46] See EID Board Policy AR 5011.2-Water supply slightly restricted Drought Stage 1 – Voluntary reductions in use (available at http://www.eid.org/modules/showdocument.aspx?documentid=2687).
[47] See EID Board Policy AR 5011.3-Water supply slightly restricted Drought Stage 2 – Voluntary and mandatory reductions (available at http://www.eid.org/modules/showdocument.aspx?documentid=2687).

The conclusion that EID should have sufficient water available to meet the needs of the Proposed Project, in addition to the other demands in its service area through 2035, rests on the following set of assumptions:

- EID, EDCWA, and EDWPA successfully execute the contracts and obtain the water right permit approvals for currently unsecured water supplies discussed in Section 4. Absent these steps, the water supplies currently held by EID and recognized to be diverted under existing contracts and agreements would be insufficient in 2035 to meet the Proposed Project demands along with all other existing and planned future uses.
- EID will commit to implement Facility Capacity Charges in an amount sufficient to assure the financing is available as appropriate to construct the necessary infrastructure as detailed in the March 2013 EID *Integrated Water Resources Master Plan*.
- Demand in single-dry years includes an additional 5 percent of demand over the normal year demand during the same time period. This conservative assumption accounts for the likelihood that EID customers will irrigate earlier in the season to account for dry spring conditions. This hypothetical demand augmentation may or may not manifest in dry years, but this conservative assumption further tests the sufficiency of water supplies during dry conditions.
- The estimated demands include 13 percent to account for non-revenue water losses (e.g. distribution system losses).

The finding of this WSA is that EID should have sufficient water to meet the demands of Proposed Project and its other service area demands for the next 20 years.

Attachment #11

A PRIMER ON CALIFORNIA WATER RIGHTS

Prepared by
Gary W. Sawyers, Esq.

The following is a "primer" on basic California water rights. It is by no means comprehensive, and is intended only as an introduction to California's system of surface and groundwater rights. Specific situations must be analyzed with reference to the operative facts.

Surface Water Rights

California has a unique system of surface water rights that combines a traditional riparian system with the appropriative system found elsewhere in the West. The result is a confused approach to water rights that often leads to more questions that certainty.

For purposes of California law, surface water includes underflow of streams, underground streams, and any other subsurface flow that is identified with a defined bed, bank or channel. Therefore, wells extracting water near a surface water supply may, in fact, be pumping "surface water" for purposes of a water rights analysis.

On many other streams in California, the surface water rights are a tangle of various categories of rights that are virtually impossible to distinguish from one another. Often, historical practice is far more relevant in determining how water is actually allocated than are the underlying water rights. Nevertheless, that historical practice is founded on basic water rights law, which recognizes four basic types of surface water rights.

<u>Riparian Rights</u>. The riparian right is a natural appurtenance to land abutting a watercourse. However, the fact that a parcel of land presently abuts the watercourse does not mean that the entire parcel possesses riparian water rights. California adheres to the "source of title" rule. Under this rule, riparian land is the smallest parcel abutting the stream which has continuously been held under single ownership in the chain of title. In other words, if a 20 acre parcel originally abutting a river is split into a 15 acre portion separated from the river, and a 5 acre parcel is still touching the river, the 15 acre parcel will forever have lost its riparian character. Even if the 15 acre parcel is later purchased by the owner of the 5 acre parcel, the 15 acre parcel will not be restored to its former riparian character. (It is possible to reserve riparian rights to a severed parcel if the reservation is explicit in the deed creating the division, but this infrequently occurs).

Riparian rights can be explicitly severed from otherwise riparian land. Thus, the verification of riparian rights requires a careful examination of the chain of title back to the original paten t, together with a detailed examination of each deed in the chain to determine if riparian rights were reserved to an otherwise severed parcel, or conveyed from an otherwise riparian parcel.

The riparian right is a right to the natural flow of a watercourse. Therefore, there can be no riparian right to store water. Generally, "storage" means the impoundment of water for more than 30 days; riparian water which is "stored" for less than 30 days is usually deemed to have merely been "regulated" within the permissible scope of the underlying riparian right.

Riparian rights are generally senior to pre-1914 and post-1914 appropriative water rights (see below), and are not lost by non-use. However, recent California court decisions suggest that unexercised riparian rights can be subordinated to longstanding downstream appropriative rights in order to avoid unfair disruption of water allocation schemes upon which water users have come to rely. As a result, an unexercised riparian right may be junior to other rights; in a case where a stream is fully appropriated, a junior right may be tantamount to no right at all, and the holder of an unexercised riparian right might find himself or herself with little or no recourse as against his or her neighbors. In addition, the right of a riparian to object to conflicting uses can be lost by prescription (see below).

Riparian right holders generally do not have priorities with respect to other riparians. Instead, each has a "correlative right" to the use of a reasonable share of the total riparian water available in the watercourse, to the extent the riparian can place that water to beneficial use on the riparian's land[1]. As a result, quantification of the riparian right is almost impossible unless there has been a stream-wide adjudication.

<u>Pre-1914 Appropriative Rights</u>. Appropriative water can generally be defined as water that is diverted for use on non-riparian land. Prior to 1914, there was no comprehensive permit system available to establish appropriative water rights in California, and the establishment of such a right required simply posting and recording a notice of intended diversion and the construction and use of actual diversion facilities. The measure of the right was the nature and scope of the use of the water diverted.

Pre-1914 appropriative rights are relatively common. However, they are also fairly difficult to establish, and require evidence of original use prior to 1914 and continued use thereafter. Recorded notices of diversion can sometimes be obtained through county recorder's offices; som

[1] In 1928, the California Constitution was amended making the exercise of all water rights (both surface and groundwater) subject to a paramount limitation of reasonable and beneficial use (see below). This amendment did not affect priorities as among different users and classes of users, but simply put a cap on the right of any user to that amount of water which can be applied to reasonable, beneficial use.

e pre-1914 diverters also file notices or reports of appropriation with the State Water Resources Control Board (the "SWRCB").

The appropriative right is lost by non-use for the prescriptive period, and therefore the continuity of use is as important as the origin of the right. Even if the existence of the right is established, the priority of the right is often difficult to determine unless all rights along the watercourse have been adjudicated. Nevertheless, in the realm of appropriative rights, California adheres to the "first in time, first in right" rule, and a true pre-1914 right will have priority over a post-1914 right.

<u>Post-1914 Appropriative Rights</u>. In 1914, a comprehensive permit system was established in California and all new appropriative uses (both for diversion and storage) subsequent to that year require application to what is now the SWRCB. A "post-1914" appropriative water right will be granted by the SWRCB only after a public process in which the applicant is required to demonstrate the availability of unappropriated water and the ability to place that water to beneficial use. The SWRCB can verify the issuance and priority of any post-1914 water right. However, since even post-1914 rights may be lost by non-use, the continuing vitality of those rights still requires confirmation that the rights have been continually exercised without lengthy interruption (except, of course, for lack of water).

<u>Prescriptive Rights</u>. This final category of surface water rights is obtained by open, notorious, continuous and adverse use for the prescriptive period (in California, five years). Since the use must be adverse, a use which harms one water user may not harm another (for example an upstream water user). The prescriptive right is therefore less of a "water right" than it is the right to prevent another from objecting to one's own water use. One cannot prescript upstream. Since the adverse use must be continuous for the prescriptive period, one year of surplus water can cut off the prescriptive period and will require the would-be prescriptor to begin the prescriptive period again. Furthermore, in one case, the courts have held that since prescription does not run against the State, the SWRCB is not bound to recognize a prescriptive right and that the State may (i) require a prescriptor to apply for an appropriative permit and to comply with all conditions imposed thereon by the SWRCB, and (ii) enjoin the prescriptive use of water by a prescriptor who refuses to do so. As a result, a prescriptive right is also difficult to establish, unless it has been adjudicated; a SWRCB adjudication or court proceeding is necessary to confirm the existence and scope of a prescriptive right.

Groundwater Rights

At present, California groundwater law is found almost entirely in reported court decisions. Unlike the law governing rights to surface water and true underground streams (which is large ly statutory), there is no comprehensive, statewide regulatory scheme governing the extraction or use of groundwater. Therefore, a great many aspects of groundwater law remain unclear or subject to interpretation.

The recent drought resulted in unprecedented groundwater pumping due to surface water shortages. It is therefore predictable that a great many groundwater cases have been (or will be) commenced, potentially resulting in a number of significant appellate decisions in the next few years. It is also quite possible that legislative changes in groundwater law will occur in the foreseeable future. California is one of the few states in the West without a comprehensive statutory framework for groundwater regulation, and there have been a number of recent efforts in the Legislature to enact sweeping groundwater legislation. Although those efforts have been unsuccessful, the recent enactment of AB 3030 (permitting local agencies to develop and implement groundwater management plans) indicates the continued interest in regulating groundwater through legislation.

There has also been a recent effort by California counties to regulate groundwater by virtue of their general municipal police powers. While counties have generally not attempted to regulate groundwater extraction, except with respect to well drilling standards and health and safety concerns, demands of groundwater during the recent drought inspired counties to become more proactive in the groundwater arena. A California court has recently held that groundwater regulation is within a county's police powers and is not otherwise preempted by general State law. As a result of this case, many counties are considering adopting sweeping groundwater ordinances. In particular, counties are concerned with potential mining of groundwater resources for use outside the county. The extent to which counties can regulate groundwater is still an open question.

Prior to 1903, California courts generally applied the English common law rule that a landowner owns beneath the surface of his or her property to "the depths of the earth and up to the heavens." This rule was known as the "absolute ownership" rule because it resulted in a landowner having the right to use as much groundwater as s/he could physically extract from beneath his or her property. There was no limitation on this right.

However, in a landmark case decided in 1903, the California Supreme Court determined that the absolute ownership rule had no place in the arid climate of California. In the wake of the rejection of the rule, the courts established three categories of groundwater rights with respect to native percolating groundwaters (i.e., those not resulting from importation and/or artificial recharge and which are not surface water for purposes of regulation).

Overlying Rights. The courts have consistently upheld the right of a landowner whose land was overlying a groundwater basin to extract and use that groundwater on the overlying land, but have restricted that right to an amount which is reasonable in light of the competing demands of other overlying users. Each such landowner is called an "overlying user"; the right that each such user has is an "overlying right." Since an overlying user's right is limited in relation to other overlying users, this right is sometimes called a correlative right. The quantification of each overlying user's correlative right depends entirely on the facts and circumstances as they exist in the basin. However, the overlying user's correlative right is generally to a reasonable share of the groundwater in the common groundwater basin for use on such landowner's land that overlies the basin.

As among overlying users, it is generally irrelevant who first developed the groundwater. Each overlying user has a right in the common supply, and the exercise of that right entitles each to make a reasonable use of the water for the benefit and enjoyment of his or her overlying land. The correlative right belongs to all overlying landowners in common, and each may use only a reasonable share when the water is insufficient to meet the needs of all.

The overlying right may be used for any reasonable, beneficial use. However, water devoted to public uses (for example, water acquired by municipalities and public utilities for distribution to the public) is not an overlying use. Consequently, at least in theory, the rights of a party extracting groundwater for a public use are no greater, as against other parties, than would be the case if the water was taken out of land that party did not own. However, as a practical matter, overlyers can find it difficult to stop truly public uses of groundwater, even if those uses are based on junior rights (see below).

Appropriative Rights. Any party who does not own land overlying the basin, who owns overlying land but uses the water on nonoverlying land, or who sells the water to the public generally is an "appropriator" and not an overlying user. The courts generally acknowledge the right of an appropriator to take the available surplus from a groundwater basin and apply it to beneficial use inside or outside the basin. For this purpose, "surplus" means available water (that is, water the use of which will not create an overdraft condition) not needed to provide for the needs of all overlying users. (Overdraft is discussed more fully below.) There is no restriction as to where the water may be used, and no requirement that the appropriator be a landowner. The water may generally be used for private or public uses without restriction, subject to the requirement that the use of the water must be reasonable and beneficial.

Among appropriators, the priority of each appropriator's right is determined by the relative timing of the commencement of use, i.e., first in time is first in right.

Prescriptive Rights. There is some question in California as to whether prescriptive rights to groundwater can be asserted. At least one case suggests that the doctrine of prescription (or at least the doctrine of "mutual prescription" pursuant to which all users of a basin prescript as against each other) no longer has a place in California. However, the better view seems to be that prescription can occur relative to groundwater, just as it can with respect to surface water.

Prescriptive rights do not begin to accrue until a condition of overdraft begins. Therefore, it is first necessary to determine when a condition of surplus ends and overdraft begins.

The definition of overdraft was articulated by the California Supreme Court in 1975. There, the court held that overdraft begins when extractions exceed the safe yield of a basin plus any temporary surplus. Safe yield is defined as the maximum quantity of water which can be withdrawn annually from a groundwater supply under a given set of conditions without causing a gradual lowering of the groundwater levels resulting, in turn, in the eventual depletion of the supply. "Temporary surplus" is the amount of water which can be pumped from a basin to provide storage space for surface water which would be wasted during wet years if it could not be stored in the basin.

Once a groundwater basin reaches a condition of overdraft, no new appropriative uses may be lawfully made. If overlying users (who, as discussed below, have priority over appropriative users) begin to consume a greater share of the safe yield, the existing appropriators must cease pumping in reverse order of their priority as against other appropriators. Typically, however, appropriators continue extraction activities unless and until demand is made and/or suit is brought. If an appropriator continues pumping from an overdrafted basin for the prescriptive period (which, as in other contexts, is five years) after the other users from the basin have notice of the over draft condition (through decline of groundwater levels or otherwise), then that appropriator may obtain a prescriptive right good as against any other private (i.e., overlying) user.[2]

If the groundwater basin comes out of an overdraft condition, i.e., there is a surplus, during the five year period, the "continuous adverse use" requirement is not satisfied. In that situation, the five year period begins anew once overdraft conditions return. Prescription generally may not occur as against public entities and public utilities.

As against other prescriptive users, the first in time probably is first in right. It has been held, however, that if multiple prescriptors continue their prescriptive uses for an extended period of time, the concept of "mutual prescription" may apply. Under the mutual prescription doctrine, all such prescriptive users would bear proportionate reductions caused by water shortages, rather than on the basis of temporal priority. However, as noted above, questions exist about the continued viability of the mutual prescription doctrine.

As with prescriptive surface water rights, an adjudication or court proceeding is necessary to confirm the existence and scope of prescriptive rights.

Overlying User v. Appropriator. As long as surplus water is available from the basin, both overlying users and appropriators may pump without restriction, provided the water is applied to reasonable and beneficial uses. Therefore, if the groundwater basin can supply the needs of all overlying users and appropriators without creating a condition of overdraft, all may continue to extract water. If there is a condition of overdraft, the overlying user will generally prevail in a dispute over priority of rights as against an appropriator (even if the appropriator is a public entity). This is because the appropriative right is only in the surplus; if there is no surplus, there is no possibility of an appropriative right (although a prescriptive right may develop or exist). Therefore, it is unlikely an appropriator could prevail as against individual overlying users in a dispute over the right to pump native groundwater.

Notwithstanding the priority of overlying users as against appropriators, it does not necessarily follow that overlying users may prevent extractions by an appropriator depending upon the timing of an action against the appropriator and the appropriator's use of the water. Where the appropriated water has been put to public use, an injunction prohibiting further appropriation may not necessarily be issued. One court has stated that "where the interests of the public are involved and the court can arrive in terms of money at the loss . . . an absolute injunction should not be

[2] Some Southern California counties are subject to the additional requirement that notice of extraction in excess of 25 acre-feet per year be filed. If the required notice is not filed in any one year, the prescriptive period starts over.

granted, but an injunction conditional merely upon the failure of the defendant to make good the damage which results from its work. Such an action, if successful, should be regarded in its nature as the reverse of an action in condemnation." Also, an absolute injunction will not be granted where other forms of relief are available and would be adequate.

<u>Overlying User v. Prescriptive User</u>. Prescriptive use establishes a prescriptive right good against the overlying users as to whom the prescription has been effected. The priority between such users depends on the amount used by the overlying users during the prescriptive period. If the overlying users continue to pump at the same or increasing levels during the prescriptive period, then neither the prescriptive user nor the overlying user has priority over the other. Rather, the prescriptive user will obtain in effect a parity, according to the following formula announced by the California Supreme Court:

> The effect of the prescriptive right would be to give to the party acquiring it and take away from the private defendant against whom it was acquired either (i) enough water to make the ratio of the prescriptive right to the remaining rights of the private defendant as favorable to the former in time of subsequent shortage as it was throughout the prescriptive period . . . or (ii) the amount of the prescriptive taking, whichever is less . . .

If an overlying user's use declines during the prescriptive period, the overlying user will lose his or her right (as against a prescriptive user) to the extent of that reduction. Ironically, those who are not exercising their overlying use rights at all may fare quite well in the face of prescriptive uses; based on comments by some courts, it appears prescriptive rights do not impair an overlyer's right to groundwater for new overlying uses for which the need had not yet come into existence during the prescriptive period.

When prescriptive rights have vested and an overlying user continues to pump during the prescriptive period, the overlyer's right to continue pumping will usually be protected. In that case, a court would more likely order a proportionate reduction in pumping by both parties.

<u>Appropriator v. Prescriptive User</u>. Technically, this condition does not often exist, since one cannot be an appropriator unless there is surplus, and one cannot acquire a prescriptive right unless there is overdraft. Nevertheless, a prescriptive user is simply an appropriator whose use has continued for a sufficient period of time in the face of an overdraft condition. If both become prescriptive users, and one is a public entity, the public entity will likely prevail because it can pr

escript against the other user, while the private user cannot prescript against the public entity. However, even though a public entity cannot lose its rights by prescription, it is subject to limitations in prescription by the exercise of self help by an overlying user.

Groundwater Resulting From Imported Water. The preceding discussion relates to native groundwater, i.e., percolating groundwater which occurs naturally and is not imported. Imported water is water derived from outside the watershed which is purposefully recharged into the groundwater basin, essentially creating an "account" for the recharger. Imported water does not include the return flow from extracted native groundwater since that water does not add to the overall groundwater supply but instead decreases the amount of extraction from the basin. Assuming no prescriptive rights have attached to imported water used to recharge a basin, the imported water belongs solely to the importer, who may extract it (even if the basin is in overdraft) and use or export it without liability to other basin users.

Common Groundwater Practices. While the legal principles summarized above are those that govern groundwater throughout the State it is important to understand that those principles are often ignored--or at least discounted--in practice. Groundwater is frequently pumped by one landowner and sold or given to another, and groundwater has often been exported from one overdrafted basin to another (especially during the recent drought). Probably more than any other body of natural resource law, groundwater law is often honored more in the breach than in the compliance. Historical practices therefore frequently overrun technicalities, and courts often attempt to honor past practices by finding (sometimes tortured) ways to make the law "fit" the circumstances. Thus, the failure to use groundwater in accordance with the principles summarized above does not necessarily mean that a water user is violating the law or is without rights to the groundwater in question.

Adjudicated Water Rights

Many "water rights" in California are not quantified, but are simply claimed and/or exercised without objection by other parties. However, when competing demands for a common water supply--whether surface water, groundwater or both--become too great, formal adjudications are sometimes commenced by one or more of the competing claimants. Both the SWRCB and the courts can conduct adjudications under appropriate circumstances, which typically result in an enforceable order allocating the water (and the water rights) in the adjudicated stream system, groundwater basin or combined water source. Adjudications typically take years (or even decades) to complete because of the often complex legal and factual issues involved.

Frequently, the result of an adjudication is an equitable apportionment of water that does not "track" with a technical application of water law principles. For example, in a recently completed adjudication in the Mojave Basin, the court noted that strict adherence to priority of rights and correlative rights among water users of equal status created uncertainty and potential economic consequences. Therefore, the court applied a "physical solution" requiring all users of the common water source to share equitably both in the water and in the reduction in use necessary to reduce extractions to safe yield. As is commonly the case in judicial adjudications, the court also retained continuing jurisdiction over the implementation of the adjudication order, making the court an ongoing "player" in the administration of the basin.

Such physical solutions may produce the most appropriate allocation of the water resource, but they also create a number of issues. The adjudication order effectively supersedes water rights law, and any interested party must become familiar with the order's impacts on existing and future involvement with impacted water users. Depending on the adjudication order, a watermaster may be in place with jurisdiction over the affected water, and special procedures may be imposed on parties dealing with the water and water rights involved. Even more vexing is the relatively common situation in which the adjudication order effectively severs the water rights from the land, making them freely transferable separate from the land on which those rights originally arose. Adjudicated water rights therefore can fall into a category distinct from more traditional water rights.

Beneficial Use and the Public Trust Doctrine

Regardless of the nature of the water right in question, two very important principles will always apply. First, under the California Constitution, water must be put to reasonable and beneficial use. No water right grants any party the right to waste or make unreasonable use of water, and any water right can be curtailed or revoked if it is determined that the holder of that right has engaged in a wasteful or unreasonable use of water.

Second, no water user in the State "owns" any water. Instead, a water right grants the holder thereof only the right <u>to</u> <u>use</u> water (called a "usufructuary right"). The owner of "legal title" to all water is the State in its capacity as a trustee for the benefit of the public. The so-called "public trust doctrine" requires the State, as a trustee, to manage its public trust resources (including water) so as to derive the maximum benefit for its citizenry. The benefits to be considered and balanced include economic, recreational, aesthetic and environmental; if at any time the trustee determines that a use of water other than the then current use would better serve the public trust, the State has the power <u>and</u> <u>the</u> <u>obligation</u> to reallocate that water in accordance with the public's interest. Even if the water at issue has been put to beneficial use (and relied upon) for decades, it can be taken from one user in favor of another need or use. The public trust doctrine therefore means that <u>no</u> water rights in California are truly "vested" in the traditional sense of property rights.

Water Contracts, Districts and Mutual Water Companies

At least in theory, all water used in California is developed and diverted based on one or more of the basic rights described above. However, it is common for the water rights relied upon by a water user to be held by another party, as in the case of water users receiving water from a district or mutual water company. In fact, most water users in California probably do <u>not</u> hold the water rights underlying much of their water supply. Nevertheless, those water users have a right <u>to</u> <u>receive</u> water separate and distinct from the water rights which support the diversion of the water in question.

Some water suppliers hold the rights to the water they deliver, while many others must acquire water from the ultimate water rights holder and themselves own nothing more than a contract right. For example, many older districts were formed in order to acquire water rights, and the districts themselves therefore hold the water rights which produce the water they distribute. Conversely, the United States is the record holder of the water rights used to operate the Central Valley Project; districts receiving CVP water supplies simply contract with the United States and distribute their contract supplies to their water users.[3]

In many (but not all) districts which provide agricultural water supplies, the right of a landowner to receive a share of the district's water supply is a matter of statute which accrues automatically by virtue of land ownership. No additional documentation is required. In other situations, a formal contractual relationship between the district and the water user is established, and the contract (rather than a statute) establishes the scope of the water user's right to receive a portion of the district's water supply. Districts currently have broad discretion relative to the use and transferability by water users of water they distribute; however, there are ongoing legislative efforts to grant water users more freedom to transfer district water allocated to them without the consent of the district, effectively transforming district water allocations into the personal property of each water user.

In the case of mutual water companies, the right to receive water from the company follows stock ownership. Mutual water company stock can be either appurtenant to the land in the co

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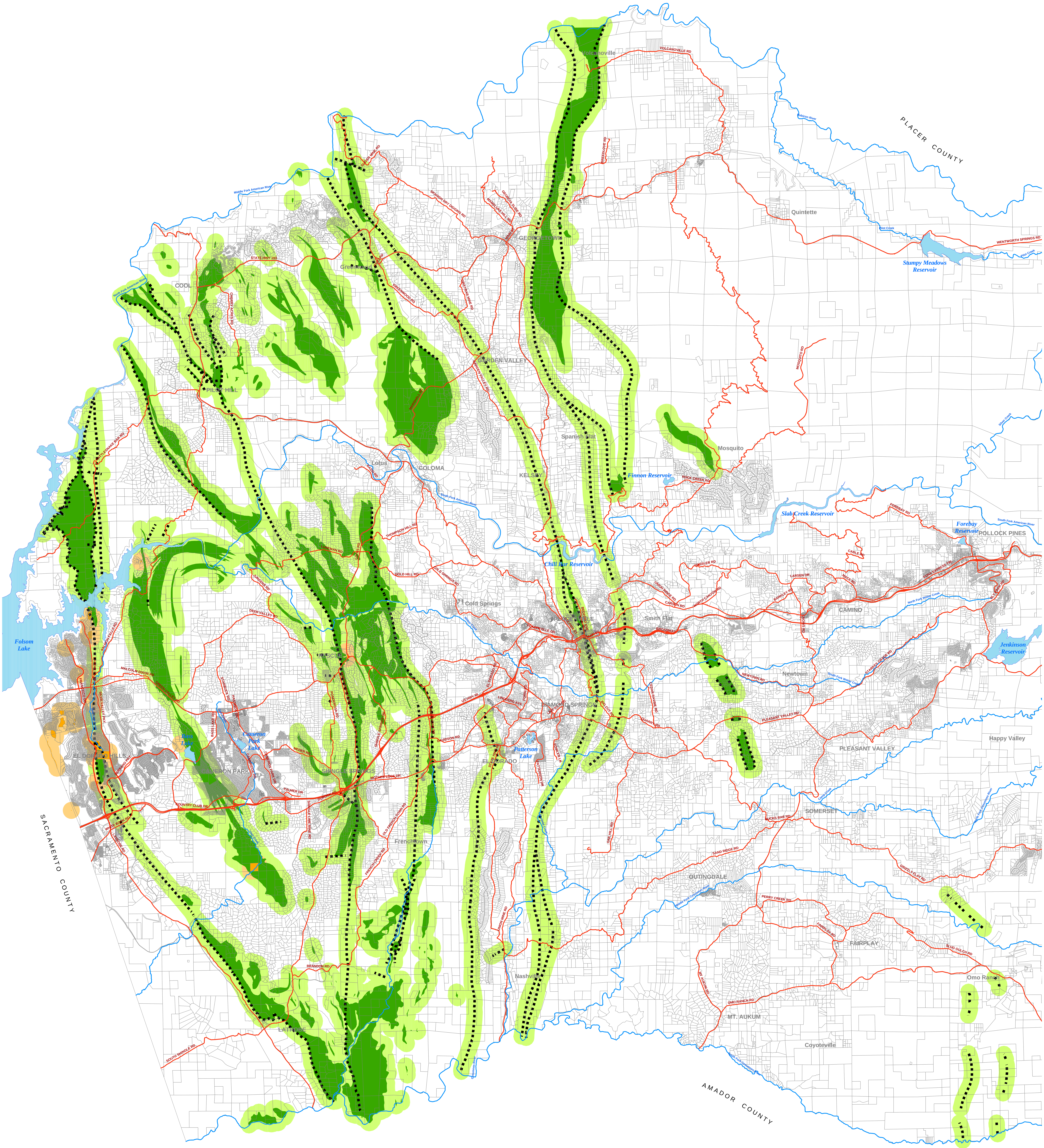
[3]Most CVP water users believe themselves to actually be the beneficial owners of the water rights underlying CVP operations, and that the United States is merely a trustee for those rights holding bare legal title. That important distinction is beyond the scope of these materials.

mpany's service are or completely separate therefrom. Generally, the stock of mutual water com
panies formed within the past 25 years is appurtenant to the lands served and passes with convey
ances of that land (although separate assignments of stock should still be prepared). For many ol
der mutual water companies, the stock (and thus the right to receive water) is completely separat
e from the land served, and separate stock assignments are required to transfer the right to receiv
e water evidenced by shares. As with districts, mutual water companies currently can control tra
nsfers of water allocated to shareholders, but could have that authority significantly curtailed by l
egislation granting water users rights to transfer water allocations over the objection of water sup
pliers.

Attachment #12



Legend

- Found Area of NOA
- Quarter Mile Buffer for Found Area of NOA
- More Likely To Contain Asbestos (Dept of Conservation Mines & Geology OPEN-FILE REPORT 2000-002)
- Quarter Mile Buffer for More Likely To Contain Asbestos or Fault Line
- Fault Line (Dept of Conservation Mines & Geology OPEN-FILE REPORT 2000-002)
- Parcel Base
- Major Roads
- Rivers & Creeks

0 0.5 1 2 3 4 Miles

Map displayed in State Plane Coordinate System (NAD 1983 California Zone 2, feet)

ASBESTOS REVIEW AREAS

Western Slope
County of El Dorado
State of California

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NOTES:

LAYER INFORMATION MAY COVER ADDITIONAL AREAS OUTSIDE OF THE DISPLAYED AREA.

PREPARED AT THE REQUEST OF: Environmental Management, DATE: 07/21/2005

MAP PREPARED BY: Frank Bruyn, DATE: 07/21/2005

G.I.S. PROJECT ID: 3089a, RELATED REPORT: na

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