Management Proposal for the Inland Sandhill Habitats of Santa Cruz County, CA

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SUMMARY

Vegetation of the sandhills of Santa Cruz County, California was studied using aerial photography, ground truthing, soil survey maps, and collection of vegetation data. Vegetation in the sandhills was described and mapped ,and accurate figures regarding the total remaining acreage of discrete vegetation types were derived. The "health" of the remaining habitat patches of sandhills plant communities was defined by criteria developed during this study. These criteria include native plant species diversity and number, species cover values, exotic species presence, forest measurements, and amounts of human disturbance. This information on habitat areas was compared with zoning regulations, current zoning information and land use patterns. A plan for the overall protection and management of the remaining sandhills habitat areas is proposed., using this and previous work on the ecology and management of these plant communities. Recommendations include higher levels of protection through county zoning changes, complete protection through establishment of ecological preserves, and more research including manipulative management techniques to restore or simulate natural processes. Suggestions are made for areas where manipulative management techniques may be tested. Also, the effect of drought as a large-scale environmental effect on the sandhill communities is discussed. Maps are provided of species and habitat distributions.

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OBJECTIVES

The objectives of this study were to derive management options for maintaining and enhancing the health of the vegetation and flora of the Sandhills of Santa Cruz County by:

1. Establishing and monitoring a series of permanent plots that can provide information on the current status and future conditions of the Sandhills flora

2. Sampling the vegetation within the Sandhills areas to gain an understanding of species associations, species' distributions, and health of the Sandhill plant communities.

3. Reviewing relevant literature pertaining to ecological processes within the Santa Cruz County Sandhills.

4. Providing a survey of the land uses which affect the Sandhills vegetation and flora.

5. Determining current zoning in the Sandhill areas and the impact of those zones on the health of the communities.

6. Developing a series of maps and overlays that show the current distribution of Sandhills plant communities, show areas determined to be areas of priority for protection, and show current planning zones of these areas.

7. Providing management recommendations incorporating the multiple uses and owners of the Sandhills habitat areas.

INTRODUCTION

Located in the Santa Cruz Mountains of California is a unique geologic substrate, the Santa Margarita Sandstone. This formation is derived from consolidated marine sediments and sandstones dating from the Miocene. Weathering of the Santa Margarita Sandstone results in the Zayante soil series. Zayante soils cover 8,000 acres, or three percent of Santa Cruz County. The majority of this soil series occurs in central Santa Cruz County, namely in the areas of Ben Lomond, Quail Hollow, Felton, Scotts Valley, and Bonny Doon. Zayante soils are "excessively drained" (USDA Soil Conservation Service, 1980). They exist in a climate with 40-56 inches of rainfall per year. Mean annual temperature ranges from 54-58 degrees F, with a yearly range from 35-40 degrees minimum and more than 80 degrees maximum.

The Zayante soils support two plant communities endemic to Santa Cruz County, Maritime Coast Range Ponderosa Pine forest and Silverleaf Manzanita Mixed Chaparral (Morgan 1983a). That portion of Maritime Coast Range Ponderosa Pine forest which occurs as an open, almost treeless community on Zayante soils in Santa Cruz County is called Ponderosa Pine Sand Parkland, or simply Sand Parkland.

Locally, Maritime Coast Range Ponderosa Pine forest is considered in the Santa Cruz County General Plan (1980) to be "Indigenous Ponderosa Pine forest," and is deserving of recognition and protection as a "Special Forest" in the Local Coastal Program Land Use Plan. It also falls under the broad protection of "Biotic Zones," which require recognition and protection of unique biotic resources.

Silverleaf Manzanita Mixed Chaparral is also endemic to Santa Cruz County. It is a highly variable community in structure and species composition. This community, perhaps better called Sand Chaparral (Morgan 1983a) contains many of the same "sand specialty species" as and intergrades with Maritime Coast Range Ponderosa Pine forest. It also falls under the broad protection of "Biotic Zones" in the Local Coastal Program Land Use Plan.

To better understand and protect the Sandhill communities the following needs should be met:

- better understanding of vegetation relationships in the sandhills
- better knowledge of the acreage and distribution of these plant communities
- methods to delineate between communities
- assessments of health of habitat patches so that priorities for protection of remaining patches can be established
- better maps of the Sandhill plant communities.

A major focus of this project has been to map the boundaries of these communities and assess their health through a combination of qualitative and subjective methods. A limited number of plots, while not sampling all Sandhills areas, allowed for better understanding of factors to consider in community delineation. I have placed areas of Sand Parkland and Sand Chaparral into categories of health and priority for preservation, supporting many of the recommendations of previous work done by Marangio (1985) and Morgan (1983a). Recommendations for management are made using a synthesis of stand health, location, contiguity with other habitat areas, and local planning regulations.

SETTING AND BACKGROUND

VEGETATION AND FLORA OF THE SANTA CRUZ SANDHILLS*

Northern Maritime Chaparral

Northern Maritime Chaparral (Element Code #37010, NDDB Natural Community Descriptions) is a northern California coastal plant community, occurring from Sonoma County to Santa Cruz County This community occurs in the immediate vicinity of the coastline, usually on sandy soils within the coastal fog zone (Holland 1986). Northern Maritime Chaparral, as part of the "Maritime Chaparral" complex, is considered to be a type of Mixed Chaparral by the California Wildlife-Habitat Relationships Guide (Mayer and Laudenslayer 1988) Northern Maritime Chaparral occurs in many phases or elements. These elements are distinguished from each other by the varying dominance of often endemic chaparral species (including *Ceanothus gloriosus, Arctostaphylos glutinosa, A. pallida, A. silvicola* and *A. tomentosa*). Typically this community occurs in pockets surrounded by other communities, such as redwood or Mixed Evergreen forests. Multiple elements of Northern Maritime Chaparral do occur in Santa Cruz County.

Silverleaf Manzanita Mixed Chaparral

In Santa Cruz County, when dominated by *Arctostaphylos silvicola*, (CNPS List 1B) Northern Maritime Chaparral has been considered to be Silverleaf Manzanita Mixed Chaparral. Silverleaf Manzanita Mixed Chaparral is a variable community of chaparral species including *Arctostaphylos tomentosa* var. *crinita, Ceanothus ramulosus, Adenostoma fasciculatum, Eriodyction californicum,* and *Lotus scoparius.* Like Maritime Coast Range Ponderosa Pine forest this community occurs only in Santa Cruz County. Because Silverleaf Manzanita Mixed Chaparral has edaphic and floristic characteristics similar to Sand Parkland, it is perhaps better described as "Sand Chaparral".

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* Taxonomy in this report is consistent with **The Jepson Manual**, 1993

Figure 1. Sand Chaparral Habitat

Sand Chaparral communities are undoubtedly changing in composition due to alteration of natural fire regimes (Griffin 1964; Morgan 1983a). These changes include senescent vegetation, high cover values (>100%) for *Arctostaphylos silvicola*, low species diversity, slower growth, limited light, poor seedbed conditions, and possibly phytotoxin accumulation through high leaf litter accumulation.

Arctostaphylos silvicola

The ecological qualities of *Arctostaphylos silvicola* are important to consider in understanding the Sand Chaparral community. The specific ecological requirements of *Arctostaphylos silvicola* have not been well studied. However, it is reasonable to infer that its general ecological requirements are similar to its nearest taxonomic and ecological relatives.

The genus *Arctostaphylos* (Ericaceae) is a major component within many chaparral communities of California. While not covering as much area as other chaparral communities in California, Manzanita (*Arctostaphylos*) chaparral often forms dense stands dominated by one or more species of

Arctostaphylos. *Arctostaphylos* is considered to be a prime example of fire-dependent species. About half of *Arctostaphylos* species (including those outside California) are "sprouters", plants that primarily regenerate through vegetative means. The other half are "obligate-seeders", plants which regenerate primarily from seed. Within California, about 75% of *Arctostaphylos* species are obligate-seeders (Fulton and Carpenter 1979). Both strategies evolved in response to fire regimes. Sprouting is an adaptation to less intense, more frequent fires. Obligate seeding is considered to be a more recent evolutionary response to less frequent, more destructive fires that perhaps would destroy the burls of sprouting species (Keeley and Zedler 1978). *Arctostaphylos silvicola* is an obligate-seeder. Both the natural fire frequency of the region and the biology of this ecological sub-group of *Arctostaphylos* suggest that *Arctostaphylos silvicola* has historically been subjected to low-to-moderate frequency fires of moderate to high intensity. This is consistent with its presence in a maritime climate.

The response of *A. silvicola* to fire has not been studied. However, certain responses can be hypothesized from studies of other obligate-seeding species of *Arctostaphylos*. These responses include increased fruit production, increased seedling germination, and increased annual biomass production. Many species of *Arctostaphylos* will seed and/or sprout only after fire. However, this may not be the case for *A. silvicola*, as some germination was observed without fire during this study period.

Sand Chaparral and *Arctostaphylos silvicola* are not as threatened as Sand Parkland because of their present extent and current lack of commercially valuable substrates. However, basic ecological research would allow better understanding of the present and future effects of human influence upon them.

Ponderosa Pine forest

Ponderosa pine covers millions of acres throughout the western US. However, because of its disjunct location, edaphic setting and associated species, the subtype of ponderosa pine forest that is

considered Maritime Coast Range Ponderosa Pine forest has been placed on the Fish and Game Priority 1 List of Communities of Special Concern.

An understanding of ponderosa pine forests in general aids in understanding the threatened Sand Parkland community. The structure and composition of ponderosa pine forests are created primarily by differences in soil moisture and fire history (Rundel et al 1977). Cooper (1961) noted that the "intolerance of ponderosa pine to shade, the infrequency of reproduction establishment, and the regular recurrence of natural fires all contribute to maintenance of pattern". Ponderosa pine forests are well adapted to recurring ground fires that cause regular thinning of undergrowth, including juvenile ponderosa pines. This leads to the open, parklike nature of large old-age pines with an open understory. Small fires create openings in which favorable conditions allow for a good seed crop to become established. The absence of such fires results in unfavorable conditions for seedlings (Rundel et al 1977). Natural fire frequencies in yellow pine forests of California have been reported to be from 3-20 years, with 7-10 years being the most common interval reported (Wagener 1961; Show and Kotok 1924; Dodge 1972; Rundel et al 1977). It has long been recognized that fire suppression beyond these intervals and the resulting buildup of fuels make control of fires very difficult, notwithstanding the problems of inhibiting regeneration. It is important to keep in mind that suppression of fire can create seemingly contradictory conditions in ponderosa pine forests. One is a lack of sufficient reproduction to offset mortality; the other is a lack of thinning of juvenile ponderosa pine trees leading to uneven aged stands of ponderosa pines (Griffin 1964; Haller 1959; Rundel et al 1977; Kilgore 1978). Typical ponderosa pine forests are predominantly even aged (Haller 1959; Cooper 1961; Griffin 1964; Rundel et al 1977).

Coast Range Ponderosa Pine forest

Coast Range Ponderosa Pine forest, is one of the "more restrictive types" of ponderosa pine habitat according to the California Wildlife-Habitat Relationships Guide (Mayer and Laudenslayer 1988). Coast Range Ponderosa Pine forest occurs in a few locations in California: in the Santa Lucia Mountains in Monterey and San Luis Obispo Counties, the Mount Hamilton Ranges of Santa Clara

County, the inner North Coast Ranges of Sonoma and Mendocino Counties, and in the Klamath Mountains of Siskiyou County. Coast Range Ponderosa Pine forest typically occurs on well drained soils in regions of light to moderate rainfall (30-40 inches annually) (Marangio 1985).

Maritime Coast Range Ponderosa Pine forest

Occurring only in Santa Cruz County, Maritime Coast Range Ponderosa Pine forest (NDDB Natural Community Description Element Code #84123, Holland 1986) is a sub-type of Coast Range Ponderosa Pine forest. Maritime Coast Range Ponderosa Pine forest occurs on sandy soils in Santa Cruz County "within the Coastal fog incursion zone" (Holland 1986), with 40-56 inches of rainfall per year. Maritime Coast Range Ponderosa Pine forest is typically a fairly dense, mature forest with a tree and shrub understory composed partially of species from surrounding vegetation types (chaparral, Mixed Evergreen forest, redwood forest, riparian communities).

Sand Parkland

Restricted to a small number of ridgetops and hills is this almost treeless community. Very widely spaced ponderosa pines exist as an overstory to populations of ephemeral herbs and scattered shrubs and suffretescents. Much of the year this habitat appears barren; during a brief period in spring it is colored with many of the showy "sand specialty species" such as *Chorizanthe pungens* var. *Hartwegii, Eschscholtzia californica*, *Erysimum teretifolium* and *Calyptridium umbellatum*. Sand Parkland is possibly the most restricted and threatened natural community in Santa Cruz County.

Figure 2. Sand Parkland Habitat

The Sand Specialty Plant Association

This association of herbs and subshrubs consists of 83 "Sandhill specialty" species (see Appendix B). These are species that are candidates for or listed as "Endangered" or "Threatened" by the California or Federal Government; plants determined to be "Locally Unique" by Santa Cruz County, plants endemic to the Zayante sands, disjunct populations, coastal relicts, or species that in Santa Cruz County are predominantly associated with the Sandhill habitats. Many of these are as-yet-undescribed ecotypes or varieties of species more commonly found elsewhere. These species may occur in many other places, yet it is their presence as a recognizable association under the scattered ponderosa pines which makes them a primary component of Sand Parkland. Two of the species are Federally listed as endangered (*Chorizanthe pungens* var. *hartwegiana*, and *Erysimum teretifolium*, which is also state listed as endangered); these species are included on the California Native Plant Society's List 1B "Plants rare and endangered in California and elsewhere". Two species are listed as "Uncommon" (CNPS List 4), *Mimulus rattanii* var. *decurtatus* and *Monardella undulata* var.

undulata. See Morgan (1983a, 1983b) Marangio (1985) Thomas (1961), and Appendix B in this report for descriptions and summary lists of these species.

Many of these species occupy disjunct distributions. The Sandhills appear to be "common ground" for many species that reach their farthest northern or southern distribution in the Sandhill areas (Thomas 1961). Many of these species appear to be undescribed ecotypes or varieties (Morgan 1983b).

Exact needs of individual species of sand specialty plants have not been researched in detail. However, it can be assumed by their unique occurrence or greater abundance in the Sandhills that their needs involve specific adaptations to the ecology and environments of Sand Parkland and Sand Chaparral. Research questions for the future are suggested in the Recommendations section (page 28).

Mixed Maritime Chaparral w/Ponderosa Pine

A considerable amount of Sandhill habitat consists of intergrading Northern Maritime Chaparral and ponderosa pines in low densities. Many ecotone areas between Sand Parkland and Northern Maritime Chaparral or Sand Chaparral are of this mixed vegetation type. This mixed chaparral/pine vegetation type tends to be most like chaparral in its composition. Small populations of some sand specialty species often occur in sandy openings within this vegetation type.

Previous Studies of the Sandhills

Griffin (1952) studied the presence of and relationship between ponderosa pine and knobcone pine. His work focused on factors influencing the distribution of ponderosa and knobcone pines in Santa Cruz County. He found potential autecological relationships between the Sandhills environment and these species, but hypothesized that effects of fire might be exerting the greatest effects upon the distribution of these two species.

Morgan (1983a,b) has perhaps studied the Sand Parkland for the longest period of time. He has placed Sand Parkland into two different "qualities"; Sand Parkland 1a and Sand Parkland 1b. These two types of Sand Parkland are differentiated by the following characteristics:

	Sand Parkland 1a	Sand Parkland 1b
Structure	Very widely space ponderosa pines Almost barren looking, usually open sand understory	Higher density of ponderosa pines and other trees Fairly continuous understory of grasses
Species	Groundcover of small ephemerals and some suffretescents. Many "sand specialty" species (see Appendix B) Few non-natives or intruding natives from other communities	Only the four suffretescents (*Eriogonum nudum, Lupinus albifrons, Lotus scoparius, Lessingia filaginifolia)* present in large numbers Small numbers of sand specialty species Many non-native spp. esp. grasses Many natives from surrounding communities

Sand Parkland 1b was considered by Morgan as "low quality" Sand Parkland. Besides these "higher" and "lower" quality Sand Parkland areas, Morgan identified many areas of "dense, mature" ponderosa pine forest which occur in the Sandhills, which are not presently Sand Parkland. These would qualify as Maritime Coast Range Ponderosa Pine forest. He identified these as late-successional stages of the Sand Parkland community. If this is true, the original distribution of Sand Parkland may have been much greater than any worker has yet to suggest.

The range of names applied to the Sandhills plant communities in previous work is confusing. Griffin (1952) referred simply to a "scattered growth of ponderosa pine trees", and not to any plant communities. Marangio (1985) recognized the Sand Parkland of Morgan (1983a), and the "fairly dense, mature stands" with more typical understory as "Ponderosa Pine Forest". However, this "Ponderosa Pine Forest" qualifies as the Santa Cruz County endemic Maritime Coast Range Ponderosa Pine forest because of its placement within the Coastal fog zone in Santa Cruz County. Also confusing is the terminology applied to *Arctostaphylos silvicola*, Silverleaf Manzanita Mixed Chaparral and Northern Maritime chaparral. *Arctostaphylos silvicola* is present in many areas which are mixed (Northern Maritime) chaparral, but these should not be considered Silverleaf Manzanita

Mixed Chaparral because *A. silvicola* is not the dominant shrub there. The vague label "Indigenous Ponderosa Pine forest" is used in the County General plan to refer to Maritime Coast Range Ponderosa Pine forest (and thus Sand Parkland).

Landscape Ecology of the Sandhill Habitats

Sandhill vegetative communities and the species within them exist as biological islands among the surrounding vegetation (Morgan 1983a). They exist as patches of habitats within the overall landscape of the Santa Cruz Mountains. Each patch, within the general framework of ecosystem processes operating on the Sandhills, has its own specific disturbance regime, population processes, and impinging factors on its survival.

The pre-white settlement Sandhills were a continually changing pattern of habitat patches with particular fire histories, sizes and species composition. These patches over time would appear to migrate over the landscape as they went through cycles of senescence, episodic disturbance and rejuvenation. Patches of all stages (or seres) would likely have been present at any one time. Disruption of natural patch dynamics can lead cyclical habitats such as the Sandhill areas into a relative "stasis" of primarily late-successional stages (Pickett and Thompson 1978; Sprugel 1991).

It may be that ponderosa pine and *Arctostaphylos silvicola* act as "keystone-species" within their respective communities, and the health of the communities and the biological diversity within them is linked to the health of these two major components. While the use of the keystone species concept has been debated (Mills et al 1993), these two species appear to fit the definition used for other natural communities in being "crucial in maintaining the organization and diversity of their ecological communities" (Paine 1969). Any attempts to maintain viable populations of the sand specialty plant association, without considering the health of these two keystone species will be fraught with disappointment (Dodge 1977; Franklin 1993; Parsons 1978; Pickett and Thompson 1978). Both of these communities are dependent on disturbance regimes to ensure maximum species diversity and community vigor (Haller 1959; Griffin 1964; Biswell 1974; Hanes 1977; Fulton and Carpenter 1979).

It may be useful to view these Sandhill habitat islands within the context of a source-sink model of metapopulation dynamics (Pulliman 1988). In this model, species may exist in some better "quality" areas (source areas, in this case probably 1a Sand Parkland) where reproduction is sufficient to balance mortality, and also in sink areas (Sand Parkland 1b possibly) where reproduction does not keep pace with local mortality, yet the population is maintained by immigration from the better source habitats. Sink habitat for one member of a community may be source habitat for another. It may also be important as a seedbank source for natural revegetation of Sandhill areas. Many marginal areas may be more important for the survival of some community members than the "highest quality" areas. In view of this discussion, every patch of Sand Parkland remaining is essential for the long term survival of this community and its inhabitants.

Overall, each patch or habitat island of the Sandhills suffers threats from four main factors:

1) The spread of exotic species, primarily introduced grasses

2) change in natural fire interval and intensity

3) Invasion by surrounding vegetation

4) Both large scale and small scale fragmentation and development

Every habitat patch is affected by these threats. However, the relative importance of each factor changes in regard to each patches' location, size, and contiguity with other Sandhills vegetation.

Diversity, Disturbance, and the Sandhills

As already discussed, natural disturbance is a shaping force of ponderosa pine and chaparral communities. Much has been done to test and substantiate the role of natural disturbance in maintaining health and diversity of many natural systems (Connell 1978; Hobbs and Huenneke 1992; Pickett and Thompson 1978). Disturbance regimes affect ecosystem structure, diversity, and function. It is recognized that maintaining an overall landscape of patches in varying stages of recovery from disturbance allows for maximum diversity for the landscape as a whole (Hobbs and Huenneke 1993) The Intermediate Disturbance Hypothesis (Connell 1978), which states that

moderate frequencies or intensities of disturbance foster maximum species richness has been well tested. This "moderate" frequency or intensity is related to the longevity of the major species in the system. In the case of the Sand Parkland and Sand Chaparral, this would refer to *Arctostaphylos silvicola* and *Pinus ponderosa.*

Both natural and human-caused disturbance can create openings for exotic species. The invasion of exotics into the Sandhills is a serious threat to their integrity; thus the timing, type, and amount of disturbance has a great effect on the health of the Sandhills habitats. However, proper placement and timing of simulated natural disturbance can have the positive effect of removing invasive species (Hobbs and Huenneke 1993). One of the effects of moderate frequencies or intensities of disturbance is to reduce competitive exclusion (Collins 1992). As many of the exotic species are "super-competitors", managed disturbance may be important to management of these species and increasing native species diversity.

Fire history in the Santa Cruz Mountains

The record of fires in the Santa Cruz Mountains is confusing. Between 1930 and 1979, 3765 fires burned 19,560 hectares. Because 92% of these fires were less than 4 hectares they were not mapped (Langenheim and Greenlee 1983). This is unfortunate, because these fires have may have had an important and observable effect on vegetation patterns in Sand Parkland and Sand Chaparral. However, fire in the Sandhill areas of Santa Cruz County is at a much lower frequency than in historical times because of residential encroachment and subsequent fire control for safety reasons (Dodge 1972; Langenheim and Greenlee 1983; Marangio 1985). Estimates of pre-suppression fire frequencies in Maritime Coast Range Ponderosa Pine forest are lacking. Estimates of fire frequencies in chaparral regions of California range from 9.5 years to 100 year intervals in pre-suppression years. Currently the mean fire interval is from 10 to 40 years in most chaparral areas in California (Muller et al 1968; Langenheim and Greenley 1983). However, these figures are averages and do not account for smaller scale differences in fire frequencies in different chaparral vegetation types. Keeley and Zedler (1978) noted that natural (lightning) fire frequency is lowest in coastal California, up to 100

years or more. Their general conclusion was that the strategy of obligate-seeding *Arctostaphylos* spp. (not resprouting after fire from a burl) has been a response to more infrequent fire regimes than in other regions with higher natural fire frequencies. This is supported indirectly by such evidence as the Sierra Nevada, an area of high lightning fire frequency, is depauperate in non-sprouting *Arctostaphylos* species (Keeley and Zedler 1978).

It has been hypothesized that coastal California plant species and communities are aggregating according to their tolerance for fire (Langenheim and Greenlee 1983). In other words, vegetation patterns may reflect fire history more than geologic substrate, soil, or other edaphic factors (Griffin 1952). Although the Sand Parkland areas have been considered to be an "edaphic complex", fire alone may be of singular importance to the Sandhills communities' health.

The effect of drought as a stochastic environmental process must be considered in management plans for the Sandhills habitats. Drought is a recurring event in California. As the Sandhills is already a (relatively) water-limited environment, drought may have potentially detrimental effects to the species and communities. This is important to consider in long-term management plans for communities. Population sizes necessary to survive drought may be much larger than previously considered (Sprugel 1991).

METHODS AND MATERIALS

Determination of Sandhill Habitat and Dominant Species Distribution

Using USDA Soil Survey maps and topographic maps, the preliminary boundaries of Maritime Coast Range Ponderosa Pine forest and Sand Chaparral areas were determined by first locating the boundaries of the Zayante Soil Series. California Natural Diversity Data Base maps were used to determine the known distribution of *Arctostaphylos silvicola*. Aerial photos from a true color series taken after the 1989 Loma Prieta earthquake were then obtained which covered the distribution of ponderosa pine and *Arctostaphylos silvicola* in Santa Cruz County. These photos are at a 1:5000 scale. A characteristic signature on the aerial photos was recognized for *Arctostaphylos silvicola* through ground-truthing of aerial photos. A similar process was used for mapping of ponderosa pine. Site visits were made to areas with questionable vegetation boundaries to clarify distribution of species. The distribution of these species was transferred to overlays upon the aerial photos. These aerial photos are property of California Department of Fish and Game, Natural Heritage Division.

Sampling Regime

A grid was overlaid upon the aerial photo maps with distribution overlay maps. Using a random coordinate system, 40 potential plot locations within the distribution of *Arctostaphylos silvicola* and ponderosa pine were plotted. By visiting these potential sites, 20 plots were selected for study based on presence of Maritime Coast Range Ponderosa Pine forest or Northern Maritime Chaparral (See figures 3a and 3b, pages 18-19). Accessibility was also a factor in selecting sites due to the short time of this project and the lengthy time required to acquire access permission to some potential sites. Sites which were within Zayante soil boundaries but contained no Sandhill habitat due to residential or commercial development were not selected.

Each plot contained nested sub-plots of $5m^2$, $10m^2$, and $20m^2$ with a common SE starting corner. Each plot has a permanent plastic marker stake. From the SE corner, the plots are placed north and west using magnetic compass readings. Boundaries of the plots were temporarily delineated with

Figure 3a
Location of vegetation plots
Bonnie Doon quad

Figure 3b
Location of vegetation plots
Felton quad

flagging tape. Using the Doing, Zonneveld, Ley method (Küchler and Zonneveld 1988), all grasses and forbs ($5m^2$ plots), shrubs ($10m^2$ plots) and trees ($20m^2$ plots) within the plots were given subjective adundance-cover classes at four survey periods during the 1992 season (May-October). Different size plots were used because of the greater size needed for larger species' relative cover-abundance quantification. May, July, September, and October 1993. From the center of the $20m^2$ relevé, distance to nearest tree in each compass quadrant was determined and species identified. Photographic documentation of each plot was made between May-July 1992. Most photographs were taken from the SE corner viewing to the NW; however, because of the dense nature of much of the vegetation some photos are to different orientations and noted as such.

Analysis of Vegetation Surveys

Using the Braun-Blanquet method, a raw data table was constructed of all species. Constancy (percentage of plots a species was present on) was determined for species on plots. Only species with constancy values at or above 5% and at or below 90% were used for manual table analysis (creation of a "Partial table"). This eliminates species which are either in such low constancies *or* high constancies that they are useless for indicating species groupings. Differential species groupings were then recognized. This is a process of visually searching on the table for species which are repeatedly grouped together on numerous plots, and suggest plant associations which serve as "signatures" for plant communities or sub-associations.

Mean distances of ponderosa pines from plot midpoints were calculated, to give an indication of ponderosa pine densities on plots. Although the overall plot sample size was small, the resulting data at least give preliminary criteria and indications for plant association differentiation.

Mapping vegetation, Land use, and Habitat condition

Collection of data on the plots and more general field surveys allowed me to recognize signatures for Sandhill plant communities. Use of aerial photos allowed me to locate areas of these communities and species that had not been previously mapped. Once the distributions of these species and

communities were determined, this information was used along with information from the vegetation surveys and general field surveys of Sand Parkland areas to derive criteria for further assessing the types and qualities of discrete Sandhill locations. I used Morgan's (1983a) 1a and 1b criteria * along with my analysis to give 1a and 1b designations to all Sand Parkland areas. I compared Morgan's previous assessment of Sand Parkland areas with my plot data and field observations of tree densities, soil cover, amounts and types of disturbance. These criteria and my findings are discussed in **RESULTS**.

Zoning Maps were obtained of the areas containing Sandhills habitat types. These zoning boundaries were transferred to the map overlays.

A series of map overlays was initially created on 1:5000 scale aerial photos. This was transferred onto 1:24000 scale maps. There are minor discrepancies on these maps because of slight differences between map types. These maps should not be considered to be documentation of presence or absence of plant communities or special-status plants.

English area dot grids were used to estimate coverage of Maritime Coast Range Ponderosa Pine forest, Sand Parkland, Sand Chaparral, and *Arctostaphylos silvicola* using the topographic maps and aerial photos with the distribution overlays. These dot grids are transparent grids which are placed over a map of any scale; within each small square of the grid is a randomly placed dot. The grid is placed over an area which has been delineated, then all dots which fall within that area are counted. Each dot represents a given number of acres at each map scale. The number of dots is divided by a ratio appropriate to the map scale to give an estimate of acreage. At the 1:24,000 scale used for this procedure, minimum mapping unit was 6.25 acres.

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* see page11

Identification of species associations

As noted in previous work, the intergrading nature of the Sandhill plant communities makes fine-scale distinctions difficult to quantify and map in many cases (Morgan 1983b; Marangio 1985). However, plant associations are readily identifiable when at the extreme of their type. Sand Chaparral is easy to note in the field and map when *A. silvicola* cover values are high, but when it exists as a more mixed chaparral type it is often difficult to assign vegetation boundaries. Maritime Coast Range Ponderosa Pine forest exists in a continuum of phases depending upon understory, cover, and density, yet at the extreme of 1b and 1a Sand Parkland it is readily noted in the field by of the absence of needle/leaf litter, low densities of ponderosa pine trees, and high "sand specialty" species diversity. Thus many community and species associations may not be mapped with high accuracy except at an extremely fine scale.

RESULTS

Plot Information

Species Associations

As mentioned previously, the intergrading nature of sandhill communities makes vegetation boundaries difficult to determine in many areas. However, analysis of the plot information and general field surveys resulted in the recognition of distinct Sandhills plant associations.

Sand Chaparral

As noted earlier, Sand Chaparral (also called Silverleaf Manzanita Mixed Chaparral) is that element of Northern Maritime Chaparral that is dominated by *Arctostaphylos silvicola.* However, the dominance of *A. silvicola* varies widely from sites such as plot BD 5 in the Bonny Doon Ecological Preserve, with *A. silvicola* cover value of 100%, to sites such as #22 along Graham Hill Road with a cover value of 20%. More importantly is the cover value of *A. silvicola* compared to the relative cover of other Northern Maritime Chaparral shrubs. When *A. silvicola* is present in a cover value greater than all other chaparral shrubs present at a site, I would consider it to be "pure" Sand Chaparral. At these sites (much of Graham Hill south area) herbaceous species diversity is extremely low; those present include *Pteridium aquilinum* and *Navarettia atractyloides.* When *A. silvicola* occurs in cover values equal or near to other values of other chaparral shrubs present at a site I would consider it to be "Mixed Sand Chaparral", a sub-type of Sand Chaparral. When *A. silvicola* occurs in lower cover values than other chaparral species present I would consider it to be Northern Maritime Chaparral.

Mixed Northern Maritime Chaparral with Ponderosa Pine

Many areas of Sand Chaparral (and a limited amount of Northern Maritime Chaparral) contain small numbers of ponderosa pine trees in low densities. It is hard to even consider the pines as an

overstory because of the extremely low densities (e.g. plot #1 with 19 meters average distance between ponderosa pines). I hesitate to designate these areas as anything but the dominant plant association occurring there regardless of the ponderosa pine trees. This has created confusion with mapping, however, because I mapped these areas as having overlapping ponderosa pine and Sand Chaparral. Thus, total acreages of these two distributions together would exceed the actual acreage of the ground surface they cover.

Maritime Coast Range Ponderosa Pine forest

Maritime Coast Range Ponderosa Pine forest is, somewhat by default, those areas of intact ponderosa pine forest not qualifying as Sand Parkland, located only in Santa Cruz County. Denser trees (e.g. plot #27, 4.12 meters average distance between ponderosa pines), moderate to dense understory of shrubs and evergreen trees, and usually heavy litter accumulation distinguish this community. Understory species include many plants from surrounding communities including *Quercus agrifolia, Toxicodendron diversiloba, Rhamnus californica,* and *Arctostaphylos tomentosa* ssp. *crinita.* Plots studied during this report which contain Maritime Coast Range Ponderosa Pine forest were #10, 23, 24, 27, and 32.

Sand Parkland

Sand Parkland is readily identifiable in the field and on the plot table (Appendix A) by a combination of characteristics. The presence of sand specialty species, open structure of ponderosa pines, sparse to almost absent understory, open sandy soil and relative low numbers of non-natives are important criteria to use in recognizing this community. The designation of 1a and 1b is relatively simple to make based upon these criteria:

- Very widely spaced ponderosa pines (average from plots containing 1a habitat-17.25 meters between ponderosa pines)
- Open, often bare sandy soil

- Many significant populations of numerous sand specialty species, notably many of the less common species including *Minuartia spp., Calyptridium umbellatum, Erysimum teretifolium, Mimulus rattanii,* and *Monardella undulata*
- Few nonnatives; those present some of the smaller grasses such as *Vulpia* spp. and *Aira caryophyllea*
- Fewer natives such as *Quercus agrifolia* and *Toxicodendron diversiloba* invading from surrounding vegetation types
- Very low density of *Arctostaphylos silvicola* (absent to <5%, cover)

Criteria to designate 1b are also similar to Morgan's. However, I stressed the relative density of ponderosa pines and the presence of any of the less common Parkland species in recognizing 1b habitat as distinct from Maritime Coast Range Ponderosa Pine forest. Criteria used for designating 1b habitat are:

- Higher density of ponderosa pines (average from plots containing 1b habitat-9.5 meters between ponderosa pines)
- Some open bare soil present, or observable just underneath litter or grassy understory
- Presence of some sand speciality species as small populations such as *Lupinus bicolor, Gilia tenuiflora, Lessingia filaginifolia, Eriogonum nudum, Eschscholtzia californica* (sand ecotype-see Morgan 1983b). Some of these are extremely ephemeral and thus may have eluded detection during past surveys
- Nonnatives present tend to be heavy growths of species such as *Bromus rubens, Bromus carinatus* and *Hypochaeris* spp.
- More natives such as *Arbutus menziesii, Quercus agrifolia,* and *Toxicodendron diversiloba*
- Higher density of *A. silvicola* if present (absent to 10% cover), and higher densities of other chaparral species

Plots studied during this report which contain Sand Parkland 1a were #2, 6, 11, and 30; those containing 1b were #4, 8, 11, 16, 30, BD 6 and BD 7.

Species totals varied among plots from 29 species (highest diversity found *during plot monitoring* was at North Ridge Quail Hollow) to 5 species (plot BD8 at Bonny Doon Ecological Preserve). These totals should not be represented as complete species total for plots, but as representations of

relative species diversity for those sites in 1993. Much higher diversity was encountered during general field surveys at some Sand Parkland locations where plots were not located.

Distribution of Ponderosa Pine and *Silverleaf Manzanita*

Analysis of the distribution of ponderosa pine in Santa Cruz County yields a figure of 2726 acres (see Table 1, page 27 for summary table of distribution). This is quite different from the 600 acres originally mapped in the county by the Forest Survey. However, this higher figure results from inclusion of all vegetation types and areas in which ponderosa pine is found in the county: Sand Parkland, more typical "pure" ponderosa pine forest, and Sand Chaparral or other chaparral types which include scattered ponderosa pine (See Morgan, 1983 for complete descriptions of these vegetation types). The smaller 600 acre figure "was typed by the Forest Survey as pure ponderosa pine type" (Griffin 1964). It is not clear what this "pure" type was. It appears that much of the habitat I recognized was not included in this original mapping because it contains elements of Sand Chaparral, mixed chaparral types, or is in small acreages that perhaps were beyond the resolution of these original workers. For example, the chaparral area north of Henry Cowell Redwoods State Park and south of Graham Hill Road is predominantly chaparral, but includes scattered ponderosa pines in extremely low densities..

Fieldwork led to the designation of more 1b (lower quality) Sand Parkland. Much of this is in the East Zayante area. Sand Specialty species present in these areas include *Lupinus bicolor, Erysimum teretifolium, Layia platyglossa, Eschscholtzia californica* and *Lessingia filaginifolia.* The *Eriogonum nudum-Gnaphalium canescens-Ericameria ericoides* differential species group noted in the Raw Table analysis was useful in recognizing many of these sites, as it occurs in low population numbers at 1b sites. Another area previously unrecognized as 1b habitat, but which I did recognize by occurrence of sand specialty plants and characteristic large, widely spaced ponderosa pines on bare sand, is the area between Ben Lomond and the Landfill on Newell Creek Road.

The 2726 acres of ponderosa pines includes 193 acres of Sand Parkland (comparable to Sand Parkland quality types 1a and 1b in Morgan, 1983). Of this total, 31.5 acres are 1a; 161.5 are 1b. I

identified a considerably larger amount of 1b habitat than previous workers. I believe the extensive use of large scale aerial photos and repeated surveys of areas during one flowering season allowed me to recognize some of these areas. Approximately 400 acres (not included in the 3126 acres) of ponderosa pine habitat (likely once Sand Parkland; see Morgan 1983a) has been removed for sand quarrying. 1073 acres of ponderosa pine overlap with Sand Chaparral; this area contains very low densities of ponderosa pines and small dispersed populations of sand specialty species. This is not a type of ponderosa pine forest, but is included on maps of the distribution of ponderosa pine. 1033 acres is more "pure" ponderosa pine forest (Maritime Coast Range Ponderosa Pine forest) with its typical understory of mixed chaparral species and mixed evergreen forest elements (such as that found north of Graham Hill Road or areas of East Zayante) and very few sand specialty species. 900 acres of the total acreage is residential development (with some of the more impressive individual ponderosa pines). This area includes much of Glenn Arbor, eastern Ben Lomond and the residential development off Lockwood Lane in Scotts Valley. These areas of ponderosa pine in residential areas are not to be considered an intact forest; their character has been altered by the loss of all but a remnant of the (albeit impressive) ponderosa pine overstory. Another approximately 200 acres5 has been developed as landfills, commercial developments, and other non-residential development. Using these figures, over 55% of the original ponderosa pine habitat in Santa Cruz County has been lost to development or its character altered to the extent that it cannot be considered Maritime Coast Range Ponderosa Pine Forest or Sand Parkland.

Arctostaphylos silvicola covers a total of 2382 acres in the county, the majority of which is on Zayante soils. Approximately 418 acres of this total has been altered by residential development. 325 acres (not included in the total) has been removed for sand quarrying. Another 414 acres (not included in the total) has been removed for development as landfills, commercial developments, and other non-residential development. Using these figures, 21% of the original distribution of *Arctostaphylos silvicola* has been removed or altered by development. An unusual stand was found during this study which had not been identified on maps, at the intersection of Empire and Ice Cream

Grades. Another stand was found north of the Bonny Doon Ecological Preserve along Pine Flat Road. It has a unique floristic composition (Predominantly *A. silvicola* and *A nummularia* with knobcone pine and tree Chinquapin overstory).

Note that there is overlap in these figures because the distribution of ponderosa pine overlaps Sand Chaparral, although much of this pine distribution is not a pine forest. This leads to confusion in acreage total. I felt it was important to map this as overlap because ponderosa pine had previously not been accurately mapped in the county.

These estimates of acreages that have been removed for development are admittedly speculative. I made the estimates of acres completely removed for development based upon a combination of soil types and the vegetation surrounding and contiguous with these areas now without original vegetation. They are admittedly hypothetical but are an attempt to derive figures for the amount of original vegetation in the Sandhills.

TABLE 1: SUMMARY OF DISTRIBUTION OF SANDHILL VEGETATION TYPES

	Remaining natural vegetation	Developed with remnants of natural vegetation	Developed with complete removal of natural vegetation	Original Extent
Maritime Coast Range Ponderosa Pine forest	**1033**	**900**	**200**	**2133**
Sand Parkland figures in parentheses	**193**		**400**	**593**
Sand Chaparral w/widely scattered ponderosa pines (not ponderosa pine forest)	**1073**	(included below in Sand Chaparral types)	(included below in Sand Chaparral types)	**1073**
Sand Chaparral types	**2382**	**418**	**739**	**3539**
TOTALS	**3608** (does not include the 1073 overlapping acres)	**1318**	**1339**	**6265** (does not include the 1073 overlapping acres)

DISCUSSION

My results differ notably from previous work in two major respects. First is that I identified considerably more 1b habitat. Secondly, I differed from Marangio's (1985) recommendations for preserves. I believe my use of aerial photos and emphasis upon ground truthing, use of criteria developed from plot studies, and amount of field work to determine vegetation boundaries allowed me to verify more accurately the locations of Sandhill communities. During this work I found that a considerable amount of the preserves recommended by Marangio contained more widespread vegetation types (probably through the use of soil survey maps to infer presence of Sandhill plant communities. It appears from my work that large preserves such as Marangio suggested are not feasible and would protect many lower quality or non-Sandhill plant communities. Many smaller open spaces/ecological preserves, conservation easements, and use of zoning guidelines I present in **Recommendations** may perhaps be more consistent with the needs of Sandhill plant communities; especially keeping an overall view of landscape level processes affecting the Sandhills.

Sand Parkland 1a and 1b habitat areas are obviously the most threatened Sandhill communities. A no-net-loss policy should be adopted by the County and cities involved regarding the development of Sand Parkland habitat. . I do not mean that mitigation may replace net losses of habitat; previous work has shown that mitigation of Sandhill habitat loss is not a real possibility (Stanley et al 1983).

Maritime Coast Range Ponderosa Pine forest is the next most threatened plant community in the Sandhills. The suppression of natural ecological cycles in these areas is limiting diversity and encouraging spread of surrounding vegetation types into Maritime Coast Range Ponderosa Pine forest. Hopefully distribution figure provided in this report will not mislead planners into thinking this habitat is not threatened.

Using my work, it will be feasible to use the preliminary criteria to recognize Sandhill plant associations in the field. Hopefully this will aid land use planners. While my maps are at a large scale which makes fine scale decisions on parcels difficult, the use of my criteria will allow field

determination. A great amount of time will be necessary to produce fine scale maps of all the Sandhills plant associations, beyond the time frame of this work.

It is difficult to assign a "health" status to Sand Chaparral locations because of the probable longer cyclical periods of this community. The community appears to regularly go through long periods (possibly of decades) of senescence. Health would be more easily and correctly defined as a lack of natural processes, namely fire. From a conservation standpoint, it would be best to concentrate on the more pure stands of *A. silvicola* and attempt to return natural fire and its effects at least to the most senescent of these areas (e.g. parts of the Bonny Doon preserve and Graham Hill south). Perhaps if more Sand Chaparral areas were returned to earlier successional stages, species diversity and population sizes of Sandhill species would increase. This would allow for more resistance to natural and human-caused perturbations. For example, the effect of recurring drought will have a greater effect on these populations without large enough populations or metapopulations to survive a stochastic natural process (Hobbs and Huenneke 1992; Pulliman 1988; Sprugel 1991). It is easier to understand in the context of a process repeating on a scale difficult to observe. The duration of seed viability of the sand specialty seed bank is uncertain. If the senescent phase of Sand Chaparral is allowed to dominate and become a stable phase, the potential for reemergence of many of the sand specialists is unknown. It may vary widely between species and perhaps sites (depending on soil moisture, possible pathogens, herbivores, etc.).

RECOMMENDATIONS

In general, recognition of the unique character and multiple threats to the Sandhill habitats is lacking. Although provisions exist within local planning ordinances for the protection of "biotic resource" areas within Santa Cruz County Planning Department guidelines, incomplete mapping and ignorance of Sandhill habitat characteristics has led to direct habitat loss and degradation. Justified fear of wildfire has led to attempted suppression of all fires. To remedy this, a multifaceted approach to habitat management needs to be taken which consists of:

- Zoning amendments and restrictions and more rigorous application of existing land use regulations
- Open space designations of better quality habitat areas
- Manipulative management to simulate fire cycles
- More research into Sandhill species and communities, and long-term inventories
- Better protection of areas from damaging activities such as off-road vehicle use, equestrian traffic, etc.
- Education of landowners

While the General Plan and Local Coastal Program Land Use Plans of Santa Cruz County have provisions for protection of sensitive habitats and biotic areas/resources (along with state and federal regulations), these provisions and regulations remain underutilized in the protection of the Sandhills areas. This is mostly a result of inadequate understanding and mapping of the distribution of Sandhill habitat areas, which this report in part attempts to rectify. It has been difficult for Santa Cruz County Planners to enforce "Biotic Zone" regulations without the knowledge of all Sand Parkland locations. This has resulted in destruction or degradation of areas which harbor species identified as deserving local, state, or federal protection. Fragmentation of habitat may be reducing some populations of these protected species to non-viable sizes.

Zoning Amendments and Applications

Sandhills habitats are included in only four zones. The majority of habitat is presently zoned **SU** (Special Use). A considerable amount of residential development and commercial mining occurs within this zone. Any use compatible with general plan provisions may be allowed in this zone. A large amount of former Sandhills habitat including some Sand Parkland is now zoned and developed as **R** (Residential zones of different densities). **M** (Mining) and **TP** (Timber Production) zones apply to relatively small amounts of Sandhill area. Hopefully, by applying broad guidelines to parcels in these zones which contain either Maritime Coast Range Ponderosa Pine forest, Sand Parkland or Sand Chaparral, habitat degradation can be slowed.

The following guidelines should be applied to zones:

SU A majority of Sand Chaparral and Sand Parkland vegetation types are currently within SU zones in the Santa Cruz County General Plan. This zone allows for any use permitted in Residential -Agricultural (RA), Single-Family Dwelling (R-1), Mountain residential (RM) Commercial (C), or Industrial (M) as long as it follows general guidelines of the General Plan. Parcel sizes can be as small as 1 acre in this zone. Because such a large amount of Sandhill vegetation is in this zone,there exists a great potential for future habitat loss or degradation. To minimize habitat fragmentation, I suggest that minimum parcel sizes be kept to 5 acres, with building confined to areas determined to have lower quality sand habitat. (Identification of a few key plants such as the differential species grouping mentioned in **Results** can aid with recognition of Sand Parkland habitat.) Clustering of dwellings on adjacent parcels would limit disturbance "edge" and limit invasion of exotic plants. Any areas within **SU** zones containing 1a or 1b Sand Parkland (ponderosa pine forest) should be maintained as open space and not developed.

Much of the sand habitat zoned as **SU** is currently subject to quarrying. Obviously this is one of the greatest losses of Sandhills habitat, as there is little or no hope for reestablishment of the original vegetation. Revegetation has not proven to be a real possibility (Stanley et al 1983).

TP Two important Sandhill areas are partially zoned Timber Production. These are the areas mapped as having Sandhill habitat south of Eagle Dell Peak near Lompico, and the Sand Parkland area of East Zayante that is west of the junction of Quail Hollow and Zayante Roads. The East Zayante areas mapped as Sand Parkland 1a and 1b habitat should be withdrawn from timber harvest due to the potential for mechanical habitat disturbance in the process of logging the potential loss of seed banks, and the loss of the Sand Parkland pine component. Disturbance in these areas should be confined to prescribed burning or other methods of simulated natural disturbance.

M One notable area is zoned solely for mining (by the Lone Star Quarry). The western section of this area (the eastern section of Lone Star Area A, see Marangio 1985) was not identified as high quality Sand Parkland in previous reports. However, I believe it contains important attributes of or potential for return to high quality Sand Parkland (including occurrence of *Erysimum teretifolium)* and should be declared open space.

R-1 A large amount of former Sand Parkland and Sand Chaparral is now in current zoning/use as single-family dwellings. This includes much of eastern Ben Lomond, Glen Arbor, parts of Quail Hollow, the Pasatiempo area and Mt. Hermon area. The possibility of direct management of these areas is limited. However, most of this area contains large individual ponderosa pines (60-95cm+ dbh), which can serve as seed sources. The removal of any of these pines for any but purely safety considerations should be restricted. Building sites should be situated to not damage these individual ponderosa pines.

Open Space/Preserves/Conservation Easements

While the potential for establishment of ecological preserves is limited at this time, the preservation of areas can be achieved through open space designation and conservation easements, perhaps allowing for some amount of tax relief for parcel owners. Some areas of Sandhill habitat should be placed in such zones because any other type of zoning or use will further degrade these unique communities. Many of the moderate density residential parcels on the fringes of 1a and 1b Sand Parkland habitats would be appropriate for this management technique.

Recommendations for manipulative experiments/management

Mechanical removal/burning of chaparral

Many Sand Chaparral and Sand Parkland areas have particularly heavy fuel loads and/or dense, senescent vegetative growth with high flammability. Some of the more extreme areas in this condition are:

Graham Hill South. This area south of Graham Hill Road and north of Henry Cowell Redwoods State Park has particularly high fuel loads and dense, treelike senescent chaparral growth (with the associated low species diversity). This area extends into the State Park, where conditions are very similar. For example, much of the chaparral surrounding the campground is very senescent, and one can be mislead as to the extent of fuel loadings because of unauthorized firewood collection immediately around the campground.

Graham Hill North. This area north of Graham Hill Road and surrounding Kaiser Quarry, while having relatively less dense chaparral vegetation than Graham Hill South, does have significant heavy fuel loads...Many of the fuels are large down ponderosa lying in deeep needle litter.

Quail Hollow "North". This area, not to be confused with the north Ridge of Quail Hollow, lies north of the greatest northern extent of Quail Hollow Road. Dense treelike chaparral and steep terrain coupled with senescent vegetation increase fire danger and limit diversity of sand specialist species.

Bonny Doon Preserve. The area west of Martin Road has stands with very high fuel loads (leaf litter) and dense senescent chaparral. On the east side of Martin Road, near and surrounding plot BD5 is an extensive stand (predominantly *Arctostaphylos silvicola*) of extremely dense chaparral with 90-100 percent absolute cover.

Empire Grade/Ice Cream Grade. Vegetation is very dense here also and fuel loads are high. Foot travel here is often almost impossible due to the senescent chaparral. Light fuels are very widespread and dense.

There are techniques in practice today which serve to reduce hazardous fuel loads and return chaparral to younger community seral stages. These include crushing of vegetation with machinery and subsequent burning (Franklin 1993). These prescribed fires are more easily controlled because of lower fuels, and temperature do not reach the degrees attained during catastrophic wildfire. The problem with this in the Sandhills would be the potential for compaction of the loose Zayante soils. An alternative method is hand clipping of material before burning, to reach the same results. This is more labor intensive, yet achieves the same results without the compaction. Especially on a small experimental scale, this could be a useful tool in management of the Sandhills. Clipping of excessive and /or exotic understory vegetation in Sand Parkland, followed by prescribed burning, might achieve a favorable reduction in vegetation and if followed up for a few seasons, may lessen the amounts of the exotic grasses which may be inhibiting native species regeneration. This technique would be highly desirable to attempt in the Sandhill sites such as occur at the west ridge of Quail Hollow Quarry, the East Zayante areas, and on the east side of Martin Road in the Bonny Doon preserve.

Grazing

One alternative to burning to remove exotics and open the understory of Parkland would be strictly managed grazing. This has been used successfully in the East Bay Parks as a fire control measure. If done in a short term, intensive approach it may have a noticeable effect on exotic species. Extreme care in timing, location, and duration of grazing must be taken for it to be successful. This is typically a spring management technique, as many exotic species are early germinating annuals which are unaffected by late spring grazing. Grazing on these annuals before later-flowering native perennials set seed can be very effective. Complicating this technique, however, is that many of the sand specialty species are themselves early flowering annuals.

Research Needs

Seedbed studies/experiments

Research should be conducted into germination requirements for some sand specialty genera and species. As mentioned previously, research has shown some of these species have favorable results from charcoal addition to soil and specific heat treatments of seeds (Keeley and Keeley 1987). Small scale manipulative experiments will lead to better understanding of these species. Other questions which could be tested by small scale manipulative tests include:

-germination responses of native and exotic species with manual clearing of exotic grasses

-seed viability of species including *A. silvicola.*

-does simple manual clearing of *A. silvicola* result in increased germination?

-do some of the less common sand specialty species (including "Species of Greatest Concern", see Appendices) exist in a dormant seedbank in locations where they have not been recorded?

Recommendations for other research

Monitoring of plots

One of the more interesting and simple research needs is simply multi-year species lists for selected sites. Plots which were established during this project could continue to be monitored at multiple seasons. Species diversity and its relationship to environmental variables such as drought could be better understood. Successional patterns and the influence of human disturbance could be better understood by long-term monitoring.

Response of A. silvicola to burning and mechanical clearing

Arctostaphylos silvicola is one of the least studied species of manzanita. Besides the need for understanding management options, research into the fire ecology of this species is important for understanding the problems with the urban/chaparral interface. In addition, information is needed

regarding the response of *A. silvicola* to alternative management such as mechanical removal/defoliation.

Taxonomic questions regarding sand specialty species

Many of the Sandhill herbs are easily observable varieties in form, color, or growth habit, yet are not recognized in the botanical literature (some lost recognition with the latest Jepson treatment). Understanding these ecotypes or varieties will increase understanding of the unique Sandhill environment.

Physical Protection of Habitat

Many areas of the Sandhills which harbor protected species need more protection from physical harm from hikers, ORV's, equestrians, etc. In particular, the South Ridge of Quail Hollow repeatedly is marked with ORV tracks and gullied trails from horse use. Other areas also receive heavy use. This should be considered in plans for the Bonny Doon Ecological Preserve. There has been notable natural revegetation at Quail Hollow Ranch Ridge since the ridge containing Sand Parkland habitat has been closed to the public (especially equestrians). The maps provided in this report will be helpful in designing a program of protection of these areas.

TABLE 2: Recommendations for Management of Specific Sandhill Locations

Note: This table is arranged according to priority for preservation/protection. Bonny Doon Preserve and Quail Hollow Ranch Ridge are listed last because they are already protected as ecological preserves.

Map Location # (refer to Appendix C maps)	Location	Habitat Types Present: *Sand Parkland=SP (1a and 1b acreage) Sand Chaparral=SC*	General Ownership	Management approach/techniques
1	South Ridge Quail Hollow	SP (1a-9, 1b-40?)	Privately owned-Quarry	Highest priority for protection. Purchase/Preservation through Open Space designation Needs better protection from ORV's and equestrian use. Trail on ridge needs rehabilitation.
2	SE corner of Lonestar Quarry	SP (1a-2, 1b-5)	Privately owned-Quarry	Very high biologic value; diversity comparable to South Ridge Quail Hollow Highest priority for protection Purchase/Preservation through Open Space designation Prescribed fire/aggressive understory management/removal of Red Brome i Protection for area from equestrian use
3	North Ridge Quail Hollow	SP (1b-18), SC	Privately owned-Quarry	Purchase/Preservation through Open Space designation Prescribed fire High biologic and scenic values. Greater diversity than mentioned in earlier work
4	West Ridge Quail Hollow	SP (1a-1.5, 1b-11.75), SC	Privately owned-Quarry. Some residential private ownership	Purchase/Preservation through Open Space designation Prescribed fire High biologic and scenic value. Greater value (diversity) than mentioned in earlier work Protection for ridgetops and slopes from equestrian use
5	East Zayante areas	SP (1a-10, 1b-14.5), SC	Private ownership-residential and quarries	Small ecological preserve should be expanded to include all 1a and 1b habitat Prescribed fire Grazing management? of 1b areas Protection from ORV's and equestrians Higher diversity and value than previously recognized-good quality 1b Parkland as indicated by presence of sand specialty species
6	Area surrounding and west of Ben Lomond Landfill	SP ( ), SC	County Landfill and Private residential ownership	Open Space designation/Preservation Prescribed fire Area has biologic and scenic values. Previously not recognized as Sand Parkland

7	Graham Hill North	Degraded SP, and SP (1b-12)	Mixture of quarry, private ownership	Protection of 1b Parkland area Prescribed fire/aggressive understory management Protection of Parkland surrounding Kaiser Quarry
8	Graham Hill South	SC, SP (1b-20?)	Private ownership	Add to Henry Cowell Park. or otherwise designate Open Space Excellent location for prescribed fire trials
9	Old Geyer Quarry	SP, SC	Privately owned inactive quarry (at present time-may be reactivated)	Area is naturally revegetating with Sandhill species; large populations of some Purchase/Preservation through Open Space designation Prescribed fire Protection for area from equestrian/ORV use
10	Quail Hollow School Area	SC, SP (1b-19 marginal)	Mostly private residential	Open Space designation Cluster development Limited use as interpretive area for local use?
11	Chaparral stand south of Eagle Dell Peak	SC	Private ownership	Prescribed fire Cluster future development
12	Head of McKenzie and Ruins Creeks.	SC	Private ownership	Prescribed fire Cluster future development if any
13	Ice cream Grade/Empire Grade intersection	SC	Private ownership	Previously unmapped location for Arctostaphylos silvicola. Needs ecological work to understand occurrence of A. silvicola on different soil type
14	Residential area with ponderosa pines: Ben Lomond (near landfill) Lockwood lane area (Scotts valley) Scotts Valley surrounding and southwest from airport)	degraded SP	Moderate to high density residential, some commercial	Educate landowners Cluster future development if any Monitor/limit removal of ponderosa pines Encourage native species landscaping
15	Bonny Doon preserve	SP (1b-20)	State Preserve	Excellent location for manipulative trials including prescribed fire, germination experiments, seedbank studies, etc. Limited public use for interpretation/education
16	Quail Hollow Ranch Ridge(s)	SP (1a-3, 1b-6)	Santa Cruz County Park	Maintain protection from hikers/equestrian use/grazing Prescribed fire

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APPENDIX A: RAW DATA TABLE FROM PLOTS

Habitat types on plot::
Sand Chaparral=SC;
Pine forest-Pf
Sand Parkland=1a/1b

	1a	1a/1b	1b	1b	1a/1b	1b	SC	1b	1b	Pf	Pf	Pf	SC/Pf	?	SC	SC/Pf	SC	SC	SC/Pf	SC	
Plot #	2	6	16	BD 6	11	4	30	BD 7	8	27	23	10	22	40	BD 8	32	1	13	24	BD 5	% Constancy
Species																					
Arctostaphylos silvicola				R	R	R	R	1	1	1	2	2	2	2	3	5	6	6	8	10	85%
Adenostoma fasciculatum		R		R		R	1	R		R		R	R	1	P	R	1	P	R	R	70%
Luzula comosa				P		A	R	A	A	R	R	M	R		P	A	R	R	R		70%
Pteridium aquilinum	R	R	A	R	A			2	P	5	5		3		A		A	R	P	R	60%
Lotus scoparius	P	P	R	R	R	P		2		R		P	R		R	R	R	R			55%
Diplacus aurantiacus			A	R		A	1	R	R			1			A	1	A	R		R	55%
Navarettia atractyloides							A	R	1		M		A		A	R	P			R	45%
Eriogonum nudum ssp. decurrens	2	R	A	P	5	R		R	R	R	R					R					40%
Gnaphalium canescens	M	R		R		R		R	R		P		A		R						35%
Ericameria ericoides ssp. blakei		R	R	R	R			R	R						A	1				R	35%
Toxicodendron diversilobum							R		R	1	1		P		R	R					35%
Senecio sylvaticus							A		A				P		R	A		R	R		35%
Bromus diandrus	A	P	M	2	7			M	A	A		M									30%
Rhamnus californica		2						R		R	R	R	P			R					30%
Arctostaphylos tomentosa ssp. crinita			R						1	1	2		2				1		R		30%
Eriophyllum confertiflorum			R			P			A		R				A	R	R				30%
Hypochaeris glabra	R			1	M	R		M	A	M											30%
Aira caryophyllea					A	P			M	A	A	A									30%
Eriodictyon californicum				R		P	P	R				R				P					30%
Vulpia myuros	R		A	M	2			M				M	R								25%
Ceanothus ramulosus		2					2			P			4				2	2			25%
Lupinus albifrons	1	P	A	R	P	R			R							R					25%
Hypochaeris radicata			M	P				M	P	R											20%
Rumex acetosella			P	M				A	A	A											20%
Koelaria macrantha				R	R	R			A												20%
Chorizanthe pungens	P	A			P	R									P						15%
Cryptantha sp.							R									P			R		15%
Achillea millefolium			R				R		A								R				15%
Filago californica	R				P	R					P										15%
Lessingia filaginifolia	P		A		P		R		P												15%
Horkelia cuneata								R	R	P											15%

Linaria canadensis var. texana	P	R				R								R							10%
Orthocarpus purpurescens	R					R					R										10%
Heterotheca sessiflora	P		P			P		R													10%
Stylocline gnaphalioides		R											R	A							10%
Briza maxima			M						A		A										10%
Arctostaphylos nummularia															7					P	10%
Dendromecon rigida															R		R				10%
Pellea mucronata	R					R		P													10%
Silene verecunda			P			R					P										10%
Bromus rubens						M					M										10%
Lotus strigosus	R					R								R							10%
Chorizanthe diffusa														M				1			10%
Cryptantha clevelandii												A		P							10%
Gnaphalium californicum			R					R						R							10%
Baccharis pilularis								R						R							10%
Castilleja affinis											R						R				10%
Vulpia sp.				1		M															10%
Poa scabrella						M								R							10%
Montia fontana											M	M									10%
Eschscholtzia californica	2	M				A															5%
Erysimum teretifolium	A	R				A															5%
Malacothrix floccifera	A			P																	5%
Mimulus rattanii																R					5%
Cytisus scoparius									R												5%
Cynarea sp.								A													5%
Layia platyglossa								R													5%
Anthirrhinum multiflorum																	R				5%
Ceanothus cuneatus															R						5%
Helianthemum scoparium				R																	5%
Plantago erecta						A															5%
Clarkia sp.						R															5%
Vulpia octoflora var. hirtella														R							5%
Madia madioides												R									5%
Salvia columbariae												R									5%
Lupinus bicolor	R										R										5%
Dichelostemma capitatum											R										5%
Galium sp.											R										5%

Chlorogalum pomeridianum									R											5%
Pentagramma triangularis									R											5%
Heteromeles arbutifolia				R																5%
Lotus sp. (nevadensis?)				R																5%
Cynosorus echinatus				A																5%
Saxifraga californica									A											5%
Polypodium californicum									A											5%
Tragopogon sp.				R																5%
Monardella undulata	P	R																		5%
Erodium cicutarium		P																		5%
Gilia tenuiflora	P	R																		5%
Vulpia microstachys		R																		5%
Plot Species Total	22	19	18	24	25	18	17	20	29	22	16	11	22	5	14	18	12	8	8	6
Mean Distance between Ponderosa pines (meters)	18.50	19.50	10.75	11.87	13.25	14.75	19.00	6.00	4.12	4.50	4.12	11.87	14.75	10.62	9.00	12.50	19.00	7.37	29.75	9.00
Ponderosa Pines in relevé?	P	P	P	P	P	P	A	P	P	P	P	P	A	A	A	P	A	A	A	P

P= Present
A= Absent

Cover scale used in plots

R= cvr <5% rare 1-10 ind.
P= cvr <5% few 10-20 ind.
A= cvr <5% abundant 20-100 ind.
M= cvr <5% very abund 100+ ind.

1= cvr 10%
2= cvr 20%
3 = cvr 30%
4= cvr 40%
5 = cvr 50&

6= cvr 60%
7= cvr 70%
8= cvr 80%
9= cvr 90%
10= cvr 100%

APPENDIX B: A WORKING LIST OF THE VASCULAR PLANTS OCCURRING IN THE ZAYANTE SANDHILLS, SANTA CRUZ COUNTY

(From R. Morgan in part)

Key to Species' Status:

S = "Sand Specialty Plants". These 83 species are "predominantly sand associated". They may grow in other habitats and/or be widespread, yet are most commonly seen or occur in larger populations in the Sandhills.

! = "Species of Greatest Concern". Those species which are either 1) the rarest species present in the Sandhills; or 2) disjunct populations of species which occur elsewhere in California . Many of these 27 species are morphologically unique, such as unusual color forms (for example *Layia platyglossa, Monardella undulata* in some locations,, and *Mimulaus rattanii* ssp. *dcurtatus* in some locations).

È = endemic species. near-endemic form, or ecotype

? = needs taxonomic study

See Stanley et al 1983 for a descriptive list of these species.

Munz (1969)	Jepson (1993)
Amaryllidaceae	
Ş *Brodiaea pulchella* (Salisb.) Greene =	(Liliaceae) *Dichelostemma capitatum* Alph. Wood
Ş !***Muilla maritima*** (Torr.) Wats.	
Anacardiaceae	
Rhus diversiloba T. and G.	*Toxicodendron diversilobum* (T. & G.) E. Greene
Asteraceae	
Ş *Achillea borealis* L. =	*Achillea millefolium* L.
Ş !È *Artemesia pycnocephala* (Lass.) DC.	
Baccharis pilularis DC.	
!*Baeria chrysostoma* F. & M. =	*Lasthenia californica* Lindley
Ş *Chrysopsis villosa* (Pursh.) Nutt. var. *camphorata* (Eastw.) Jeps. =	*Heterotheca sessiliflora* (Nutt.) Shinn ssp. *echioides* (Benth.) Semple
Ş *Coreothrogyne filaginifolia* (H. & A.) Nutt. var. *virgata* (Benth.) Gray=	*Lessingia filaginifolia* (Hook. & Arn.) M.A.Lane var. *Filaginifolia*
Ş *Happlopappus ericoides* (Less.) H. & A. ssp.*Blakei* Wolf =	*Ericameria ericoides* (Less.) Jeps.
Ş *Eriophyllum confertiflorum* (DC.) Gray	
Ş *Filago californica* Nutt.	
Ş *Gnaphalium beneolens* Davidson =	*G. canescens* D.C. ssp. *beneolens* (Davidson) Stebb. & Keil
G. californicum DC.	
Ş *G. "zayanteense"* proposed	
Heterotheca grandiflora Nutt.	
Hypochaeris glabra L.	
Hypochaeris radicata L.	
Ş !È *Layia platyglossa* (F. & M.) Gray	
Madia sp.	
Ş *Malacothrix clevelandii*	
Ş !*Malacothrix floccifera* (DC.) Blake	
Senecio sylvaticus L.	
Ş *Stephanomeria virgata* Benth.	
Ş *Stylocline gnaphaliodes* Nutt.	
Boraginaceae	
Ş *Cryptantha Clevelandii* Greene	
Ş *C. micromeres* (Gray) Greene	
Ş *C. muricata* (H. & A.) Nels. & Macbr. var. *jonesii* (Gray) Johnston=	*C. muricata* H. & A.) Nels.
Ş !*Pectocarya penicillata* (H. & A.) A. DC.	
Ş !? *Plagiobothrys tenellus* (Nutt.) Gray	
Brassicaceae	
Ş !È ***Erysimum teretifolium*** Eastw.	
Ş *Thysanocarpus curvipes* Hook.	
Campanulaceae	
Campanula angustiflora Eastw.	
Caryophyllaceae	
Ş !? ***Arenaria californica*** (Gray) Brewer =	*Minuartia californica* (A. Gray) Mattf.
Ş !*A. douglasii* Fenzl ex T. and G. =	*M. douglassii* (Torrey & A. Gray) Mattf.
Ş *Cardionema ramosissimum* (Weinm.) Nels. and MacBr.	
Loeflingia squarrosa Nutt.	
Ş !***Silene verecunda*** Wats. ssp. ***platyota*** (Wats.) Hitchc. and Maguire	
Cistaceae	
Ş *Helianthemum scoparium* Nutt.	
Crassulaceae	
Ş !È *Dudleya palmeri* (Wats.) Britton and Rose	
Ş *Tillaea erecta* H. and A. =	*Crassula connata* (Ruiz Lopez & Pavon) A. Berger
Cupressaceae	
Ş È *Cupressus abramsiana* Wolf	

Cyperaceae
  S *Carex globosa* Boott.
Ericaceae
  Arbutus menziesii Pursh.
  Arctostaphylos Andersonii ???
  A. crustacea Eastw.= *Arctostaphylos tomentosa* ssp. *crustacea* (Eastw.) P. Wells
  Arctostaphylos Nummularia Gray var. *sensitiva* (Jeps.) McMinn = *A. Nummularia* A. Gray
  S È ***A. silvicola*** Jeps. & Wiesl.
  A. tomentosa (Pursh.) Lindl. ssp. *tomentosiformis* (Adams) Munz = *A. t.* ssp. *crinita* (McMinn) R. Gankin
  Vaccinium ovatum
Fabaceae
  Cytisus scoparius (L.) Link.
  S *Lotus scoparius* (Nutt.) Ottley
  S *L. strigosus* (Nutt.) Greene
  S *Lupinus arboreus* Sims
  S *L. albifrons* Benth ex Lindl.
  S È ? *L. bicolor* Lindl. ssp. *umbellatus* (Greene) Dunn
Fagaceae
  Castanopsis chrysophylla (Dougl.) A. DC.= *Chrysolepis chrysophylla* (Hook) Hjelma
  Lithocarpus densiflora (H. & A.) Rehd.
  Quercus agrifolia Neé
  Q. chrysolepis Liebm.
  Q. wislizenii A. DC.

Hydrophyllaceae
  Eriodictyon californicum (H. & A.) Torr.
  ? *Nemophila pedunculata* Dougl. ex Benth.
  S *Phacelia distans* Benth.
  S !? *P. douglasii* (Benth.) Torr.
  P. nemoralis Greene
  ? *P. ramosissima* Dougl. ex Lehm.
Juncaceae
  S *Luzula subsessilis* (Buch.) Wats. = *Luzula comosa* E. Meyer
Lamiaceae
  S !***Monardella undulata*** *Benth.*
  ? *M. villosa* Benth.
  S *Salvia mellifera* Greene
  S *Scutellaria tuberosa* Benth.
  Salvia columbariae Benth.
Liliaceae
  S *Calochortus venustus* (extinct?)
  Chlorogalum pomeridianum (DC.) Kunth.
Onagraceae
  S *Clarkia purpurea* (Curtis) Nels. & Macbr.
  S *C. rubicunda* (Lindl.) Lewis
  S *C. unguiculata* Lindl.
  ? *Epilobium minutum* Lindl. ex Hook
  S *Oenothera contorta* Dougl. ex Hook. *Camissonia contorta* (Douglas) Raven
  S *O. micrantha* Spreng *C. micrantha* (Spreng) Raven
Papaveraceae
  Dendromecon rigida Benth.
  S È ? ***Eschscholzia californica*** Cham.
  S !È ***Hesperomecon linearis*** (Benth) Green var. ***pulchella*** (Greene) Jeps. = *Meconella linearis.*(Benth.) Nelson and MacBr.
Pinaceae
  Pinus attenuata Lemmon
  S ? *Pinus ponderosa* Lawson
  S !*Pinus sabiniana* Dougl.
  Psuedotsuga menziesii (Mirb) Franco

Plantaginaceae
  S *Plantago erecta* Morris.
Plumabaginaceae
  S !***Armeria maritima*** (Mill.) Willd.var *californica* (Boiss) G.H.M. Lawr.
Poaceae
  Aira caryophyllea L.
  Briza maxima L.
  Bromus diandrus Roth
  Bromus rubens L.
  Bromus tectorum L.
  Cynosorus echinatus L.
  S !*Festuca confusa* Piper = *Vulpia michrostachys* (Nutt.) Benth. var. *confusa* (Piper) Leonard & Gould
  S *F. rubra* L. *V. m.* var. *ciliata* (Beal) Leonard & Gould
  F. eastwoodae Piper = *V. o.* (Walter) Rydb. ssp. *hirtella* (Piper) Henrard
  S *F. octoflora* Walt. var. *hirtella* = Piper *V. m.* var. *pauciflora* (Beal) Leonard & Gould
  S !È? *F. pacifica* Piper *Koeleria macrantha* (Ledeb.) J.A. Schultes
  S *Koeleria macrantha* (Ledeb.) Pers. = *P. secunda* J. Presl ssp. *secunda*
  Poa scabrella (Thurb.) Benth. ex Vasey =
Polemoniaceae
  S !? ***Gilia tenuiflora*** Benth.
  S !È? ***Linanthus parviflorus*** (Benth.) Greene
  S *Navarettia atractyloides* (Benth.) H. & A.
Polygonaceae
  S *Chorizanthe diffusa* Benth.
  S È *Chorizanthe pungens* Benth. var. *Hartwegii* (Benth.) Goodman
  S È ***Eriogonum nudum*** Dougl. ex Benth. ssp. ***decurrens*** (Stokes)
  E. vimineum Dougl. ex Benth.
Polypodiaceae
  Polypodium californicum (Kaulf.)
Pteridaceae
  S *Pellea mucronata* (Eaton) Eaton var *mucronata* = (Dennstaedtidaceae) *P. m.* var. *mucronata*
  Pityogramma triangularis (Kaulf) Maxon= *Pentagramma triangularis* (Kaulf) Yaskievych, Windham
  Pteridium aquilinum (L.) Kuhn var. *pubescens* Under. & Wollenweber

Portulacaceae
  S !? ***Calyptridium umbellatum*** (Torr.) Greene
Ranunculaceae
  S *Delphinium parry Gray* ssp. *seditosum* (Jeps.) Ewan
Rhamnaceae
  Ceanothus papillosus T. & G.
  S *Ceanothus ramulosus* (Greene) McMinn var. *dubius* Howell= *C. cuneatus* (Hook) var. *cuneatus*
  (has also been called *C. cuneatus* var. *dubius* Howell)
  Rhamnus californica Esch.
Rosaceae
  Adenostoma fasciculatum H. and A.
  S ? *Horkelia cuneata* Lindl. *H. cuneata* Lindl. sspp. *cuneata & sericea*
  and var. *sericea* (Gray) Keck=
Rubiaceae
  Galium spp.
Saxifragaceae
  Ribes divaricatum Dougl. = (Grossulariaceae) *R. divaricatum* Dougl.
  S *Saxifraga californica* Greene

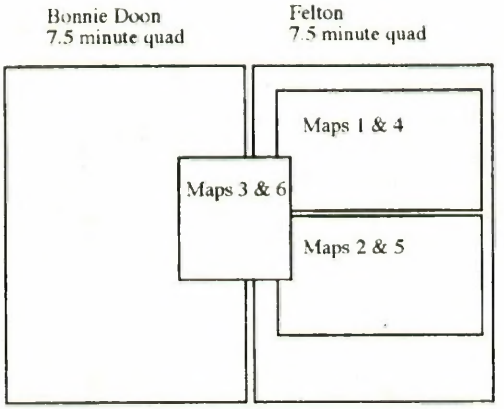
Scrophulariaceae
- S *Anthirrhinum multiflorum* Pennel.
- S *Castilleja affinis* H.A.
- S !? ***Collinsia bartsiifolia*** Benth. var. ***hirsuta*** (Kell.) Pennel
- *Mimulus aurantiacus* Curtis = *Diplacus aurantiacus*
- S *Linaria texana* Scheele = *L. canadensis* var. *texana*
- S !*Mimulus androsaceus* Curran ex Greene
- S !? *M. rattanii* Gray var. *decurtatus* (Grant) Pennell
- S ! ?*Orthocarpus purpurescens* Benth.
- *Asarina stricta* Penn. = *Anthirrhinum kellogii* (Greene)

Taxodiaceae
- *Sequoia sempervirens* (Lamb.) Endl.

APPENDIX C: DISTRIBUTION MAPS

List of Distribution Maps:

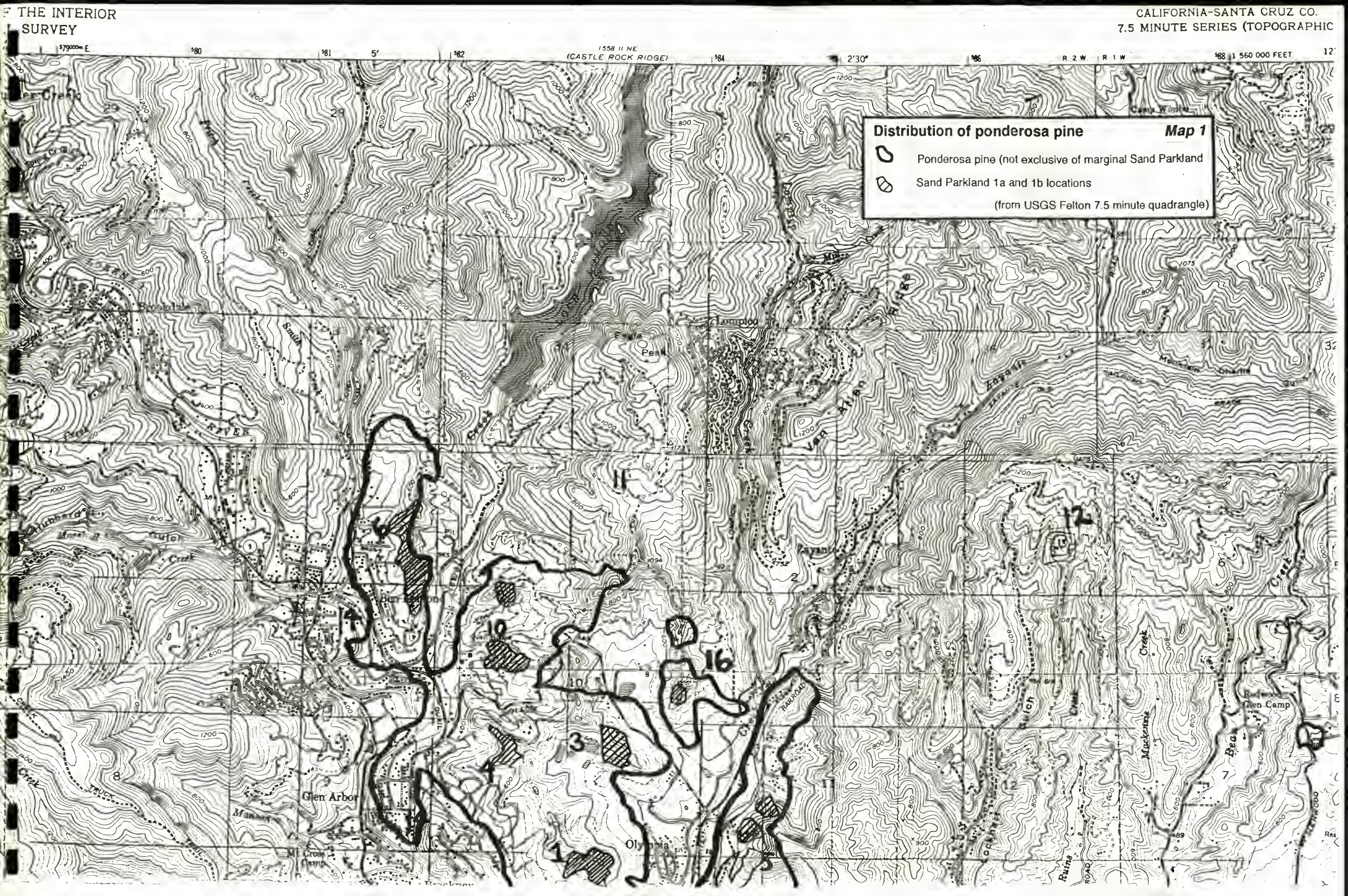
Orientation of distribution maps:

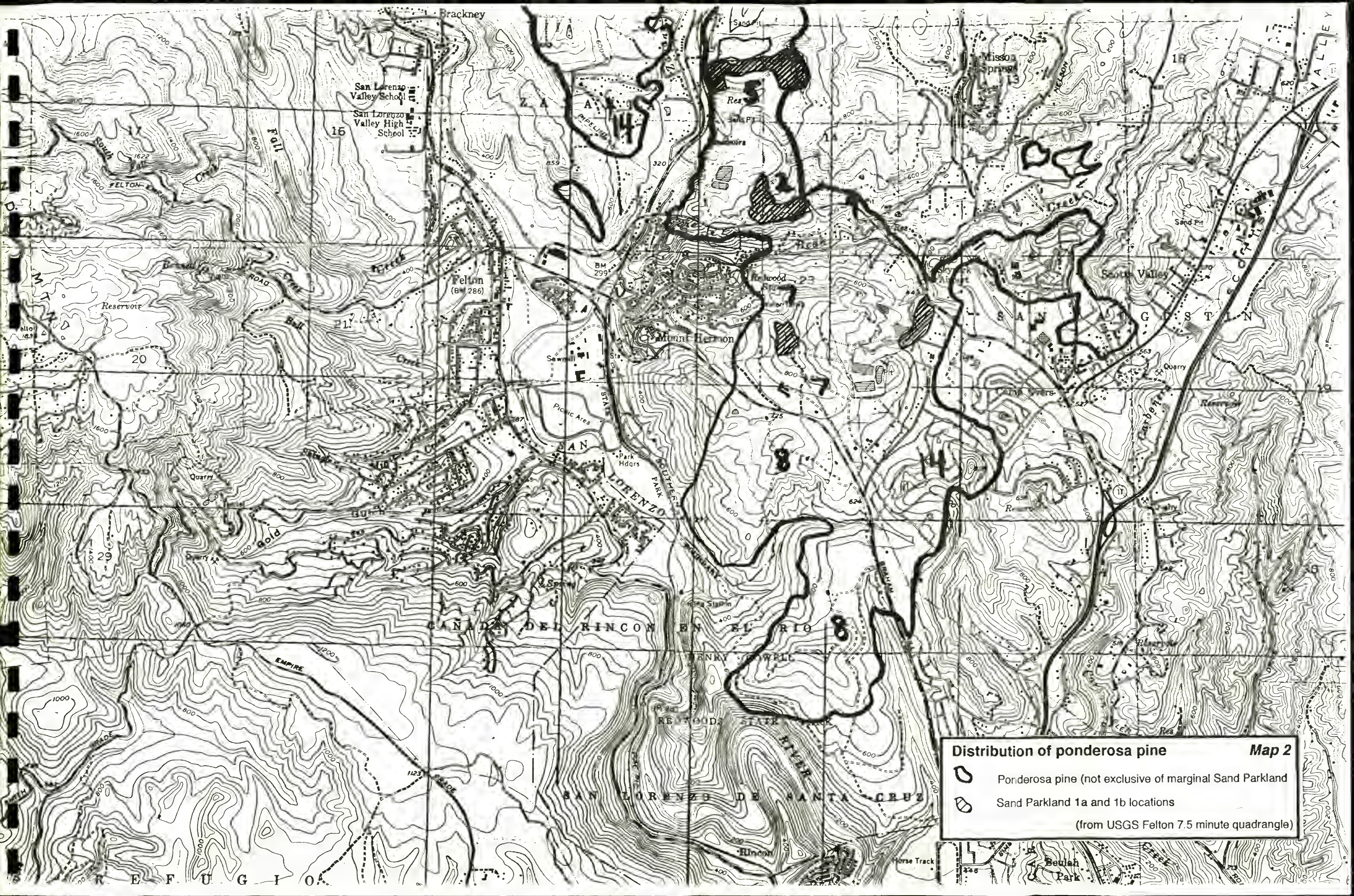


Note: Numbers on distribution maps are for reference to Sandhills site list, page 37

F THE INTERIOR
SURVEY

CALIFORNIA-SANTA CRUZ CO.
7.5 MINUTE SERIES (TOPOGRAPHIC



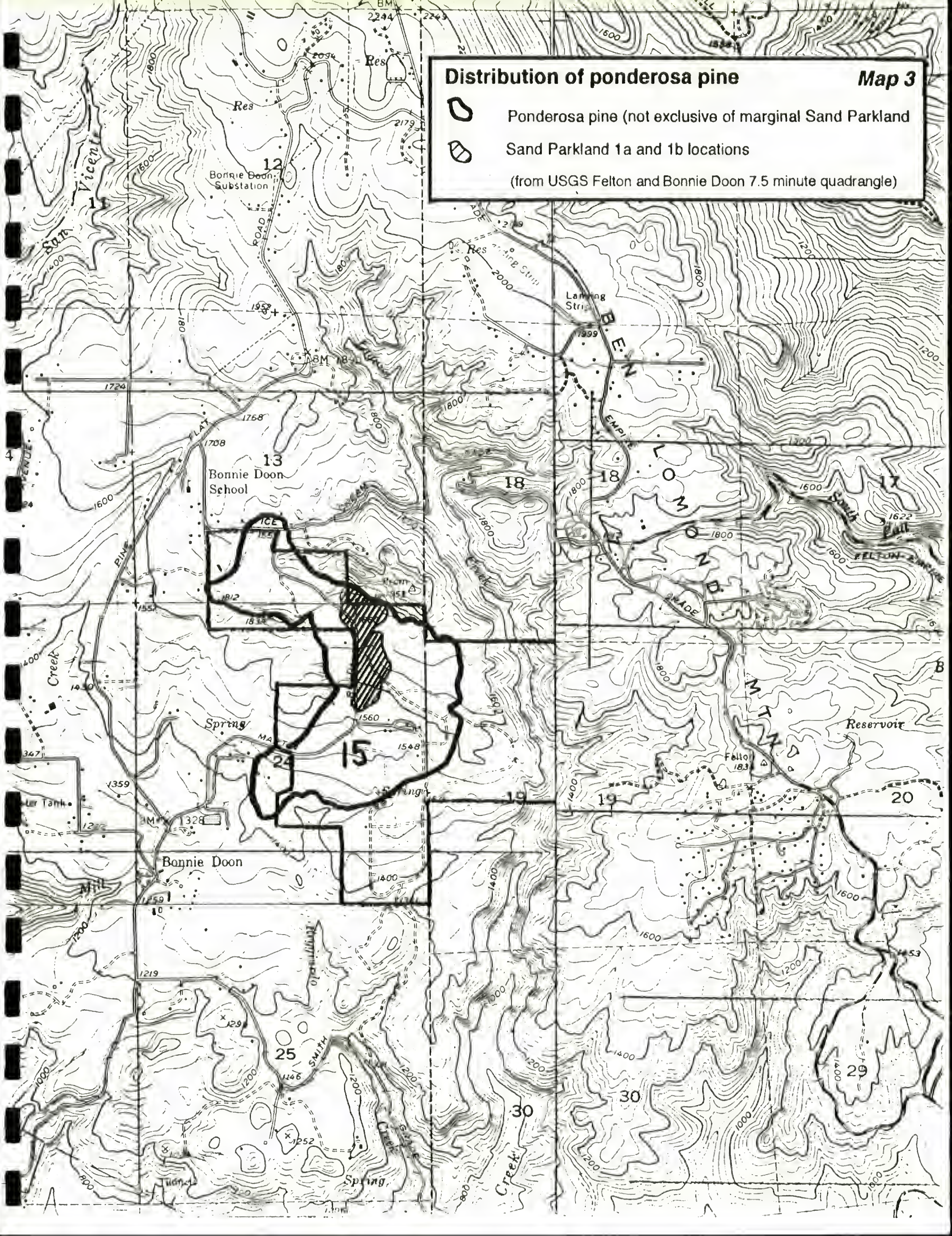


Distribution of ponderosa pine ***Map 2***

Ponderosa pine (not exclusive of marginal Sand Parkland)

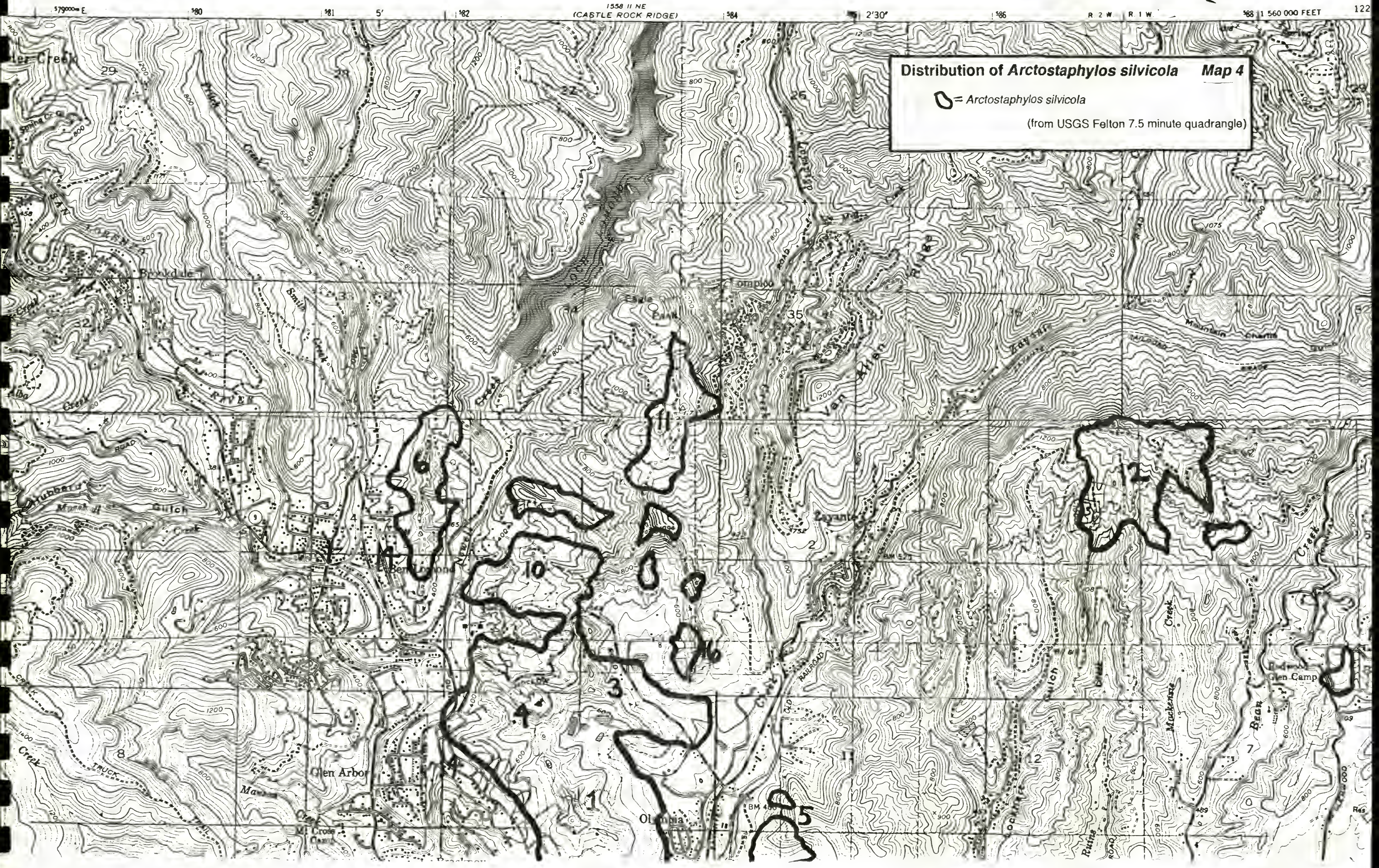
Sand Parkland 1a and 1b locations

(from USGS Felton 7.5 minute quadrangle)


Distribution of ponderosa pine
Map 3
Ponderosa pine (not exclusive of marginal Sand Parkland
Sand Parkland 1a and 1b locations
(from USGS Felton and Bonnie Doon 7.5 minute quadrangle)
Bonnie Doon Substation
Bonnie Doon School
Bonnie Doon
Landing Strip
BEN LOMOND MTN
Reservoir
Spring
15

THE INTERIOR
SURVEY

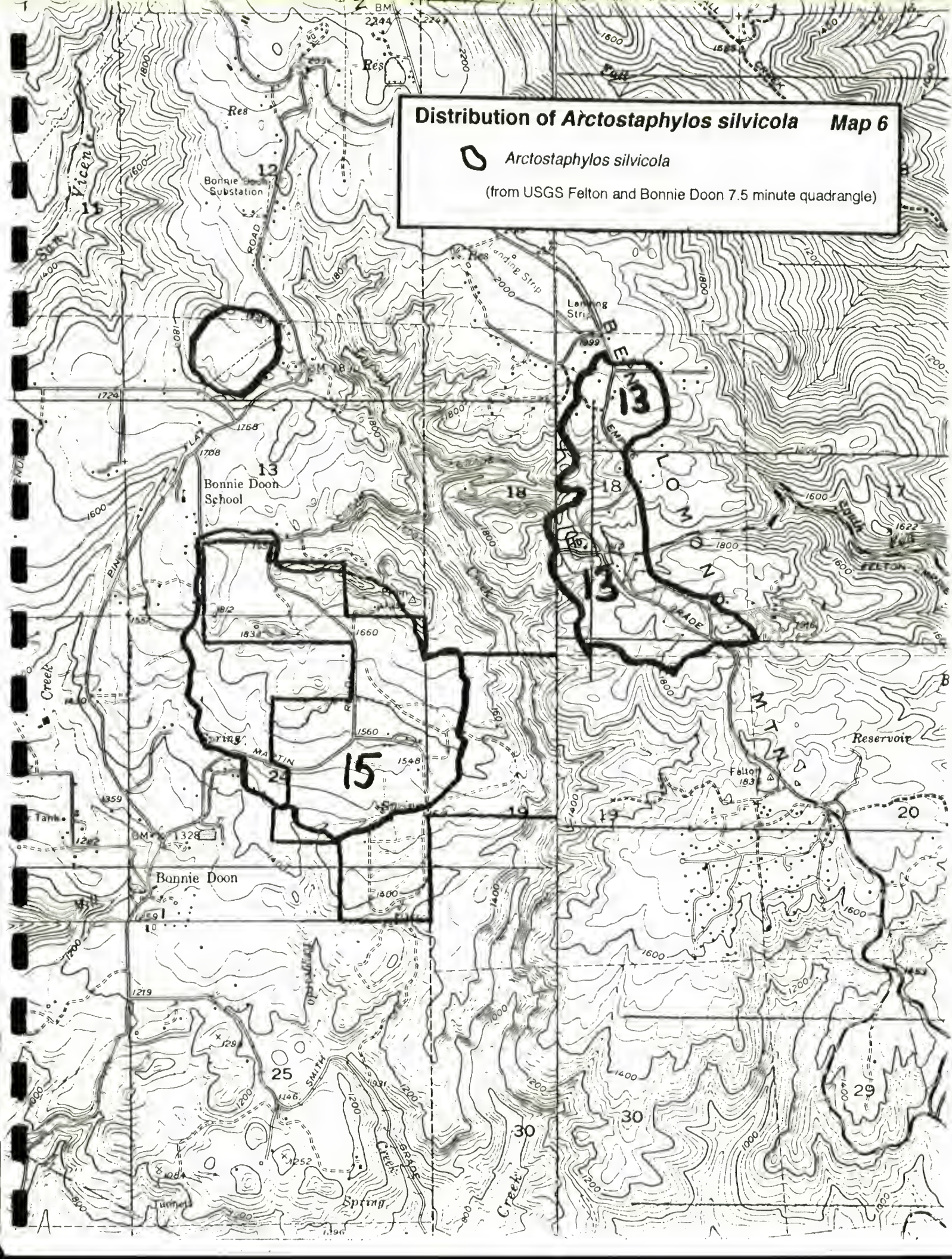
CALIFORNIA-SANTA CRUZ CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



Distribution of *Arctostaphylos silvicola* Map 5

Arctostaphylos silvicola

(from USGS Felton 7.5 minute quadrangle)


Distribution of *Arctostaphylos silvicola* Map 6
Arctostaphylos silvicola
(from USGS Felton and Bonnie Doon 7.5 minute quadrangle)
Bonnie Doon School
Bonnie Doon
Reservoir
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15
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19
20
25
29
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APPENDIX D: IMPORTANT CONTACTS

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